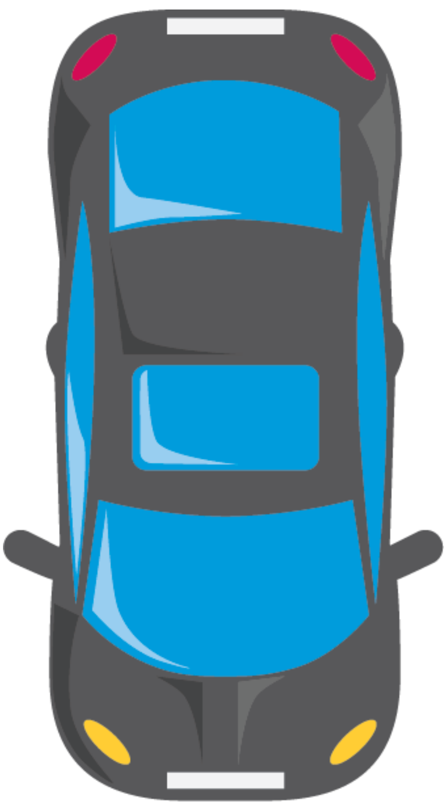
White Paper – Automotive Industry

Technology Cluster Manager (TCM)

Technology Centre System Program (TCSP)

Office of DC MSME, Ministry of MSME

October, 2020



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ABBREVIATIONS

ACMA	Automotive Component Manufacturers Association (of India)
AI	Artificial Intelligence
AMP	Automotive Mission Plan
AR	Augmented Reality
ASRS	Automatic Storage and Retrieval System
B2B	Business-to-Business
BEV	Battery Electric Vehicles
BRT	Bus Rapid Transit
BS	Bharat Stage
CAFE	Corporate Average Fuel Economy
CAGR	Compound Annual Growth Rate
CNC	Computer Numerical Control
DHI	Department of Heavy Industries
3DP	3-Dimensional Printing
EMC	Electromagnetic Compatibility
EU	European Union
EV	Electrical Vehicles
FAME	Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles in India
FDI	Foreign Direct Investment
FTA	Free Trade Agreement
FY	Financial Year
GDP	Gross Domestic Product
GPM	General Purpose Machines
GUTS	Green Urban Transport Scheme
GVC	Global Value Chain
HALT	Highly Accelerated Life Tests
ICAT	International Centre for Automotive Technology
IIOT	Industrial Internet of Things
IIT	Indian Institute of Technology
INR	Indian Rupee
IoT	Internet of Things
IT	Information Technology
ITS	Intelligent Transport System
LPG	Liquified Petroleum Gas
MSME	Medium, Small and Micro Enterprises
NATRiP	National Automotive Testing and R&D Infrastructure Project
NEMMP	National Electric Mobility Mission Plan
NMT	Non-Motorized Transport
NVH	Noise Vibration & Harshness

OEM	Original Equipment Manufacturers
OT	Operational Technology
PSL	Passive Safety Lab
R&D	Research and Development
SIAM	Society of Indian Automobiles
SPM	Special Purpose Machines
TC	Technology Centres
TCO	Total cost of ownership
TCSP	Technology Centres Systems Program
TPEM	Technology Platform for Electric Mobility
TTL	Tyre Test Lab
USD	United States Dollar
VR	Virtual Reality

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1 Introduction

1.1 Background

Technology Centre Systems Programme (TCSP) is a national programme undertaken by the Ministry of Micro, Small and Medium Enterprises with the assistance of the World Bank. The programme seeks to enhance the technological and skill base of MSMEs in certain manufacturing sectors to improve the competitiveness of MSMEs, via upgraded and new Technology Centers (TCs).

The objective of the programme is to enhance the productivity of selected MSME clusters by improving their access to manufacturing technology, establishing a strong focus in providing business & technical advisory services, and improving availability & employability of skilled workforce through TCs[1]. As part of the programme, KPMG has been appointed as the Technology Cluster Manager (TCM) to support TCs and undertake technology and cluster development activities.

The objective of TCM is to increase business opportunities for MSMEs through market linkages, enhance the competitiveness of the cluster business environment, increase the number of MSMEs utilizing the services of TCs, develop a financially self-sustainable business model for cluster related services provided by TCs, identify technologies (Industry 4.0) of the selected sector for TCs, evaluate existing training programs & develop new training programs for rollout at TCs, conduct a gap analysis of TCs, strengthen the capabilities of TCs to provide technical advises to their clients, increase awareness amongst stakeholders on Environmental, Health, and Safety (EHS) requirements[2].

As part of the project, White Papers in different sectors are being prepared to help identify the future roadmap for the sector in general and the TCs in specific. This White Paper focuses on the automotive sector. Automotive Industry globally is one of the largest industries and is a key driver of the economy. Owing to its deep forward and backward linkages with several key segments of the industry, the automotive industry has a strong multiplier effect on the economy[3].

1.2 Objective of White paper

This white paper is part of the engagement of KPMG with the Ministry of Medium, Small and Micro Enterprises (MSME) and aims to provide Automotive sector-specific information such as leading global technologies, manufacturing techniques, latest innovation in design, technology or manufacturing processes. This White Paper also highlights the degree of alignment of the current services of the TC with the market needs and recommend a future course of action for the TC to serve the sector in synergy with the ongoing trends. The TCs will contribute by providing inputs to MSMEs on manufacturing technology & business advisory in these areas. The paper further contains suggestions on the adoption of new technologies in the Automotive Sector by TCs and MSMEs in the cluster.

[1] DCMSME website, 25 May 2020
[2] DCMSME website, 25 May 20220
[3] Annual Report DHI 2018-19

2 Sector Overview

Automobiles have changed the way people have lived and worked in comparison to how people have lived a century ago. Every vehicle trip whether personal or commercial leads to economic transactions benefitting others. It is estimated that building 60 million vehicles gives employment to 9 million people directly. Each direct job in the sector gives another 5 indirect jobs in the industry in the country[4]. The contribution of the automotive industry in a country's GDP has increased in recent years and thus the sector plays a pivotal role in the socio-economic development of a country. Not only this, the automotive industry is capital and knowledge-intensive[5].

2.1 Global scenario

According to estimates, the average annual turnover of the world automobile industry is more than 3 trillion USD, corresponding to 3.65% of world GDP. The production in the automotive industry has increased by 25% over the last ten years (2007-2017). The industry has invested more than 92 billion USD in R&D and production[3], becoming among the top three major sectors dominating in investment in R&D (among 2500 leading companies). Moreover, the tax revenue from car manufacturers in 26 industrialized countries is more than 470 billion USD per year.

Description	USA	Japan	Germany	South Korea
Share of GDP in world production	2,442	56	185	185
The share of the automotive industry in GDP (%)	12	12	10	10
The country's share in the world exports of goods	91	38	32	32
Commodity exports (USD billion)	15,049	6,249	5,268	5,268
The volume of exports of machinery and transport equipment (USD billion)	6,649	4,006	3,151	3,151
The volume of export of cars (USD billion)	538	919	375	375
Number of employments in the automotive industry (direct) in thousands	870	803	320	320
Number of employments in the automotive industry (indirect) in millions	72	55	18	183

Table 1: Macroeconomic and Automotive parameters in 2017[5]

Outstanding successful economies were able to further improve their contribution to GDP and exports to other countries until 2019. For example, the most important industrial sector in Germany is the automotive industry. Approximately 880,000 people employed in the automotive industry in 2016 generated an economic output of 142 billion USD. This corresponded to a share of 4.7 % of the gross value added in Germany[6]. However, the production volumes showed downward trends during 2018-2019 due to global slowdown (table 2).

[4] OICA website, 10 June 20, 2020
[5] Saberi 2018
[6] Destatis 2019

In million units	2018	2019	Delta in %
China	23,5	21,4	-8,9
Europe	19,7	18,7	-5,1
NAFTA	5,0	4,3	-14
South America	2,7	2,6	-3,7
Japan	8,4	8,3	-1,2
India	4,0	3,6	-10
Asia (India, China, Japan)	7,7	7,4	-3,9

Table 2: Comparison of global production volumes

2.1.1 Structure of Automotive Industry

The automotive industry is facing competition globally, which has led firms to develop and implement new strategies. Innovation is identified as one of the strategies, allowing firms to avoid destructive price competition and create unique selling propositions[7]. Today, the industry is structured like a pyramid. Suppliers are increasingly taking over the entire supply of coordinated components as an integrated system to OEMs and are thus becoming system partners. Suppliers are now catching up in areas that were previously considered core competencies of OEMs (engine construction, interior design, bodywork, etc.). Over the past decades, the share of suppliers in the value-added has risen steadily, especially in the classic areas of electronics/electrics, chassis/chassis, and exterior, and is now over 80%. This trend is currently continuing: While electronics/electrics remain stable, drivetrain and exterior rose by 2% from 2012 to 2019. Even more, interior (7%), motor and drivetrain (13%), and chassis (12%) have achieved enormous growth for suppliers[8]. Integration partners support OEMs in combining these systems, e.g. through contract development and production of vehicle derivatives. Magna produces e.g. Mercedes-Benz G-Class from 1979 onwards, BMW X3 from 2003-2010, and Peugeot RCZ from 2010-2015 - Valmet and AM General are other contract manufacturers.

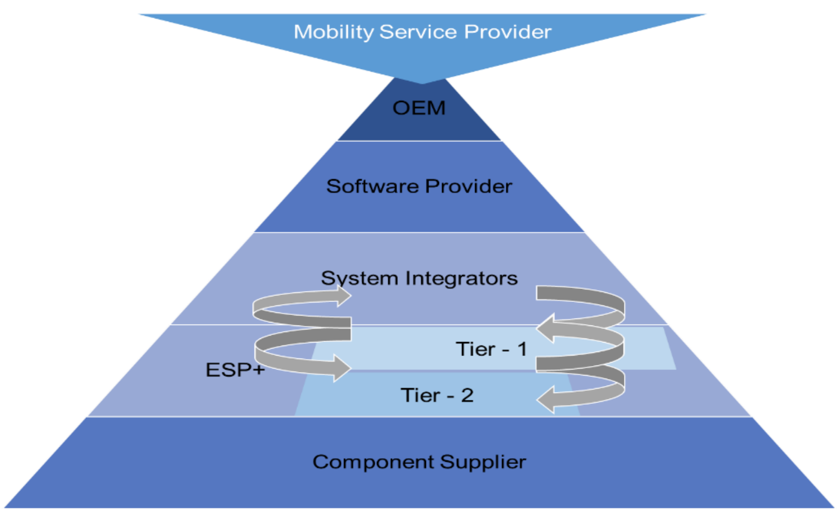

Figure 1: Pyramidal Structure of the Automotive Industry[9]

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[7] Staiger & Gleich 2006
[8] PwC Autofacts 2015
[9] Own illustration, ESP: Engineering Service Provider

In recent years, the appearance of mobility service providers has been increasingly observed, with attempts to use their platform solutions to promote the customer interfaces of OEMs or their dealers to the end customer, and even the business model - away from vehicle sales or ownership to cross-modal split usage. Industry-related cooperation partners contribute to the optimization of one-off expenses and economies of scale, such as by developing joint platforms and engines.

In the future, mobility service providers will still be above the OEMs in the value chain. It is estimated that besides the classical one-time vehicle sales of 4 trillion US$ and the aftermarket 1.2 trillion US$, the new revenue streams out of mobility services will be 1.5 trillion US$ market in 2030[10]. The traditionally sequential value chain will be replaced by network organizations and new competitors as OEMs, like BYD or Tesla, as well as mobility service providers, like Uber and Didi (e-hailing) or Zipcar (car sharing), have entered the market to secure market shares and direct access to customers.

Traditional IT providers, like Apple (Consumer electronics) or Google (Software), are entering the market and taking over the integration of the individual components. In this context, we will observe such shifting positions along the value chain: some OEMs will develop into mobility service providers, the supplier landscape will be reordered and consolidation of the market will take place more and more: cooperation and mergers of established players to exchange expertise[10].

2.1.2 Global Business Trends

There are **six megatrends** having direct impulse on the automotive industry. Based on them, we have identified 11 **key factors for business success** in the automotive industry.[11]

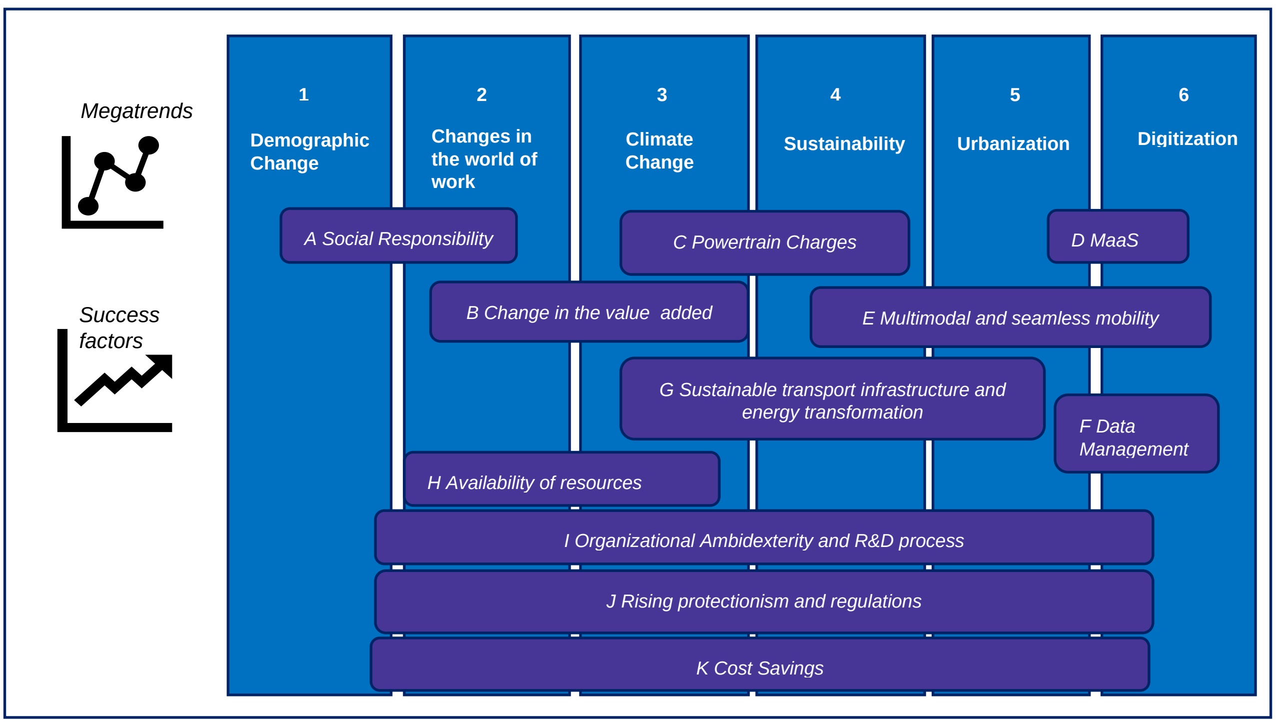

Figure 2: Megatrends and success factors for automotive actors

[10] McKinsey 2016
[11] Own illustrations

Megatrend 1: Demographic change
Worldwide, the median age will rise from 29 to 34 years between 2011 and 2030. In 2030, Europe will have the oldest population with a median value of 45 years and the USA will have a median age of 39.5 years[12]. Aging is increasingly viewed in a more positive light and associated with freedom, the possibility of self-determination, and the redesign of one's own life. Demographic change also brings with it challenges such as a growing shortage of skilled workers and high burdens on social security systems. According to a report by Bain, the demand for vehicles in the US would reduce to 11.5 million due to demographic trends[13]. According to research, Millennials have a lower rate of car ownership than previous generations at their age[14]. We have witnessed a radical change in consumer behavior due to the introduction of car-sharing, ride-hailing, and self-driving vehicles.

Megatrend 2: Changes in the world of work
The acquisition and optimal use of human capital will continue to increase in the future, especially in the engineering sector. Recruitment patterns and job opportunities are influenced by the globalization of the labor market. The use of social media, particularly mobile recruiting, personnel marketing via apps, and individual offers based on user profiles are new channels that supplement classic recruiting models. Furthermore, the change in the temporal and geographical conditions of employment relationships, in particular the increasing flexibility and digitalization, will continue to increase[15]. If one compares the current hourly labor costs in the automotive industry - Germany is in the lead with €54.93, followed by Sweden with €43.10, France with €41.05, the USA has an average hourly wage of €38.16, Japan has €29.51 - it can be assumed that these will continue to increase significantly in the course of the changes described[16]. In India, the average hourly rate[17] is around €2.78, which is 20% more than the national manufacturing average.

Megatrend 3: Climate Change
The global mean temperature has risen by 1°C over the past 120 years, mainly due to the burning of fossil fuels. Over the next 20 years, the global average temperature will rise by 0.2 - 0.4°C per decade. Other key environmental problems include increasing air, water, and marine pollution, and elevated levels of particulate matter represent a health hazard, particularly in cities in developing and emerging countries.
In 2010, NASA declared that the largest climate change pollution contributor in the world were automobiles[18]. The gases and pollutants released by cars; buses promote warming in the atmosphere. Several countries have announced their target of reducing greenhouse gas emissions. Automobile makers are increasing their production of electric vehicles (EVs) to show their commitment to reducing carbon emissions by vehicles produced by them. The government is introducing incentives to boost production and sales of EVs.

Megatrend 4: Sustainability
The significance and influence of sustainability on decisions and behavior in society, politics, and the economy will continue to increase. In particular, customers' increased awareness of environmental protection and social responsibility is increasingly forming the basis for consumer decisions regarding environmentally compatible and morally sound products and services. The automobile industry is adopting sustainability as its strategic priority initiatives to reduce their impact on the environment. Organizational sustainability practices can eliminate waste and bring profitability to firms.

Megatrend 5: Urbanization
The continued growth of the urban population accompanied by a change in the way of life and behavior of the inhabitants. The resulting infrastructural, political, social, and economic challenges require special

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[12] UN 2012
[13] A triple threat to Automakers: Recession, Demographics and Disruption, 21 May 2020
[14] Demographic Shifts: Shaping the future of car ownership, 21 May 2020
[15] Universum Global 2013
[16] VDA 2020
[17] Indian Wage Inflation - IHS Markit Analysis, Published 02 November 2010
[18] Germany has proven the modern automobile must die, 22 May 2020

consideration. Today, 50% of the world's population lives in cities, and this figure is expected to rise to 58% by 2025[19]. It has been observed that there is an inverse correlation between population density and vehicle ownership[20]. The major share of urban transportation is public transit and car-sharing. The percentage of 19-year-old in the US having driving license was 87% and < 70% in the years 1983 and 2010 respectively[21].

Megatrend 6: Digitization

The speed of development of information and telecommunications technology will continue to increase in the future, integrating an ever-wider range of products and services. The focus of this development is on increasing user comfort and simplifying work routines for the user. A major driver of digitization is the miniaturization of memory chips. Many optical functions of Google Glass, for example, will soon be able to be imaged with a contact lens. Digitization is set to spur innovation, reduce cost, and improve efficiency throughout the automotive industry. Digitization in the supply chain would reduce costs and bring transparency by interlinking processes. Connectivity and automation would enhance overall efficiency. Siemen's electronic plant in Amberg, Germany was 25% automated in 1990 and is now 75% automated. Output has increased 8.5 times and defects have decreased to less than 12 per million[22].

The above-mentioned megatrends support the eleven key factors for business success, which have been detailed out in Annexure IV.

2.1.3 Product and Demand

The structure of an automobile or its design hierarchy follows a systemic and functional approach: the subsystem level (shown here using BMW's KIFAG as an example in Figure 3[23] and 4[24]) comprizes of the body, interior, chassis, drive train, and complete vehicle. Thus, under the drive system, in the internal combustion engine (ICE) case the module level with fuel tank, combustion engine, transmission, etc. follows. Below this, in the case of the engine, a component level is the starter, engine block, engine cooler, etc.

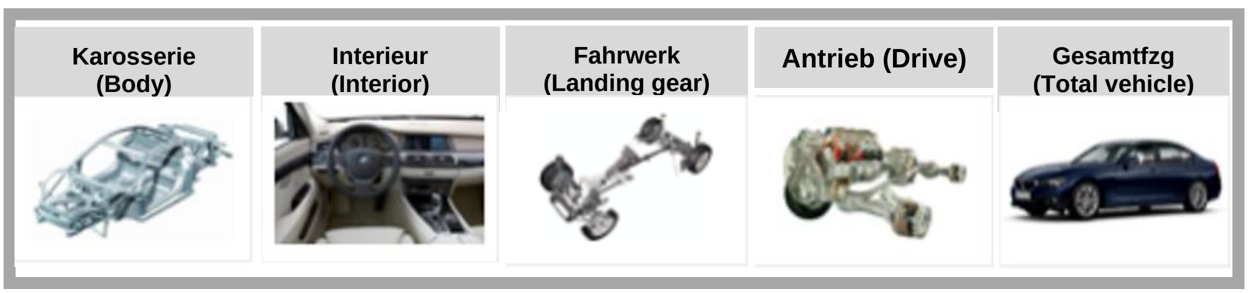

Figure 3: KIFAG-Categorization of Vehicle components at BMW

Virtually all manufacturers, VW in this case, pursue platform, module, and modular strategies to generate synergy effects. One platform serves for several variants of a vehicle. The modularization of individual

[19] Arthur D. Little 2014
[20] Will Urbanization of the Suburbs' Affect Vehicle Ownerships, 26 May 2020
[21] Urbanization and Automotive Market
[22] Building a digital automotive industry, 1 June 2020
[23] BMW Group
[24] Deloitte 2017

components generates further synergy across vehicle classes. In the modular strategy, the platform binding

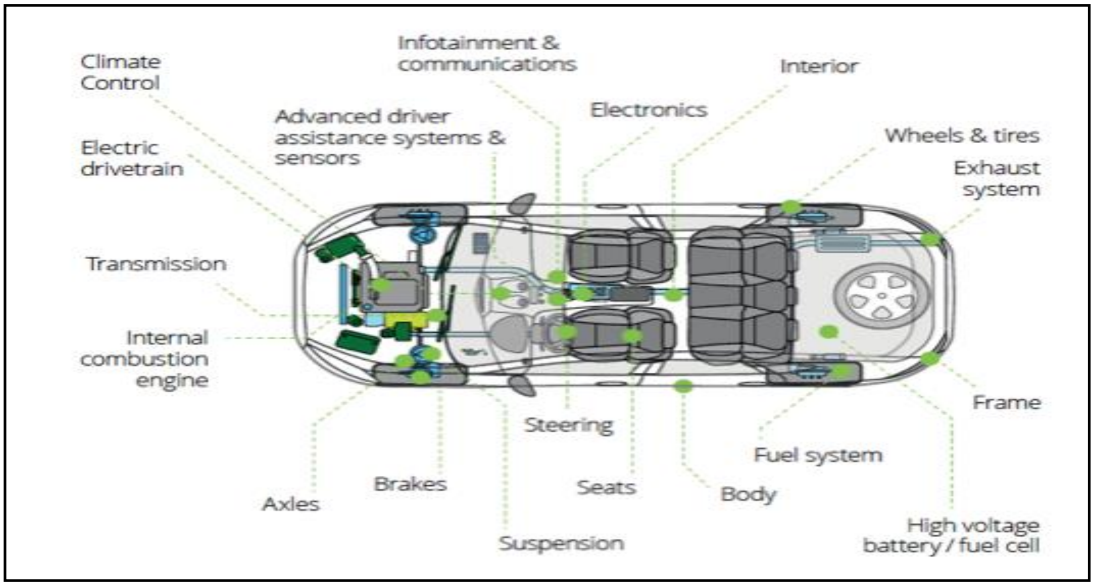

Figure 4: Electric car components

of individual modules is eliminated, and, synergy effects are realized across the vehicle of individual components that generates further synergies across vehicle classes. Corresponding to that the classical product life cycle gets under pressure. Classically, new vehicles are introduced every 6 to 7 years, including all the new technological advances that are then made. Prior to this, the vehicle is created in a product development process lasting about 4 years. After about 3-4 years a product upgrade (PA), the so-called facelift, is usually carried out to counteract the negative sales and profit development of the classic postcode. The basic technical architecture remains unchanged, but new equipment variants including engines are offered and the design is refreshed. The advancing technology development, especially in the area of software, increases the pressure on OEMs to establish short-lived product life cycles for applications.

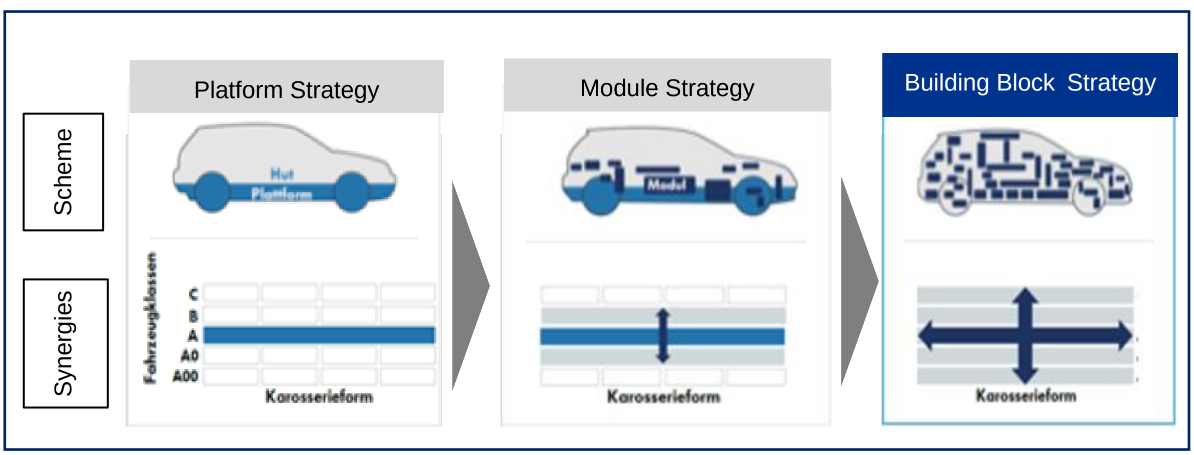

Figure 5: Modular building block strategy for synergy generation in the VW group

A close interlocking of the product life cycles of applications and vehicles is necessary to use applications in time. The applications are developed for different vehicles and iteratively rolled out over the duration of their life cycle. The Connected Car scopes can usually only be adapted at certain points in the product life cycle (e.g. facelift) of the vehicle. In addition to these short-term adjustments to the development process, there will be significantly shorter development cycles in the medium term due to closer integration between hardware and software development (agile processes). The automotive industry produces a product that is indeed complex, where in addition to connected-car topics and autonomous driving, the powertrain is a dominant subsystem.

To make an impressive example, Mercedes-Bank C-class may be considered. There are several different derivatives with more than 80 special equipment variants and packages. 1027 technically possible vehicle variant combinations are possible. There are more than 32,000 single components with more than 20,000 parts being delivered by suppliers. The vehicles are developed by about 180 different engineering service providers, produced by more than 560 suppliers and sold by about 400 dealers in 24 core markets. Combined with a product development time of more than 30 months and a ramp-up phase of 3-4 months, the consequences are tremendous (KIT 2016).

Progressive digitalization contributes to shortening development times in all process steps. In the design phase, digitization takes the upper hand with volume manufacturers, less so with premium manufacturers, as it is not meaningful enough for design decisions. The software is continuously developed and UTA is updated with the aircraft industry as a model. In the long term, the development process is divided into three layers: Chassis, computer layer, and software.

Each of the layers has different development times until the respective, individual SOP. Due to greater standardization and reduced complexity, the long-term usage cycles of the chassis will increase to 8 - 10 years. The computer layer, on the other hand, must be renewed every 3 - 4 years to be able to process the increasingly complex software (especially AI and machine learning algorithms for autonomous driving).

2.1.4 Production and Supply Chain

A significant change has been noted in the production volume of a different vehicle. With more than 80% production, Sedan/ Wagons were majority vehicle type produced in 1975 and it fell to 37% in 2018. The production share of pickups was 13% and 14% in 1975 and 2018 respectively. Minivan/vans production varied from less than 5% of the market in 1975 to 11% in 1995, to 3% in 2018. By the model year 2018, the production of truck SUVs was 35%, and car SUVs was 11%. In the model year 2018, 48% of the fleet were cars and 52% were trucks[25].

The global sales from auto parts exports by country totaled USD 412.1 billion in 2018. From 2017-18, exports for global automotive parts increased by 5.8%. Exports for automotive parts from European countries were highest in 2018 valued at USD 199 billion or 48.3% of the global total. It was followed by Asia (29.3%) and North American (21%)[26].

[25] EPA2019

[26] World's Top Exports 2020

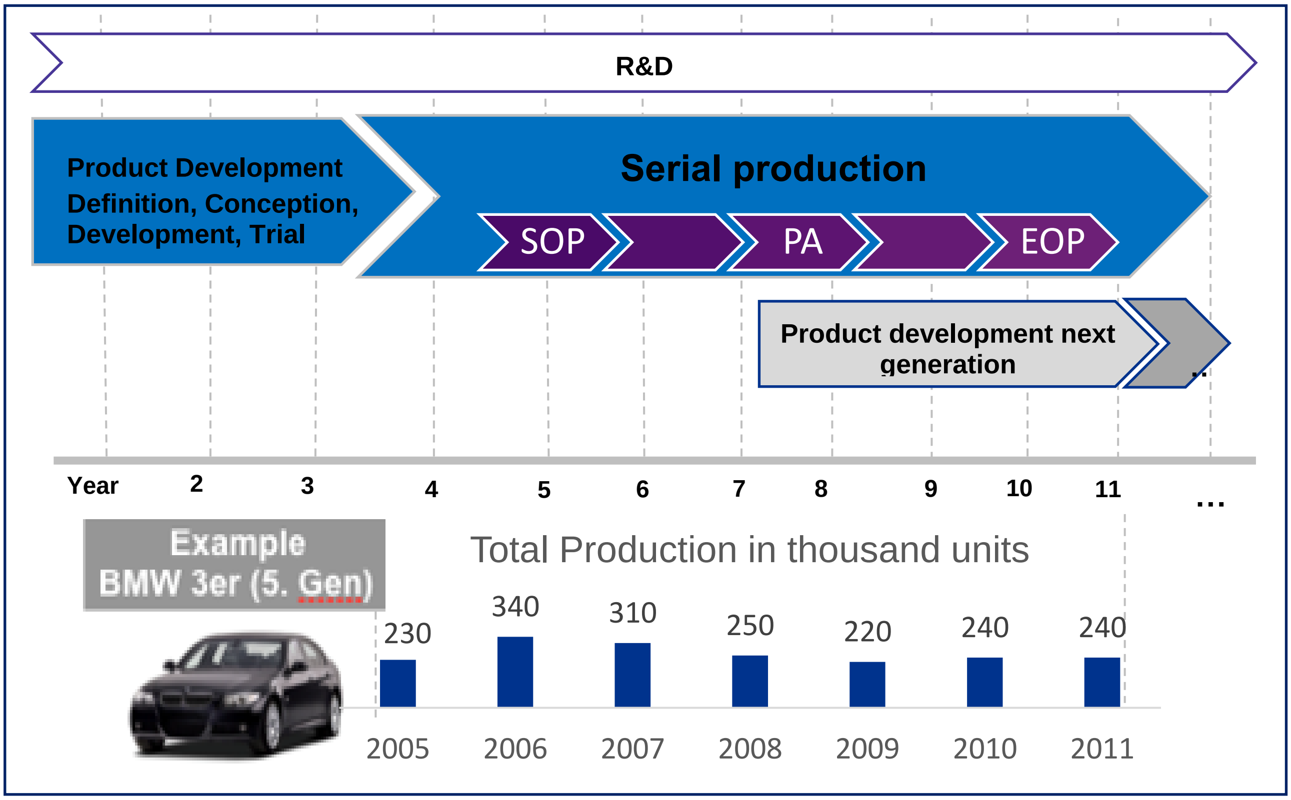

Figure 6: Classical product life cycle, Source: BMW Group, Pischinger & Seiffert 2016

Automation has been affecting the automotive industry production, processes, and the whole ecosystem for decades. Advances technologies such as collaborative robots or cobots, 3D printing – the entire manufacturing field are seeing a revolution and a push towards full automation. Companies such as BMW, Nissan, Ford ensure the safety of workers in its plants and quality goods and components by relying on cobots. Moreover, additive manufacturing is used by companies such as Audi, Rolls-Royce, Porsche to produce metal prototypes and spare parts for their vehicles. It is speculated that with the emergence of the COVID-19 pandemic, where social distancing is a key to survival, more automotive organizations will incorporate the use of these technologies in their regular manufacturing processes (Industry Europe 2019).

	Product Portfolio	Design	Product Development. (H/w)	Product Development. (S/w)	Raw material	Production	Sales	Services
Global established OEM	**Broad**	X	X	X		X	X	X
Chinese emerging OEM	**Broad/ Focused**	X	X	X		X	X	X
Tech Giants	**Focused**	X		X			X	
Software specialists	**Focused**			X				
Mobility Providers	**Focused**							
Suppliers	**Focused**			X	X	X		X

Table 3: Supply Chain roles along the automotive value chain (Mckinsey 2016)

Diverging markets will open opportunities for new players, who will initially focus on a few selected steps along the value chain and target only specific, economically attractive market segments – and may expand from there. Especially raw materials suppliers, who are supplying rubber, glass, steel, plastic, and aluminum classically, get more and more into the focus of automotive bargaining scenarios. As the new electric vehicles are being strongly focused in both developed and developed economies, it is highly probable that without the significant improvement in the use of materials and more pronounced recycling cycles, it will not be possible to achieve a changeover to fully electric vehicles. Moreover, the geopolitical concentration of rare earth is extremely strong. There is strong demand for lithium (80% held by Chile, Bolivia, and China) and nickel (56% held by Australia, New Caledonia, and Brazil), the main components of the traction battery. The case with electric motor and fuel cell components is also similar[27].

2.1.5 Regional Development

It has been observed that vehicle assembly place and parts production are usually located close to end markets due to political interest, market variation, and technical necessity[28]. Market saturation, the high level of motorization in the population and the tendency of car manufacturers to localize have also fostered the spread of final assembly, which is now taking place in many more countries than 30 years ago.

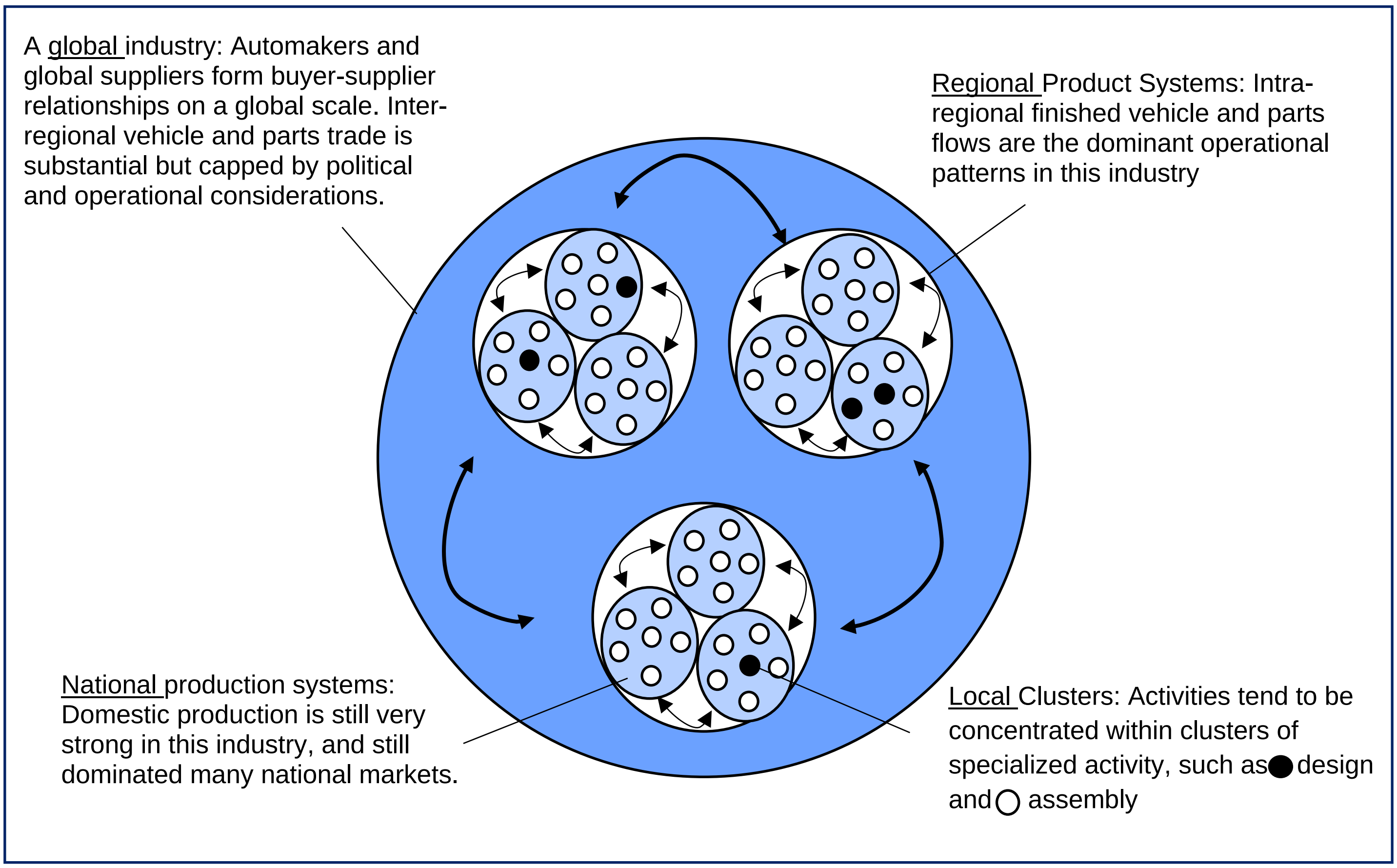

Figure 7: The nested geographic and organizational structure of the automotive industry

Often, for specific automotive components, suppliers are the only source to get the product. This imposes the need for partnership, associations, and collaboration. It not only raises costs for suppliers, who are

[27] U.S. Geological Survey 2013
[28] Sturgeon 2008

serving multiple customers but also results in the consolidation of most engineering work in a few geographic clusters, usually near the headquarters of the lead companies. Moreover, component suppliers have taken on a grander role in engineering design. Because vehicle designs are customized to local markets, suppliers have set-up their centers close to their main clients to enhance partnerships and associations. Buyer-supplier relations typically spread multi-production regions. This has resulted in regional, national, and local value chains in the automotive industry (**Figure** 7[28]). Dominant firms and industry associations, large-scale employment, and high unionization charges and iconic status of automobiles in society (particularly consumers and policymakers) increase the political clout of this industry. Therefore, even in the absence of import tariffs and local content rules, foreign assembles have voluntarily restricted exports and set up local production to forestall political backlash. The heterogeneous nature of the economic geography of the automotive industry can be seen from the availability of design technology in clusters. Economic geography is also affected by the main automotive firms due to their huge purchasing power[29].

As Bathelt et al (2004) emphasize, the presence of firms in a cluster is an impetus for developing, maintaining, and sharing tacit knowledge. The decentralized nature of the automotive industry has encouraged the development of strong R&D networks. Non-university research institutes, universities, and companies work together in numerous industrial and research clusters to improve or invent new products, solutions, services, and processes. By linking the individual competencies, important R&D clusters in the automotive industry are prevalent. These clusters have gained international recognition through the integration of industry, especially SMEs, science, and training in automotive-related fields such as mechatronics, microelectronics, mechanical engineering, manufacturing processes, and materials science.

According to Phuoc Luong Le 2015, there are six groups of benefit to support SME development.

i. Geographical proximity including a convenient traffic system, proximate to suppliers, proximate to producers, proximity to seaports and/or airports
ii. Professional labor including the ease to access the sources of professional labor and reduce relevant costs of recruitment
iii. Supports of technology which means that is easy for technological transfer and cooperation, technological supports for accessing customer databases of an automobile industrial cluster and technological supports for accessing market information
iv. Networks for cooperation comprising opportunities for being allied to large and/or multi-national companies, reliable and sustainable relationships with suppliers, that fact that is easy to access services (training, maintenance, etc.), to be supported by large companies in improving professional skills and the widening of markets based on cooperative relationships in the cluster
v. Corporate competence improvement with the goal to reduce relevant costs of inventory, relevant costs of scrap and defect, given-back items by customers, transportation costs, import and/or export costs training costs and to improve the in-time and right-quantity delivery, the response time for customer orders and the productivity
vi. Supportive policies and consulting including the supports of consulting services, preferential policies of the government such as supported capital, industrial development and so on, the opportunities for applying new management theories and methods and being shared with knowledge by professional conferences and programs which are conducted by the cluster

The focus location of global centers of automobile production is placed in Figure 8[30]. This underpins the scientific theses of the cluster theory that there is always an agglomeration of more than one OEM production site per region and in every region, multiple suppliers are located.

[29] Sturgeon 2009
[30] Automobile Production 2016

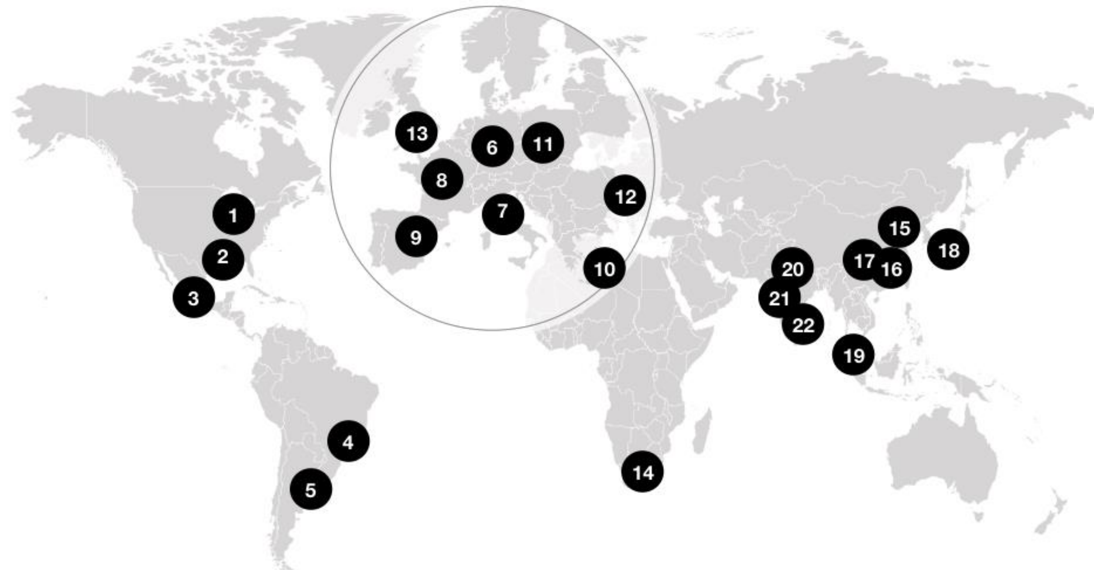

Figure 8: Centers of automobile production across the globe

German Automobile cluster- a case study

The factors such as geographical distance, technological distance, cooperation experience explain the cooperation behavior of the firms in the automotive industry in Germany. Another strong point of the auto sector is the close technological and geographical links between carmakers, suppliers, logistics firms, equipment suppliers (e.g. engineering companies), and research institutions in the university segment and beyond. The structure of this automotive cluster in Germany is probably unique worldwide and enables continual productivity gains and innovations (Deutsche Bank 2014). Also, firms with high levels of absorptive capacity tend to be more often involved in innovation networks.

It has been observed that the preference for modular knowledge bases is an industry-specific property which is related to the automotive product architecture and manufacturing. The high modularity of knowledge in the automotive industry seems to play a very important role in the innovation networks which can be found in this industry. Once R&D is increasingly shifted to suppliers and once the industry structures changes is a character from a strongly hierarchical architecture towards a more horizontal network organization, knowledge needs to become more modular. In fact, in the automotive industry suppliers are expected to gain even larger shares in the value chain during the next years. This tendency concerns production but also R&D. For R&D the share of the OEMs is expected to drop from 60 % in 2012 to only 47 % in 2025. Beneficiaries are suppliers and in engineering service providers. The automotive cluster is one of the largest and most important sectors in Germany contributing to around 20% of total German industry revenue in 2013. The sector accounts for over 30% of all passenger cars in the world.

The cluster produces 3.5 million more units than the next closest European competitor. The German car industry has been leading the segment globally for many years with 3 German companies amongst the top 10 global automotive manufacturers. German automotive industry is not limited to car manufacturing, 21 one of the world's top 100 suppliers are also German companies. In 2014, the revenue for German suppliers rose to an all-time high of 70 million euros with the employment of 290,000[31]. The largest market for exports

[31] GTAI 2015

from Germany in Europe with over 50% of exports followed by the United Kingdom and the United States at 17 and 15%, respectively[32]. In addition to the branding efforts, the premium nature of the automotive cluster has to do with investments. The automotive cluster is the largest recipient of Foreign Direct Investment in the country amounting to over 44% of the total investments. The industry spent a substantial amount of EUR 17.6 billion, on R&D in 2014, which is equivalent to one-third of Germany's total R&D expenditure[32]. OEMs and suppliers are an integral part of the technological market transformation globally. The industry is focused to improve the combustion engine energy efficiency, alternative drive technologies such as electric, hybrid, fuel cell cars, and lightweight materials and electronics. The headcount in R&D is growing with 95,000 employees (+3%) of 756,000 (+1.9%) employees in the industry as a whole[31].

On the factor conditions, the absence of natural resources and more recently high labor costs forced productivity improvement and lead to a focus on premium products in the automotive sector. The comparably good education system and a highly trained workforce add to the high-value creation. Strongly related industries such as machinery allow for local sourcing and knowledge spillovers which tremendously increases the competitive position of the region and good education further favors premium manufacturing. Companies are in strong competition with each not only about customers but also skilled personnel[33]. Additionally, cars are widely considered a status symbol in Germany, and especially Baden-Wuerttemberg itself has one of the highest demands for premium automobiles. Due to high-security standards and a strong regime of environmental regulation, firms are constantly being forced to innovate in key areas such as driver safety and emission. The high gas prices in Germany furthermore make German cars considerably more fuel-efficient than for instance their American counterparts. The firm context is coined by competition but also joint industry efforts in areas such as labor force training and strong personal ties between company executives. At the same time, it is a problem for manufacturers that the German car market is getting more and more mature with the aging population slowing down growth in the market. There is a strong network of supporting agencies such as the chambers of commerce as well as the institutes for collaboration such as Automotive BW and E-Mobility BW that are offering several activities and services to companies in the region.

Among those activities are branding, fairs, and networking channels as well as assistance for small and medium-sized companies to enter world markets. Due to EU regulation, there are strict limits to the degree of how new companies can be incentivized through monetary means to settle in the state. Another problem that has frequently been brought up by the experts interviewed is that universities might be limited in the degree to which they work on possible breakthrough research because industry funding directs them to prioritize research on sustaining established industries.

2.1.6 Key Players and Strategic Directions

In addition to the manufacturers and providers of mobility-focused throughout the study, the focus of this chapter will be entirely on the suppliers. Due to the extremely high value-added share of the total vehicle of sometimes more than 90%, it is quite justified to describe the suppliers as core players in the automotive industry. Even if the development is significantly influenced by the changing tendencies of the OEMs, the suppliers have to find solutions and reactions to these impulses. But the general global economic and political situation also applies to them. Within the last years, we observe record revenues despite difficult circumstances in the world, like Brexit, impulsive US trade policy and cooling of the Chinese economy, the global 100 biggest automotive suppliers achieved revenue growth of 7.6% year on year. Additionally, the investment spending in the future puts pressure on the margins which are declining to an average of 7.7% of EBIT.

While German suppliers assert their market position, Bosch, Continental, and ZF Friedrichshafen underscore with their top 10 positions the strength of the German suppliers, Chinese suppliers are advancing. For example, CATL is the climber of the year, profiting from the increasing penetration of

[32] Di Bitonto 2015
[33] Zhakiyanov et al. 2015

electromobility[34]. As profitability champions US companies ITW (22.5%), EATON (17.2%), Garrett Motion (15.6%) as well as Swiss TE Connectivity (18.1%) and CATL (15.6%) lot of specialist companies are in the forefront. Growth champions are the Chinese Joyson Electronics (111.2%), CATL (48.1%), South Korean LG Electronics (28.4%) as well as US Tenneco (26.8%) and Meritor (21.5%). On average the total revenue of the top 100 increased by 7.6% to € 889 billion, thereby growing much more strongly than in the prior year. In 2017, the world's biggest automotive suppliers had only grown by 1.1%. In order to become a member of the "Top 100 club"in 2018, at least € 2.9 billion revenue was necessary. In 2017, € 2.6 billion had been necessary to be a member[34].

		RANK	REVENUE IN €							PROFITABILITY					
S No.	Company	Country	2018	2017	Δ	2018	2017	ΔAbsolute	ΔRelative	Type	2018€	2018€	2017€	2017€	Δ
1.	Mitsubishi Electric	JP	51	55	4	5,276	4,829	447	9.2%	OI	502	9.5%	600	12.4%	-2.9%
2.	Pirelli	IT	52	49	-3	5,195	5,352	-157	-2.9%	EBIT	703	13.5%	674	12.6%	0.9%
3.	Harman (Samsung)	US	53	56	3	5,156	4,803	353	7.3%	OI	110	2.1%	44	0.9%	1.2%
4.	Grupo Antolin	ES	54	53	-1	5,016	5,037	-21	-0.4%	EBIT	161	3.2%	291	5.8%	-2.6%
5.	Magneti Marelli	IT	55	52	-3	4,998	5,204	-206	-4%	N.A.	./.	./.	./.	./.	./.
6.	NTN	JP	56	57	1	4,926	4,583	343	7.5%	OI	235	4.8%	261	5.7%	-0.9%
7.	Hyundai WIA	KR	57	54	-3	4,795	5,025	-229	-4.6%	OI	84	1.8%	53	1.1%	0.7%
8.	Hankook Tires	KR	58	50	-8	4,757	5,314	-557	-10.5%	OI	493	10.4%	619	11.6%	-1.3%
9.	Eberspacher	DE	59	58	-1	4,610	4,481	130	2.9%	N.A.	./.	./.	./.	./.	./.
10.	Alps Electric	JP	60	64	4	4,586	3,980	606	15.2%	OI	314	6.9%	301	7.6%	-0.7%
11.	Delphi Technologies	US	61	63	2	4,237	4,047	189	4.7%	OI	378	8.9%	371	9.2%	-0.3%
12.	Dr aximaier	DE	62	62	0	4,200	4,100	100	2.4%	N.A.	./.	./.	./.	./.	./.
13.	Freudenberg	DE	63	61	-2	4,160	4,206	-46	-1.1%	N.A.	./.	./.	./.	./.	./.
14.	Hanon Systems	KR	64	60	-4	4,157	4,357	-200	-4.6%	OI	304	7.3%	365	8.4%	-1.1%
15.	Namak	MX	65	66	1	4,102	3,740	362	9.7%	OI	354	8.6%	309	8.3%	0.4%
16.	Leoni	DE	66	65	-1	4,013	3,875	137	3.5%	N.A.	./.	./.	./.	./.	./.
17.	Tokai Rika	JP	67	69	2	3,972	3,548	423	11.9%	OI	249	6.3%	215	6.1%	./.
18.	Mando Corp.	KR	68	59	-9	3,965	4,435	-470	-10.6%	OI	138	3.5%	65	1.5%	0.2%
19.	IAC	LU	69	67	-2	3,924	3,673	252	6.9%	N.A.	./.	./.	./.	./.	2.0%
20.	Meritor	US	70	85	15	3,761	2,964	797	26.9%	OI	309	8.2%	197	6.6.%	1.6%

Table 4: The Top 20 Automotive suppliers

An analysis of the development of the respective components of the automobile industry, it very quickly becomes clear that the upheaval in technology will result in major changes in the supplier structure. The main beneficiaries will be players who specialize in batteries or fuel cells and the electric drive train as such, as well as autonomous driving systems and their sensors, or who have them in their portfolio. Due to the general uncertainty, a rather slight growth, and in parts also slightly declining sales of automobiles until 2030, most of the components are subject to a slight decline. The biggest losses will be suffered by all players involved in the fuel system, exhaust system, internal combustion engine, and transmissions. Many, but not all, of these companies are additionally exploring electrical powertrain technology, i.e., they are acting ambidextrously. For some of them, this is even an imperative, because their previous products will be obsolete, and thus their knowledge base will be without any value once the paradigm shift is finalized. Furthermore, several suppliers who have not been active within the conventional powertrain are seizing the

[34] Berylls 2019

chance to enter this field through the strategic window of opportunity during the change of the technological paradigm. This ambidextrous strategy is often based on the existing knowledge base in relevant fields, especially electrical or chemical engineering, that was originally built up in different domains. Furthermore, similar to car manufacturers, there are probably suppliers who cannot afford explorative activities exploration in heterogeneous innovation networks. It is a paradox, that exactly the kind of behavior which made them successful oligopolists provides them an inferior basis for potential-oriented modes of explorative learning and networking. For the suppliers, the situation has to be analyzed in a more differentiated way, because not all of the 100 biggest suppliers, globally, are engaged in powertrain business, but all are exploitatively engaged within their core business. Due to the fact that the conventional powertrain is the dominating subsystem within the automobile, a majority of the suppliers are also exploiting this field. Many, but not all, of these companies are additionally exploring electrical powertrain technology, i.e., they are acting ambidextrously. For some of them, this is even an imperative, because their previous products will be obsolete, and thus their knowledge base will be without any value once the paradigm shift is finalized. Furthermore, several suppliers who have not been active within the conventional powertrain are seizing the chance to enter this field through the strategic window of opportunity during the change of the technological paradigm. This ambidextrous strategy is often based on the existing knowledge base in relevant fields, especially electrical or chemical engineering, that was originally built up in different domains. Furthermore, similar to car manufacturers, there are probably suppliers who cannot afford explorative activities due to inefficient exploitation in their core business. In summary, the explorative engagement of the supplier group is too low by far, such that market squeeze-outs by the technological paradigm shift are very likely. Specifically, because of the expected gradual transformation between the conventional and electrical paradigms, with an intermediate hybrid-phase, they are losing a unique chance by failing to learn ambidextrously.

2.2 Indian Scenario

2.2.1 Automotive Industry

The Indian automotive sector contributes 22-25 percent of India's manufacturing GDP. The collective vision of the government and the industry, i.e. Automotive Mission Plan 2016-2026 (AMP 2026), indicates that the industry has the potential to scale up exports to 35-40 percent of total output by FY2026 and become one of the major automotive hubs in the world. AMP 2026 has set a road map for the industry for the next 10 years with targets as follows:

- Industry revenue to increase 3.5x-4x to INR 17,789.72 billion-INR 20,526.60 billion (from INR 5,063 billion)
- Increase in production of (a) passenger vehicles to 9.4 million-13.4 million units, (b) commercial vehicles to 2.0 million-3.9 million units and (c) two-wheelers to 50.6 million-55.5 million units
- Contribution to GDP to be over 12 percent
- Generating around 65 million new jobs

The well-developed Indian automotive industry of India produces a variety of vehicles such as passenger cars, light, medium and heavy commercial vehicles, multi-utility vehicles, scooters, motorcycles, mopeds, three-wheelers, etc. The category-wise share of automobile production for FY19 is shown in figure 8.

As per the current statistics, the auto Industry's turnover is estimated to be equivalent to 7.1% of overall GDP. India ranked fourth in automobile production in the world in 2018 with sales increasing 8.3 percent year-on-year to 3.99 million units. In the same year, it was fourth and seventh in passenger and commercial vehicle production respectively[35]. While domestic automobile production increased at 6.96 percent CAGR between FY13-19, the overall domestic automobile sales increased at 6.71 percent CAGR between FY13-19. In FY19, year-on-year growth in domestic sales among all the categories was recorded in commercial vehicles at 17.55 percent followed by 10.27 percent year-on-year growth in the sales of three-wheelers. Automobile exports grew 14.50 percent during FY19. It is expected to grow at a CAGR of 3.05 percent during 2016-2026.

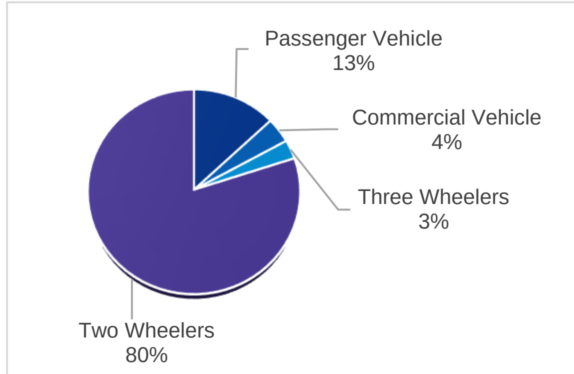

Figure 9: Share of each segment in total production volume (FY19)

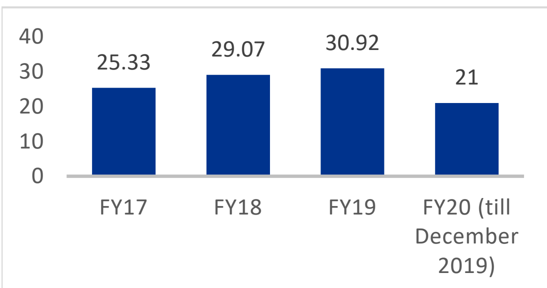

Table 6: Number of Automobiles Produced (in million)

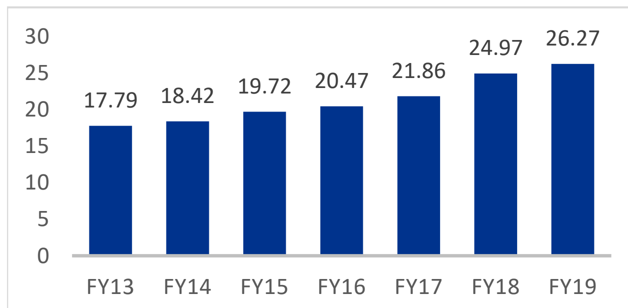

Table 5: Number of Automobiles sold in India (in millions)

2.2.2 Auto Component Industry

Auto Components Industry in India was US$ 57 billion in 2018-19 as compared to US$ 51.2 billion in 2017-18. It is expected to grow to US$ 200 billion by 2026. The auto component sector share in India's GDP is 2.3 percent and India's export is 4 percent and it has generated 1.5 million employees in the country[36].

Auto component exports from India were US$ 15.2 billion in 2018-19 as compared to US$ 13.4 billion in 2017-18. USA, Germany, the UK, Thailand, and Italy are the top destinations for auto component exports. Aftermarket segment which includes tire, battery, brake parts, was $10.1 billion in 2018-19 as compared to US$ 9.2 billion in 2017-18. The overall details of

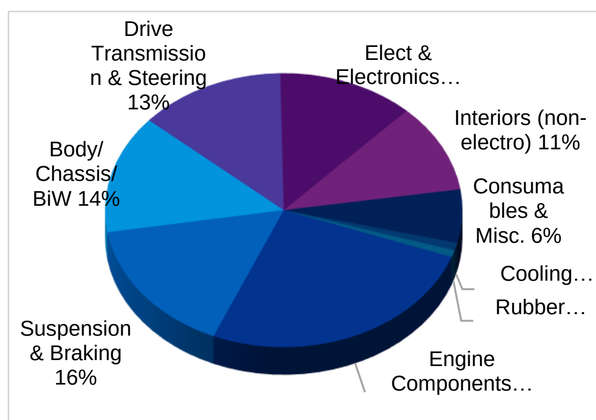

Figure 10: Auto Component Wise Share

[35] Indian Automotive Industry Report, IBEF, 28 May 2020
[36] ACMA Annual Report 2019

Automotive Components Industry-Performance (Rs. in 100 Crore) are given in table 8[36]:

Year	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	CAGR
Turnover % Growth	2160 5.60	2117 -2.00	2348 11.1	2556 8.8	2921 14.3	3456 18.3	10%
Exports % Growth	526 23.30	621 16.70	685 11.4	709 3.5	731 3.1	905 23.9	11%
Imports % Growth	744 11.60	771 3.60	829 7.5	906 9.3	905 -0.1	1066 17.8	7%

Table 7: Automotive components Industry-performance

2.2.3 Evolution of the automobile sector

The automobile industry in India started evolving during the 1950s. The sector noticed major upheaval in 1982 after a JV was signed between the Government of India and Suzuki Motor Corporation. Maruti Suzuki transformed the vehicle transportation network in India. In true sense, Maruti changed the dynamics of the Indian passenger car industry. The evolution of the automobile sector in India can be summarized as below.

1950 to Late 1980s
- Supply driven market, limited models and designs
- Emphasis on indigenization of parts and assemblies
- Manufacturing based on GPMs, SPMs and transfer lines
- Focus on petrol and diesel
- MSMEs primarily involved in job works, at the instance of manufactures

1990s
- Shift from mere indigenization to efficiency and better designs
- Launch of automobile policy, facilitating entry of global assemblers
- Emphasis on making more fuel-efficient cars
- Introduction of CNCs and SPMs for all the parts/ assemblers
- Availability of imported designs and parts
- Introduction and popularization of LPG, natural Gas as prime source
- MSMEs elevated as parts supplier for non-critical parts

Early 2000
- Fully delicensed, free imports of automate component and 100% FDI allowed
- Focus to make India as parts supplier in global supply chain
- Focus on exports of automobiles from India
- Introduction of robots and additive manufacturing machines
- Focus on fuel efficiency and conservation of resources
- Shift to a demand driven market within India
- MSMEs marked its footprint in export market

2010 onwards
- Aspiration to make India as automobile manufacturing hub for global market
- Shift to CNCs and 3D printing technology with automated production shops
- Increasing focus on EV
- Market developed to an extent of asking for customized vehicles
- Introduction of lighter materials for production for parts
- MSMEs taking up as role of parts designers and developers

Figure 11: Evolution of Automobile sector in India

2.2.4 Growth trends

According to a McKinsey report, *the auto component industry in India: Preparing for the future*, multiple trends are impacting the automotive and auto component industry and creating specific growth opportunities[37]. Some of these growth trends are discussed below.

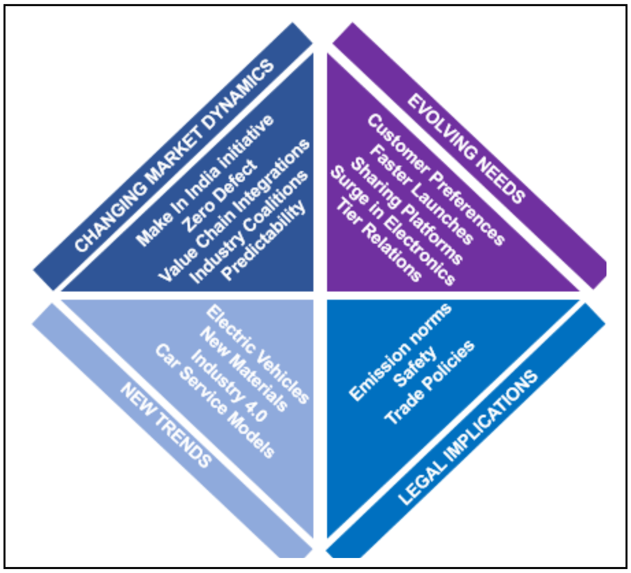

Figure 12: Growth Trends in automotive industry

A. Changing Market Dynamics

Customer needs, market demand, evolving supply chain models, novel operating models, and market fluctuations are creating a challenging environment for automotive manufacturers.

The Make in India Initiative: With deeper localization across various tiers, the industry can indigenously produce vehicles at a higher percentage. This gives OEMs a cost advantage and makes India a favorable hub for exports across the world. With Asia deemed to be the next growth engine of the globe, manufacturers are keen to set up base close to meet the demands in various Asian markets. In 2017 nearly 40 of the top 100 Tier1 suppliers had bases set up in Asia. India lies at this epicenter to meet demands from this mega continent and has emerged as a favorable destination for many conglomerates.

Zero Defect: With the high costs involved in recalling vehicles, OEMs are now focusing on quality and manufacturing excellence. OEMs are closely monitoring and encouraging their suppliers to adopt a zero-defect policy. To better comprehend the nature of the recall, it becomes important to have traceability of all the models produced. This virtual tagging will ensure the only the vehicles that need attention are recalled, hence saving millions of dollars in comparison to a batch recall.

Value Chain Integration: It is anticipated that in the coming years Tier1 suppliers will not restrict themselves only to supplying parts to OEMs but go beyond this by playing the role of system integrators.

Industry Coalitions: Challenging times have brought many manufacturers to ally to share their technical prowess to save R&D costs and capture more market share. The Suzuki-Toyota alliance is a fine example with both companies benefitting from each other's strengths.

Predictability: Several factors alter the normal supply chain operations. These factors vary from unexpected natural disasters to geopolitical tensions and can have a significant impact on costs. It is also essential to understand the shift in customer preferences and technological advances while predicting demand forecasting.

[37] The auto component industry in India: Preparing for the future, McKinsey, 11 June 2020

B. Evolving Needs

A paradigm shift in customer preferences, technology, and cost-saving attributes have forced automobile manufacturers to re-think their strategies to ensure they survive the fierce competition.

Customer Preferences: Higher disposable incomes and lower cost of ownership with the availability of attractive finance options have brought a gradual shift in customer preferences from an entry-level car to a high-end luxury vehicle. Hence OEMs must rethink strategies to continuously cater to this genre of customers.

Faster Launches: As product lifecycles continue to shrink due to customer preferences for fresher and more technologically advanced models, the industry has seen more launches in the past decade than ever before.

Sharing Platforms: One effective way to reduce costs and lower manufacturing and operational complexity is to use a single platform across various models. Economies of scale can be achieved as common components that can be used across several models.

Surge in Electronics: Globally automotive engineering has witnessed a surge in the use of electronics in various systems that were previously purely mechanical. With governments enforcing stricter emission norms, electronics integrated into mechanical systems provide a good medium for retrieving data that can analyze the performance of vehicles. Indian automotive manufacturers are gradually getting in line with global standards and hence we can expect a surge in electronics in Indian cars too.

Tier Relations: OEMs are closely working across Tier suppliers to enhance the latter's value chain integration and quality of components produced. These steps would help various Tier suppliers to reduce costs, produce better quality, and eliminate waste. These are then passed as benefits to the OEM and is a win-win situation for both.

C. Disruptions

The advent of various new technologies, processes, and services has significantly impacted the standard working procedures for OEMs who must constantly redraw their strategies to fit the market needs.

Electric Vehicles: Traditional gasoline automotive manufacturers would have to invest in cleaner models such as Electric Vehicles which may soon see a surge in sales once the charging infrastructure gets in place. Stricter emission norms and customers awareness are the two factors that are pushing OEMs to invest heavily in electric vehicle technology.

New Materials: Automotive manufacturers are also investing heavily in research on the use of novel materials that are lighter and sturdier. This would help in achieving better fuel efficiency without compromising on the safety of the occupants.

Industry 4.0: With the advent of IoT, Blockchain, 3D Printing, Smart Manufacturing, and several other digital technologies, the automotive industry must rapidly shift gears to use these technologies to the maximum use to deliver a better and faster product to the consumer.

Driverless Cars: With the advancement in emerging technologies, autonomous vehicles have started revolutionizing the world and driverless vehicles have shown incredible potential for disruption in automotive industry. This technology provides several benefits such as less fuel stations, less requirement of vehicles, associated services and this will also reduce carbon footprint as the number of cars will be less for a family. These advance cars are anticipated to have predictive models for maintenance and service with enhanced security features.

Car Service Models: The car ownership model faces several challenges from integrators that provide ride-hailing services, ride-sharing platforms, and car rental services. OEMs may hence have to develop models specifically to cater to services that need cost-effective models.

D. Legal Implications

Automotive manufacturers are constantly under pressure from external factors that regulate the industry and manufacturers are required to adhere to these policies strictly.

Emission Norms: Indian authorities have enforced the BS-VI norms and automotive manufacturers have geared up to curb emissions to comply with these norms.

Safety: Authorities have also enforced a few mandatory requirements in all vehicles such as ABS technology. With passenger safety given paramount importance, OEMs ensure that their vehicles pass all necessary crash test requirements.

Trade Policies: OEMs must closely monitor international trade policies that impact the transfer of parts or finished products across borders. Trade agreements, tariffs, and import duties are some of the important factors that determine the pricing of the final product.

2.2.5 Foreign Direct Investment (FDI) in India

FDI plays an important role in the economic development of a country. The capital inflow of foreign investors allows strengthening infrastructure, increasing productivity and creating employment opportunities within the country. Additionally, FDI acts as a medium to acquire advanced technology and mobilize foreign exchange resources. Availability of foreign exchange reserves in the country allows RBI (the central banking institution of India) to intervene in the foreign exchange market and control any adverse movement in order to stabilize the foreign exchange rates. As a result, it provides a more favorable economic environment for the development of Indian economy.

India is expected to be the world's third-largest automotive market in terms of volume by 2026 and FDI Inflows to Automobile Industry have been at an increasing rate as India has witnessed a major economic liberalization over the years in terms of various industries.

FDI policy in India allows 100% FDI along with full delicensing under the automatic route for automobile sector. Hence, making it easy for investors to set up their manufacturing plant/shop in India. The cumulative FDI equity inflow[38] in the Automobile industry is USD 24.5 billion during the period April 2000 to June 2020. This constitutes 5.15% of the total FDI inflow received across sectors. It is expected to attract USD 8-10 billion[39] more in local and foreign investments by 2023.

Industries are looking at investment in automobile industry as significant opportunity. The current[40] value of automobile industry at $75 billion is expected to reach $300bn by 2026. The auto hubs of India have significant potential as they are increasingly being used as base for exports to SEA and MENA regions. Some of the recent/planned FDIs in automotive sector are as follows:

- Force Motors planned to invest Rs 600 crore (US$ 85.85 million) in order to develop two new models over the next two years.
- Morris Garages (MG), a British automobile brand, announced plans to invest an additional Rs 3,000 crore (US$ 429.25 million) in India.

[38] Make in India, Automobile Sector FDI, 22 October 2020

[39] Auto sector may see $8-10 billion in investments by 2023, 01 January 2020

[40] FDI India, 22 October 2020

- Tata AutoComp Systems, the auto-components arm of Tata Group entered a joint venture with Beijing-based Prestolite Electric to enter the electric vehicle (EV) components market.
- Hyundai Motors Company and KIA Motors Corporation plan on investing $300 million in taxi service giant Ola to build unique fleet and mobility solutions

2.2.6 Production and Consumption trends

The industry produced a total of 2,90,73,892 (29.07 million) vehicles, including passenger vehicles, commercial vehicles, three-wheelers, two-wheelers and quadricycle in FY18, against 2,53,29,383 (over 25 million) in FY17, registered a growth of 14.8 percent.

Category	2013-14	2014-15	2015-16	2016-17	2017-18
Passenger Vehicles	30,87,973	32,21,419	34,65,045	38,01,670	40,10,373
Commercial Vehicles	6,99,035	6,98,298	7,86,692	8,10,253	8,94,551
Three Wheelers	8,30,108	9,49,019	9,34,104	7,83,721	10,21,911
Two Wheelers	1,68,83,049	1,84,89,311	1,88,30,227	1,99,33,739	2,31,47,057

Table 8: Trends in Domestic Production[41]

Some of the significant trends in domestic sales are as below:

- The domestic sales of passenger vehicles grew at 7.89 percent in 2017-18, against 9.23 percent in 2016-17.
- Commercial vehicle segment sales registered a growth of 20 percent in 2017-18.
- Three-wheeler grew at a 24 percent growth rate from the previous year 2016-17.
- Two-wheelers grew at 14.80 percent, compared with 7 percent in 2016-17.

Category	2013-14	2014-15	2015-16	2017-18
Passenger Vehicles	25,03,509	26,01,236	27,89,208	30,47,582
Commercial Vehicles	6,32,851	6,14,948	6,85,704	7,14,082
Three Wheelers	4,80,085	5,32,626	5,38,208	5,11,879
Two Wheelers	1,48,06,778	1,59,75,561	1,64,55,851	1,75,89,738

Table 9: Trends in Domestic Sales

The Indian auto industry boasts of good export volumes in many developing countries. Some growth trends in the exports in various categories are as below:

- The two-wheeler segment grew at 20.29 percent in 2017-18.
- Three-wheeler export grew over 40 percent from 0.27 million to 0.38 million.
- Export for passenger and commercial vehicles has declined in 2017-18 compared to the previous year.

Category	2013-14	2014-15	2015-16	2016-17	2017-18
Passenger Vehicles	5,96,142	6,21,341	6,53,053	7,58,727	7,47,287
Commercial Vehicles	77,050	86,939	1,03,124	1,08,271	96,867
Three Wheelers	3,53,392	4,07,600	4,04,441	2,71,894	3,81,002

[41] SIAM

Two Wheelers	20,84,000	24,57,466	24,82,876	23,40,277	28,15,016

Table 10: Trends in Exports

Multi-utility online marketplace for Rural India - NayaGaadi.com

In India, vehicle manufacturers generally prefer to open their showrooms in big cities or at district centres and thus rural markets are given less focus for marketing and promotion. To bridge this gap and leverage the ongoing digitalization to enhance connectivity, innovation of e-market place is playing an important role and these platforms are evolving day by day in digital world. One such platform is NayaGaadi.com which is rural India's first multi-utility marketplace for all new vehicles. It provides test drives, financing solutions and door delivery of vehicles at customer's end. This empowers rural customers with access to information and services and enables them to experience all benefits associated with buying a vehicle.

2.2.7 Regional analysis

Economic growth is a feature of cities and regions, which have been industrialized. Industrialization depends on a lot of factors such as proximity to resources and markets, transportation cost, localization and urbanization economies, policy decisions on infrastructure, exchange rates, land use, globalization, etc.[42]

The 'cluster' concept particularly emphasizes inter-firm relations that reduce the cost of production by lowering transaction costs among firms. The co-location of firms in the automobile industry generates benefits including sharing of sector-specific inputs, skilled labor, and knowledge, intra-industry linkages, and opportunities for efficient subcontracting. In the automobile industry, it is common for competitors in the market to launch joint projects for new products and process development[43].

Following automobile clusters are paving a path for the booming automobile industry in India, all set to reach a market size of USD 300 Billion by 2026[44]:

- Delhi-Gurgaon-Faridabad in the north
- Mumbai-Pune-Nashik-Aurangabad in the west
- Chennai- Bengaluru-Hosur in the south
- Jamshedpur-Kolkata in the east of India

Chennai Automobile cluster- a case study

Chennai is called the hub of the Indian Automobile Industry and at times referred to as "Detroit of India". But it did not happen overnight, rather it required vision, strategic planning, and careful execution to develop the auto cluster of Chennai. A lot of factors contributed to the formation of this cluster. Firstly, it was the coordinated and joint efforts of both the State and Central government that made it possible to develop the region into an auto hub. The state political leaders of Tamil Nadu in the 1950s and 1960s were instrumental in bringing auto component firms to Chennai. Both the governments put effort and intervened at the right time to ensure that the bottlenecks are removed. The state government developed many industrial estates in and around Chennai to encourage the opening of small firms and ancillary units, many producing auto components.

Secondly, the descent infrastructural set up such as the presence of seaports and airports in Chennai propelled the growth. These ports were well connected and thus Chennai scored high on accessibility parameters making it an attractive proposition for the entrepreneurs to set up their businesses. Thirdly, Tamil Nadu already had few large and established industrial houses such as the TVS group, the Rane group and the Chettiars. The presence of these groups further helped in development of the auto cluster.

[42] C. J. Chen and Adam Rose, "The Joint Stability of Input-Output Production and Allocation Coefficients", Modelling and Simulation, Vol. 17, 1986, pp. 251-55

[43] M. Porter, The Comparative Advantage of Nations, London: Macmillan, 1990

[44] India's Automobile Hubs, 27 May 2020

The fourth factor was the availability of a highly skilled workforce. due to the presence of many engineering colleges including the famed IIT Madras.

Fifth, the role of small firms and ancillary units in the formation of the Chennai auto cluster is very crucial. In the 1950s and 1960s, North Chennai saw the setting up of many ancillary and components units by the large industrial houses such as TVS, Rane, and the Amalgamations group. An industrial zone in Padi, a neighborhood on the outskirts of Chennai was developed by TVS group. This zone later came to be known as TVS Nagar. From the very beginning, these auto components manufacturing firms did not just limit their focus to the local market of Chennai rather they targeted PAN India. The reason for this can be attributed to the low demand, which was not enough to sustain the business for the auto components manufacturers, generated by the two auto assemblers of Chennai viz. Standard Motors and Ashok Leyland. Thus, with PAN India reach, these firms flourished and expanded their operations by setting up new businesses and plants and adding new product lines to the existing businesses. As these firms expanded, many entrepreneurs started setting up a new business to support these large components manufacturers. These small firms came to be known as tier2 and tier3 suppliers, who supplied components to the tier1 suppliers.

Now, Chennai was already established as a supplier market due to the presence of large industrial components manufacturing groups and small players. This attracted big global auto giants such as Ford, Hyundai, and Mitsubishi to set up their operations in and around Chennai in 1990. The 2000s witnessed the IT boom in India opening newer possibilities for firms operating in Chennai Clusters. The presence of IT and internet infrastructure helped establish new business models and it allowed firms to go global by setting up digital B2B commerce.

2.2.8 Government Schemes and Policies

The Government launched several schemes and programmes to develop the ecosystem in the automobile industry. A large focus has been on supporting MSMEs as they play a vital role in strengthening the automobile industry. The following schemes and programs have been launched by the Department of Heavy Industries to provide an impetus to the growth of the industry.

S No.	Government Initiative	Description/Policy Objective
i.	Automotive Mission Plan 2016-26	States regulations and policies with regards to technology, manufacturing, and testing, research and design, sales, imports and exports, repair and recycling of automotive components, and electric vehicles[45],[46].
ii.	Charging Infrastructure Guidelines for EVs, Ministry of Power, 2019[47]	Guidelines on quicker adoption of EVs by facilitating affordable charging infrastructure and eco-system including tariff charge and employment generation.
iii.	Faster Adoption and Manufacturing of Hybrid and Electric Vehicles (FAME)	▪ Launched in 2015 under NEMMP to support hybrid/ electric vehicles market development and Manufacturing eco-system[48]. ▪ Investment of INR 359 crore was done to support about 2.8 lakh hybrid and electric vehicles. ▪ Investment of INR 300 crore was sanctioned to support 425 electric and hybrid buses. ▪ An amount of INR 43 crore was sanctioned for the development of 500 charging Stations/ infrastructure[49].
iv.	FAME India Phase-II	▪ Implemented for 3 years from 1st April 2019 with total budgetary support of Rs. 10,000 crores.

[45] Auto Mission Policy
[46] Automotive Mission Plan 2016-26 (A current raiser)
[47] Charging Infrastructure for EV- Revised Guidelines ad Standards Ministry of Power, GOI
[48] National Mission on Electric Mobility
[49] Ministry of Heavy Industries and Public Enterprises website, 20 May 2020

S No.	Government Initiative	Description/Policy Objective
		▪ To support the electrification of public and shared transportation through demand incentive approx. 7000 e-Buses, 5 lakh e-3 Wheelers, 55000 e-4 Wheeler Passenger Cars, and 10 lakh e-2 Wheelers. ▪ About 14,160 Electric Vehicles supported till 26.02.2020 amounting to about Rs. 50 crores. ▪ 5595 electrical buses have also been sanctioned to various State/ City Transport Undertakings. ▪ 2,636 EV Charging Stations have been sanctioned amounting to Rs 500 crore (Approx.) in 62 cities across 24 States/ UTs
v.	Green Urban Transport Scheme (GUTS) 2017	▪ This scheme promotes low carbon sustainable public transport system in urban areas by encouraging the use of NMT, public bike sharing, BRT systems, ITS, urban freight management, etc. ▪ The amount allotted by the government to implement the scheme is INR 25000 crore for the cities having a population above 5 lakhs and all capital cities[50].
vi.	National Auto Policy (Draft) 2018[51]	The objective is to provide a roadmap for the automotive industry by promoting sustainable mobility, focusing on R&D, increasing exports, providing employment opportunities - leading to an increase in GDP contribution of the country.
vii.	National Automotive Testing and R&D Infrastructure Project (NATRiP)[52]	▪ Approved with a cost estimate of INR 3727.30 crore. ▪ Aims at setting up of 7 state-of-the-art automotive testing and R&D centers across the country. The places are within the Northern auto-cluster at ICAT-Manesar, Haryana, and Southern auto-cluster at GARC-Oragadam, Chennai, Tamil Nadu, and up-gradation of existing centers at ARAI- Pune and VRDE-Ahmednagar in Maharashtra for Western auto-cluster[53]. ▪ NATRiP would support MSMEs in the development and certification of auto-components, for OEMs and after-sale parts. ▪ NVH Lab is developed under the project at ICAT, Manesar, Haryana. The facility has PSL, EMC Lab, and TTL[54].
viii.	National Electric Mobility Mission Plan 2020 (NEMMP)[55]	NEMMP 2020 provides the vision and the roadmap for the faster adoption of electric vehicles and their manufacturing in the country.
ix.	Technology Platform for Electric Mobility (TPEM)	TPEM is creating a collaborative platform for developers, suppliers, automakers to work together in five areas — lithium battery technology, motors, and drives, charging infrastructure, drive cycle and traffic pattern, light-weighting of XEVs —and developing affordable electric technology, which will be open for use by all in manufacturing two-wheelers, three-wheelers and commercial vehicles used for public transport.

Table 11: List of major Government Initiatives

Under the new GST regime, GST on EVs has been reduced from 12% to 5%. In the budget of 2019-20, a provision of additional income tax deduction of Rs 1.5 lakh on the interest paid on loans taken to purchase electric vehicles was announced.

[50] Press Information Bureau Publication, 20 May 2020
[51] Department of Heavy Industry, 20 May 2020
[52] NAPTRiP, Driving India to the Future, 3 June 2020
[53] Press Information Bureau Publication, 27 July 2016
[54] Press Information Bureau Publication, 19 May 2020
[55] Department of Heavy Industry, 20 May 2020

2.2.9 Automotive Industry post COVID-19

The automotive sector was bracing for a difficult year even before the COVID-19 pandemic. Auto sales had been tepid for 12 to 15 months[56] when the outbreak stalled production and overall economic activity. The industry now faces concerns on short-term liquidity as well as long-term growth in revenue and profitability, even as automakers restart production and dealerships record sales again with a gradual relaxation of the lockdown. As it emerges from this crisis, the industry will need to realign itself to some of the new realities of the post COVID-19 world that are outlined here. These themes are set to shape its road to recovery. Auto Sales Post COVID 19, KPMG India

Preference for Personal Mobility: The pandemic has brought about marked changes in consumer habits and behaviors. There is likely to be a shift away from shared mobility options as people prioritise social distancing and personal hygiene. This would effectively translate into a higher preference for affordable personal mobility, which could boost sales for auto manufacturers, especially in the entry-level vehicle category. A similar trend was witnessed when the lockdown ended in China, where car ownership gained traction vis-a-vis car-hailing and sharing. India is expected to follow a similar path, which could help reverse the declining sales trend in the automotive sector**.**

The outbreak, however, has also greatly strained personal finances with significant job losses across sectors. As a result, the consumer's financial ability to purchase new cars might be constrained. The automotive sector will have to devise innovative purchase/leasing schemes to drive automotive sales. As new cars may be unaffordable for certain sections of the population, the two-wheeler and organised used car market might also stand to gain.

Going Digital: The increasing preference for contact-less online transactions has emerged as a major trend and is expected to reflect in automotive purchases as well. There was already a shift towards online models in after-sales with increases in online booking of appointments, doorstep pickup/delivery and online payments. Several original equipment manufacturers (OEMs), both premium and mass market, have already recognized this trend and launched a complete online buying experience[57], starting from initial enquiries and customization of features, to booking, financing and delivery in a completely contact-less transaction. Even test drives are today offered at the customer's doorstep, thereby eliminating the need to visit a showroom.

While there will always be a section of customers that continues to prefer the traditional route of purchasing a car, the increasing acceptance of online purchases may ultimately reduce the dependence on expensive real estate. Companies will have to focus on delivering superior customer experience by ensuring a frictionless path to purchase in an online world to benefit from this trend.

Online Marketing: The pandemic has significantly accelerated the pace of the shift towards digital marketing including augmented and virtual reality technologies[58]. Traditional marketing events, such as auto shows and exhibitions, will take a backseat for some time with social distancing being the norm. Going forward, this will significantly disrupt traditional marketing channels and directly impact how advertising dollars will be spent. Digital media platforms likely will be the gainers.

Innovating with New Features: In adapting to the post COVID-19 world, several consumers will look for better health, hygiene and sanitation features in their vehicles. Certain features like in-built sanitisation, enhanced air-purification systems and anti-bacterial surfaces may see a spike in demand. Consumers are likely to lean towards cars that offer such features and might even be willing to pay extra for their own physical and mental wellbeing. Companies that incorporate such innovation while staying cost-effective will likely have the upper hand in terms of sales.

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[56] Automobile Domestic Sales Trends, Society of Indian Automobile Manufacturers, accessed 20th May 2020

[57] Mercedes Benz India, Express Store, accessed 20th May 2020

[58] iVisualizer, BMW India, accessed 25th May 2020

Growth of Subscription Models: A growing shift to asset-light models and preference for experience rather than ownership is fast gaining favour with millennials. When customers have a less positive outlook in general, they tend to avoid capital-intensive purchases. In the auto industry, this may translate into greater interest in car subscriptions and short-term leasing models. Several startups already exist in this sphere but the focus will now shift to reliable and robust execution to ensure a clear path to profitability.

In conclusion, the easing of lockdowns offers hope that the automotive sector will soon set a course for recovery. This will be a testing time for the sector and the recovery trajectory will depend on how well manufacturers and retailers are able to respond to challenges and adapt to the evolving trends in the post COVID-19 world.

2.2.10 Towards Atmanirbhar Bharat

The idea of Atmanirbharta or self-reliance achieves the vision of India focusing on holistic and sustainable development. With its growth agenda, the government is set to play an important role in creating a conducive environment for business. The present market aspirations in the automotive sector and the subsequent developments that are taking place through the introduction of EV, fuel efficient and hybrid vehicles have given a level playing ground for Indian industries to avail the opportunities in the global supply chain.

The Indian automotive industry has been mainly importing components like suspension & braking, body/chassis/BiW, drive transmission & steering, engine components, and cooling systems from China. In FY19, the total imports for auto components were at USD17.6 billion and China happens to be the largest exporter of auto components to India. 27% of India's auto part imports, including engine and transmission parts, came from China, according to data from the Auto Component Manufacturers' Association of India (ACMA). Therefore, there is a huge opportunity for Indian automotive industry to bridge this demand supply gap by enhancing manufacturing capabilities and increasing localisation of auto components.

To achieve this aspiration of Atmanirbharta, the auto clusters should become self-reliant for producing newer components, sub-assemblies and enable themselves to introduce such components at short notice. In effect, the auto clusters shall become standalone nodes for components supply – starting from technology, customisation of capital goods used for production, design, prototype production, testing and small batch supply for field trails to OEMs. Clusters in a region can also share such facilities to ensure maximum capacity utilisation collectively.

Becoming self-reliant demands a collaborative approach amongst cluster units to curb the imports in automotive sector. This can be achieved by with the help of TCs and cluster bodies:

- Getting specialization on the full product cycle, each unit focusing on specialised areas – on material, process, and methods. The facilities available under the CFC and the TC in the cluster can be fully availed to attain this specialization.
- A small group specialising in customising the capital goods within the cluster or in the region.
- Establishing a Centre of Excellence (CoE) for the product group specialised within the cluster or in the TC serving that cluster. CoE can be housed either in the cluster CFC or in the TC, depending upon the preference of the units.
- Having specialisation in the cluster on materials technology, testing, etc.
- Develop the capital goods industry relating to the auto products. The AM and associated equipment shall be available at affordable price or at a CFC/TC.
- Have the needed design, prototyping and testing facilities within the cluster.
- Accomplish cost economies using the latest technologies especially under Industry4.0

- Offer a choice on alternative methods of production for the buyer in the supply chain, in line with their cost and quality expectations

The best example of Atmanirbharta can be seen in farm machineries, especially tractors. In 1961-62, before the Green Revolution, India produced only 880 tractor units, which catapulted to about 900,000 units in 2018-19, making India as the largest tractor manufacturer in the world. India also exported[59] almost 92,000 tractors in 2019, largely to African and ASEAN countries. Tractor companies have started to compete and bring out better products at low cost. Cost control is the immediate issue to be addressed to sustain the present growth and export market. The high cost allows import of tractor parts from cheaper overseas sources. The focus of the Indian auto manufacturing industry shall be to focus on cost control so that more farmers will start using the tractors. Mahindra & Mahindra leads the pack with almost 40% share. The new class of entrepreneurs and start-ups are coming up with special apps for 'Uberisation of tractor services' so that farmers can avail of these services at low cost, without owning a tractor. In a smallholder economy, owning a tractor is a high-cost proposition as it is not fully utilised. This needs to be made more efficient through modern tools of creating a market for tractor services.

[59] Unshackle private sector for atmanirbhar agriculture, 20 July 2020

3 Challenges being faced by the Sector

3.1 SWOT analysis of Automotive Sector in India

The Indian automobile industry is cost-competitive in terms of labor and raw material making it an attractive location for auto manufacturers. The Indian automobile industry has witnessed unprecedented growth. Its domestic market is growing and is supported by the government through schemes such as Make in India etc. Introduction of Goods and Services Tax (GST) by the government has removed the cascading effect of taxes and has thus reduced the cost of doing business. Skilled manpower in the form of qualified engineers and automotive experts having deep knowledge of international quality standards are other favorable factors for strengthening the sector growth[60]. A detailed analysis of strength, weakness, opportunities, and threats of the Indian automobile industry is discussed in this section.

Figure 13: SWOT analysis of automobile industry in India

STRENGTHS

Evolving Industry: The domestic automobile industry in India is growing at CAGR of 6.71% in FY 13-19 in sales and 6.96% in manufacturing[61]. As the 4th largest auto market (2018), it continues to build upon developing technology like cloud/computing models, IoT, in-car apps, autonomous driving development via IoT, etc. In India, the sector grows from clusters which generate job opportunity in those areas.

Increasing Demand in Value for Money vehicles: The current market experiences acute competition with evolving technology which has driven the players to adopt measures to gain an edge. Major players of the sector are attempting to adapt methods that deliver 'Value for Money' affordable products, have high mileage, and are fuel-efficient. Earlier this year (2020), MG Motors India launched MG ZS EV electric SUV in its line and announced its plan to launch an affordable electric vehicle in the coming years[62].

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[60] Indian Auto Component Industry: Challenges Ahead, 7 June 2020
[61] Automobile Industry In India, IBEF, 2020
[62] Growth of Automobile Industry in India, IBEF

Increasing Demand for Commercial Vehicles: There is also a rising demand for luxurious commercial vehicles with easier controls and safety measures. Major players like Daimler, Bharat Benz, and VOLVO are targeting developing nations globally to hit the niche of luxurious public transport. This market covers medium and heavy commercial vehicles that are dominated by players like Tata Motors with a turnover of $42 million and running its cars, buses, and trucks in over 20 locations globally[63]. Some of its most reliable products are Tata Signa, Tata Tipper Truck, Tata Prime and Tata LPT 3118[64]; Mahindra and Mahindra is not only the world's largest tractor company but is also one of the largest vehicle manufacturers in India for two-wheelers, buses, trucks, tempos, and commercial vehicles. Ashok Leyland is the 2nd largest commercial vehicle manufacturer in India with a product line of reliable vehicles like City Transit Bus, Tusker Twin Axle Lorry, Titan Double Decker Bus, and Ashok Leyland lorry[65].

Manufacturing Facilities in Asian nations for cost control: India and China have the capacity to provide cheap labor and lower manufacturing costs compared to their competitors and hence, major companies like VOLVO and Bharat Benz are setting up facilities in India to cut any margins possible. The VOLVO group Trucks has an assembly plant at Hosakote Bangalore that is spread over 120 acres of land and has been operational since 1998 as the first EU commercial vehicle manufacturer in India[66].

WEAKNESS

Limited spending in Research and Development: The automotive industry thrives on the implementation of emerging technology and for which countries like Japan and Europe spend approximately 40% on Research and Development. However, the Asian Pacific numbers inch close to 12% (2015)[67].

Recalling of sale: A downside of the sector is the fragility of its reputation and susceptibility to controversies. Often, vehicles are recalled to account for a technical dis-functionality according to government guidelines which cause a significant loss. In June 2020, Honda Cars India recalled approximately 65,651 models (2,498 units of the Amaze, 16,434 units of the City, 7,500 units of the Jazz, 7,057 units of the WR-V, 1,622 units of the BR-V, 360 units of the Brio and 180 units of the CR-V)[68] from 2018 to address an issue with the fuel pump and rectify it free of cost. Audi India has also recalled 137 Audi TT cars for a possibly damaged and leaking fuel tank defect in models manufactured between 2015-19. [69]

Bargaining power of customer: Today, the customer has a range of variants to choose from and assess the best product according to their needs. This promotes not only stiff competition among competitors in the market but also causes a shift from supply to demand based on price, safety, comfort, appearance, and quality.

Government Regulations: The laws applied by the central government play a huge role in the functionality of an industry. The regulations on entry of outside commercial vehicles in another state, excise duty, decreasing duration of registration validity, fuel prices, etc. contribute to the fall in sales. In 2019, Maruti Suzuki India saw a fall of 36.7% in sales, after which SIAM recommended lowering of GST to 18% to help the industry recover[70].

Employee turnover: While the industry employs 32 million people[71] in its value chain, it also witnesses high rates of employee turnover. Retaining employees for a long duration has proven to be a challenge

[63] Automotive Technology, 22 June 2020
[64] Top 12 Major Manufacturer of trucks in India, Walk Through India
[65] Top 12 Major Manufacturer of trucks in India, Walk Through India
[66] VOLVO group, 22 June 2020
[67] Driving innovation through R&D to establish India as a global manufacturing hub for Auto Components, Economic Times, 22 June 2020
[68] Honda Cars India recalls cars Economic times, 2020
[69] Audi TT Recalled in India, Economic Times
[70] Government Action is key for any course correction in the auto sector, Live Mint
[71] Indian Auto Industry Status Report, Economic Times

since employees feel dissatisfied with factors like accommodation facility, holiday packages, pay structure, workload, recreation facility, and transport facility.

OPPORTUNITY

Fuel-efficient Vehicles: The market is trending to fuel-efficient vehicles and growing towards optimization of fuel-driven combustion engines at an efficient price. The Indian market captures efficient vehicles for both petrol and diesel. For diesel-driven cars Swift (29kmpl), Ciaz (28kmpl), Dzire (28kmpl), Baleno (27kmpl) and Ertiga (26kmpl) rank within the top five whereas highest-ranked fuel-efficient petrol-driven cars are Maruti Celerio (26kmpl), Alto K10 (25 kmpl), Alto 800 (24 kmpl), Tiago (24 kmpl) and Toyota Pruis (23kmpl)[72].

Changing lifestyle: The customer today is highly informed and has a better understanding of what they want from their investment and are willing to spend flexibly for the same. These rapidly evolving customer expectations give the companies the wavelength to introduce newer technology like vehicle tracking, safety alerts, cruise control, diagnostics, and other smart driving facilities in their product lines to generate higher demand.

Investments/Market Expansion: Tapping into new markets in Asia and BRIC with current expertise will open new doors for the sector and escalate the growth. The Tamil Nadu government signed pacts with 17 companies to bring in investments worth INR 15,100 crore. One of those companies is Daimler India Commercial Vehicles embarking an INR 2,277 crore expansion and generating 400 new jobs in SIPCOT park, Chennai[73].

OEM priorities: With a change in the standards of an automotive vehicle, OEMs need to collaborate with other electronic sectors for better results. The electric, automated, or connected vehicle demand offers an opportunity for collaboration and alliances. In 2017, Japan's Toyota Motor Corp. and Suzuki Motor Corp developed affordable EVs for India together and created an allegiance to jointly develop autonomous driving technology whilst using Toyota's factory in India for manufacture[74].

THREATS

Rising Competition: The presence of multiple players in the market causes a threat of being pushed out due to factors like undeveloped technical advancement, unaffordability, manufacturing costs, etc. In the past, Maruti Udyog Limited dominated the Indian market until a collaboration with Suzuki of Japan which lead to 17 new ventures and the new competition in the market. Today, major players like Honda (5.2% passenger market share), Ford (2.4%), Tata Motors (5.9%), Mahindra and Mahindra (7.5%), Hyundai (16.4%), Toyota Kirloskar (4.3%) and Maruti Suzuki (49.7%)[75] dominate the market leaving little place for other companies.

Slow Economy: The pace of the country's economy plays a huge role in the sustenance of any sector. The Automotive sector contributes over 8% to the country's GDP and 15%[76] to the government's tax collection but saw close to zero sales in April 2020 due to the impact of COVID-19 pandemic on the world economy.

Fuel Prices: Fuel prices affect sales in the automotive industry significantly. An increase in price takes away from the customer's disposable income and directly affects their daily expenses. In 2017, the domestic passenger vehicle market saw a fall of 5.6% in sales due to a rise of 17.7% in petrol prices and 24.99% in diesel prices[77].

[72] Most efficient fuel driven cars in India, Financial Times

[73] Tamil Nadu inks deals for over RS 15,00 Crore investment, 47000 plus jobs, Economic Times, 22 June 2020

[74] OEMs bet on collaborations to ensure sustainability, Live Mint

[75] Complete Indian Auto Sales Analysis 2018, Economic Times

[76] Auto Companies head or zero sales in April, Economic Times, April 2020

[77] Car sales slide on rising fuel prices, The Hindu

Exchange Rates: India's automotive market is heavily dependent (82%)[78] on crude oil prices and rupee-dollar exchange rates as a net importer. A weaker currency lowers the investors' confidence, makes imports expensive, increases possibilities of inflation, and can cause stagnation or decrease in the growth of a sector.

Environment Regulations: In February 2006, India signed the UN WP 29 1998 Agreement and applies in the Global Technical Regulations (GTR)[79]. There are other norms in a place like the Emissions Norm and the Auto Fuel Policy. These regulations cause technological disruption and embed high costs to meet legitimate standards. Moreover, companies in India, companies stand to face penalties if they miss their emission target.

Some of the challenges mentioned in the above analysis are intrinsic to India only, however, considering the strength of the Indian automobile industry, it important to analyze the opportunities and leverage on the strength of the industries. The industry provides great prospects for investment and employment to skilled and unskilled labor. Some of the areas where industry players can focus and build on the strength are as below:

- **Investment in EV vehicles and components:** The government is promoting the adoption of alternative fuels through FAME2, where "FAME1" offered incentives to electric vehicles (EV) and hybrid EV buyers, FAME2 is expected to incentivize electrification of the public transport fleet of buses and taxis. There is a huge demand for electric vehicles in India, which is visible through an order for 10,000 electric vehicles by the government's energy-service company known as Energy Efficiency Services Limited. Likewise, local governments in ten cities, with populations of one million or more people, have placed orders for 390 electric buses during phase one[80]. Moreover, demand for EV components such as batteries and battery materials, electric motors, power electronics would spike with EV penetration.

- **Export opportunities**[37]: Despite exporting to 160 countries, India's share of global exports is only 3.5 percent or USD 13.5 bn of USD 386 bn. Various reasons for this can be low quality of fit and finish and raw material, resistance to change, and innovate as globally required. However, with the enforcement of BV-VI emission norms means that the same specification would be required in India and developed markets. So, manufacturers would have the opportunity to export components. Further, India's contribution to the top 15 imported components for the US, EU, and China remained minuscule, ranging from 0.7 to 1 percent, suggesting room for growth.

- **Focus on Import material substitution**: Auto components import to India values greater than USD 15 Billion. With impetus on Make in India initiative by the government, manufacturers can develop parts in India.

- **Commoditization of premium features:** Customers now demand premium features such as Bluetooth connectivity, Keyless entry, Daytime running lights, Gesture control infotainment system, EBD module, Electronic seat adjustment system, etc., for their vehicles. Auto-components manufacturers can add production of these to their portfolio to address the growing demand for such features.

- **Data-enabled services and solution:** A modern connected vehicle has on average 40 microprocessors and generates 25 GB of data per hour.[81] Auto component manufacturers could collect customer, vehicle and machine data to build deep consumer insights and develop new use cases.[37]

[78] Comparing exchange Rates and Crude Prices with Auto Industry's Growth, Business World
[79] SIAM
[80] Department of Heavy Industries, Ministry of Heavy Industries & Public Enterprises, Government of India, http://dhi.nic.in.
[81] Connected cars will send 25 gigabytes of data to the cloud every hour, QUARTZ

The positive indications in the form of investment, expansion plans, collaborations owing to the strengths and opportunities are as follows[82]:

S. No.	Firm details	Highlight	Timeline
1	Tata AutoComp Systems + Prestolite Electric (Beijing based): Joint Venture	Entered EV component market	Jan-2020
2	Force Motors	To invest Rs 600 crore (US$ 85.85 million) and develop 2 new models in the next 2 years	Dec-2019
3	Morris Garages (MG) – A British automobile brand	To invest Rs 3,000 crore (US$ 429.25 million) in India	Dec-2019
4	Audi India	To launch all-new models – Including in sedans, SUVs, EV	2019
5	MG Motor India	To launch MG ZS EV electric SUV in 2020 and affordable EV in 2-3 years	2019
6	BYD-Olectra, Tata Motors, Ashok Leyland	To supply electric buses to state departments	2019
7	BMW	Launched 7 Series facelift and introduced new X7 SUV at Rs 98.90 lakh (US$ 0.14 million)	2019
8	Ashok Leyland	Plan to invest Rs 1,000 crore (US$ 155.20 million) to launch new models in the commercial vehicle category	2018-19
9	Hyundai	To invest US$ 1 billion by 2020 and plan to enter in hybrid and electric vehicles launch with an investment of Rs 9,200 crore (US$ 1.31 billion)	Oct 2018
10	SAIC Motor	To invest US$ 310 million	2018
11	Mercedes Benz	Chakan plant manufacturing capacity increased to 20,000 units per year	2018
12	Mahindra Electric Mobility	Set up an electric technology manufacturing hub in Bangalore with an investment of Rs 100 crore (US$ 14.25 million)	Nov 2018
13	KIA Motors	Plans to invest USD 1.6 billion in its manufacturing facility in Andhra Pradesh.	2019

Table 12: Recent investment plans and collaborations

Indian automotive sector has faced setbacks due to poor infrastructure for supply chain and exports. This is coupled with our limited knowledge of product liability and handling offshore warranty and limited experience in system integration. Further, due to lower investment in research and development, we continue to rely primarily on build-to-print models. Recent analysis of listed Indian automakers' annual report for FY 2018-19 shows two-wheeler makers spent[83] merely 2 per cent of their turnover on R&D,

[82] IBEF
[83] Automobile R&D investments, Business Standard, 13 July 2019

while other auto companies spent 3-5 per cent. These companies have increased their expenditure on R&D in FY 2018-19 owing to regulations and emergence of new technologies.

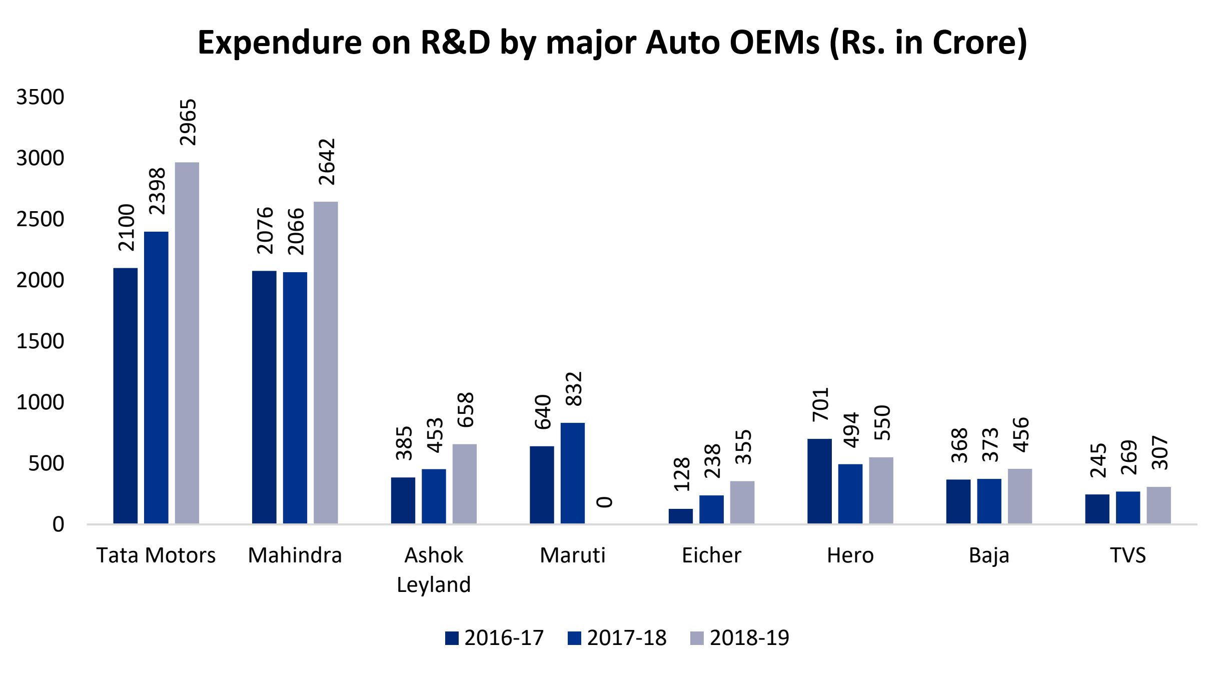

Figure 14: Expenditure on R&D by major auto OEMs (Rs in Cr)

The automotive sector is also threatened by increasing competition from low-cost countries such as China, Taiwan, etc. A large number of OCMs entering the Indian market may result in the migration of talents from suppliers to OEMs. The impact of unseen circumstances such as COVID-19 has threatened the industry by impacting all stakeholders in the auto industry value chain. It resulted in a shortage of raw material, shifting of production to other countries, liquidity crunch to delays in availability of models, deferred launches, and shrinkage in consumer demand[84].

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[84] Opinion: COVID-19 impact in Indian economy industry- Taking action in troubled times

4 Emerging Technologies in the sector

The future of the auto OEMs and auto component industry is being shaped by multiple trends and technologies. Market dynamics evolve due to change in customer demands, operating models, and other factors. There is an imperative need for Indian MSMEs to adapt these upcoming technologies to be on par with their global competitors. This will help them in pursuing export opportunities and enhance import substitution.

The assessments of relevant technologies and technology trends for the automotive industry are derived from a composition of Gartner hype cycles (Gartner 2018, Gartner 2019, Gartner 2019b) combined with KPMG's and its partner firm's experience across numerous projects. The presentation of the maturity level cannot be taken as a blanket statement but must be examined in a company- and context-specific manner. The clustering logic is used for structuring and does not represent a dichotomous chained order of precedence.

Very Low	Low	Medium	High	Very High
4.1 Emerging Memory Technology 4.2 Low Impact Materials	4.3 Factories through Smart Automation 4.4 Highly Accelerated Life Tests (HALT)	4.5 Wearable Technologies 4.6 Smart Materials 4.7 Multi-Material 3D Printing and Additive Manufacturing 4.8 Industrial Internet of Things (IIoT) and Connectivity	4.9 Smart Robots and Cobots 4.10 Augmented Reality and Virtual Reality	4.11 Predictive analytics 4.12 Light weighting- Shift to Magnesium from Steel and Aluminum 4.13 Energy Storage Solutions

Figure 15: Emerging Technology and degree of relevance for automotive players

4.1 Emerging Memory Tech

Emerging Memory Tech describes the development of new storage media to secure large amounts of data in the long term. To this end, a wide variety of methods such as ultrasound or holography are being tested. The size and longevity of the data as well as the speed of the storage process are the critical parameters that are subject to constant improvement. New storage materials such as glass or bone are also being tested. The field of optoelectronics and quantum electronics will become increasingly relevant in the future as new white laser technologies are used to transfer data 100,000 times faster than before.

4.2 Low Impact materials

Low Impact Materials characterizes organic and biodegradable materials that represent an alternative to conventional materials. Equipped with a high resource, eco, and energy efficiency, these materials contribute to environmental protection. For example, insulating materials from the biomass of the cattail plant or textiles made from the bark of a fig tree are used. These materials can, for example, be disposed of in a particularly environmentally friendly manner after use by means of closed-loop recycling processes. Our industrial culture stands at a crossroads. In just a few years, we will no longer have enough quantities of important raw materials for the construction of high-tech products. The design and structure of the automobiles will be affected by those technologies.

4.3 Digital Factories through Smart Automation

Digital transformation in factories has led to the convergence and integration of Information Technology (IT) with Operational Technology (OT) and has led to the creation of Digital Factories that make use of artificial intelligence. Production facilities and systems are made flexible and fully connected to enable the flow of information from connected systems and operations to learn and adapt as per requirement.

Digital factories can enable smart automation where the machines can adapt, and manufacture products based on the demand in real-time. It reduces the need for human interference in the production line. Machines are fitted with sensors and data collection devices to monitor and control the performance of the machine to make them smart. It creates a responsive working environment where production lines can be reconfigured, flexible, and adaptable in real time and remotely.

The automotive industry is leading the change in smart factories. Smart factories would result in greater product control. Every step in the process would be monitored and would have a digital footprint, and this would lead to greater product quality and efficiency of production lines. The flexibility of production lines would be at the core of smart automation. There would be more focus on value-adding activities for the workers in a production line. Cobots are expected to help and aid the workforce and increase their productivity. By the end of 2022, automotive manufacturers expect that 24% of their plants will be smart factories and 49% of automakers have already invested more than $250 million in smart factories[85].

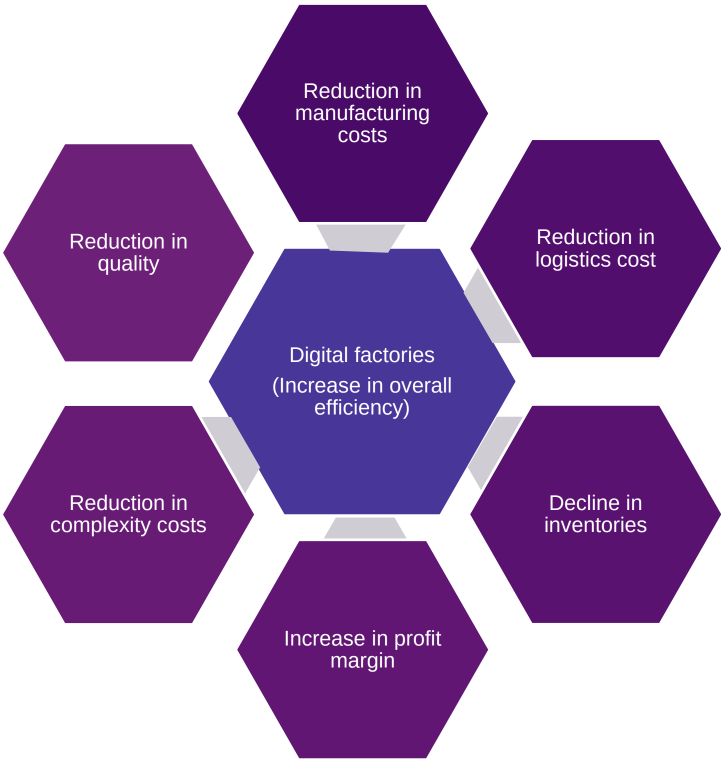

Figure 16: Digital Factories through Smart Automation

For MSME automobile component suppliers, investing in digital infrastructure and supply chain integration with the OEMs is the key to success and gaining efficiencies of digital factories. Supply would be based on the real-time data and will need to produce and maintain inventory to supply inventory just-in-time and just–in–sequence as per requirement.

[85] Capgemini – Automotive Smart Factories

4.4 Highly Accelerated Life Tests (HALT)

In this competitive industry, it is important to introduce newer components and vehicles in a short time to meet the market aspirations for variety. And to test the reliability of that new product, life tests are conducted which are typically very time taking, delaying the overall launch of the project. Therefore, in order to predict the lifetime of the product, the operating parameters are accelerated to a higher level to predict the suitability of the product, within a short time. This needs specialized techniques and test rigs – to carry out Highly Accelerated Life Tests (HALT). These techniques are needed when newer products are introduced in the market.

This enables auto manufacturers to have a quicker turnaround for new product introductions. With the introduction of Electric Vehicles, the demand for HALT is likely to go up. Such facilities alone can facilitate a quick introduction of EVs. The specialized test rigs and testing centers are the need over the next decade.

Figure 17: Highly Accelerated Life Tests

4.5 Wearable Technologies

The term Wearable Technologies stands for clothing and accessories in which electronic components are incorporated or which consist of intelligent materials. They were often first developed for space travel or for people with disabilities and are now finding various areas of application in our digitally networked everyday lives.

Wearables can Simplify business processes along the automotive value chain. The categories where wearable technology can be used in the auto industry are operational activities (such as in assembly line or designing process), consumer interactions (like safety process), and customer's driving experience (e.g. smartwatches and smart glasses). Smart glasses can be used by workers to augment their daily tasks by improving the vision of automotive parts and the location where they are stored.

Logistics Providers	Dealerships	Third-party	Repair Shops	Automotive Customers
Training and development	Training and development	Virtual Test drives	Real-time diagnostics monitoring	Real-time alerts
Quality inspections	Simplifies gate-in, gate-out	Interactive product manuals	Step-by-step instructions of operating procedures	EV status monitoring
Collaboration and decision support	Pre-delivery inspections	Customized in-store experience	Service and maintenance	Remote access
Service and maintenance	Collaborative and decision support	Improving sales-person efficiency through cheat-sheets		Navigation
				Driver vital health monitoring& telemedicine
				Configuration of user preferences

Table 13: Wearable Technology along Automotive Value Chain

A wearable device, Chairless Chair, used by BMW among its factory workers provides seated support, comfort, and flexibility for individuals working on manufacturing lines[86].

4.6 Smart Materials

Materials are becoming increasingly intelligent using new technologies and advanced scientific knowledge. These smart materials adapt to changes in the environment by, for example, an increase in temperature, mechanical stress, or a change in pH value. By means of a mimetic poly-alloy, smart materials are already able to perform a self-healing function. Metamaterials, which absorb light and electromagnetic radiation differently than natural materials, also open new possibilities, for example for the manufacture of lenses. Materials with shape memory alloys can assume various crystalline states up to superelasticity. This helps to re-design the automotive interior towards autonomous driving and driverless car situations. Most materials used to change their shape and structure on the application of external stimuli and retain its original shape when the stimuli are removed. Some smart materials reduce product complexity and the weight of the automotive. Actuators and sensors made from smart materials have the capability to enhance vehicle performance & features and improve fuel cost. Common shape alloy metals used in the automotive industry are Cu-Al-Ni alloy, Ni-Ti alloy, and Cu-Zn-Al alloy[87].

4.7 Multi-Material 3D Printing and Additive Manufacturing

3D printing refers to the creation or printing of 3-dimensional objects from a digital file. It uses the concept of additive manufacturing in which layers of material are added together to create a 3-dimensional object. 3D printing has various benefits as it helps to create strong and complex structures with lesser material wastage. Additive Manufacturing has seen a significant rise in uses like rapid prototyping, the printing of custom spare parts, lighter and stronger body parts, etc. The automotive industry has been a major adopter of additive manufacturing techniques, with Ford purchasing the third 3-D printer ever made 30 years ago.[88] It is forecasted that the industry for additive manufacturing will rise to $12,614 million in 2028 from the current levels of $1,456 million in 2018 at a CAGR of 27%.[89]

3D printing or additive manufacturing has helped in rapid prototyping or creation of prototypes with reduced lead times. It has helped to create lighter, safer, and stronger products. It plays a major role in customizing products in the manufacturing process. The need for the technology is in the area to “production” them for large batch production

However, most of the 3D printing machines use separate nozzles for each of the material, limiting the capability of printing the true prototype part. This results in a huge variation in products, from one material to another. Therefore, researchers have developed multi-material 3D printing machines to address the issue. The resultant product, printed by using the inter-mixing of multiple materials, has higher mechanical strength, and is more durable.

However, there is a huge shortage in terms of supply of skills in relation to 3D printing. As the technology is in its development stage large scale deployment in manufacturing has not yet happened. 3D printing development can lead to a reduced number of suppliers for parts as printing would be a more economically viable alternative.

4.8 Industrial Internet of Things (IIoT) and Connectivity

Internet of Things refers to the network of devices connected over the internet. Industrial IoT represents a wide range of IoT based applications, smart product design principles, and data-driven automation practices in the industrial sector of the economy. Industrial IoT enhances the functioning of equipment using sensors to remotely monitor and improve maintenance capabilities of the equipment. IIoT applications are beneficial to the industry as they help in improving the efficiency of operations, predictive maintenance, monitoring staff and improving the quality of manufacturing.

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[86] https://www.wearable-technologies.com/2016/08/how-can-the-car-industry-benefit-from-wearables/
[87] http://hitechaes.blogspot.com/2014/05/the-use-of-smart-materials-in-automotive-applications.html
[88] Forbes – Additive Manufacturing: The future of Automotive Industry
[89] SmarTech Markets Publishing – Opportunities for AM in Automotive Production

IIoT applications have found use in the creation of digital factories and facilities that help managers track the production line to automate and optimize production. IIoT application-based sensors can help to track the environment and working conditions of machinery and provide real-time data and recommended adjustments to improve the lifetime of the equipment. IoT can help automotive industry to track the movement of products across the production cycle and help to reduce waste, errors in production lines through use of computer vision and increasing efficiencies of inventory and supply chain management.

Industrial Internet of things will lead to improvements in processes, supply chain and quality of automotive products. However, there would be increased pressures on the industry to reduce inefficiencies and move towards automation. Due to use of sensors like computer vision, there would be a greater focus on the improvements in qualities of inputs.

SMEs and vendors would need to integrate their supply chains with the OEMs and be prepared for a competitive environment. There would be convergence of services and products. Automotive players are investing heavily into IIoT in collaboration with technology companies. There would be greater focus towards implementation of ERP systems, Supply Chain Management Systems and IT infrastructure for traditional auto component manufacturers.

Case Study on Application of IoT for Early Warning System

The connectivity and information sharing have always been point of concern in any manufacturing industry, as availability of appropriate information at right time can change the entire performance of process, decrease defect rates and eventually make customers satisfied.

Challenge: Bosch was receiving complaints due to faulty parts being sent to customers as there was problem of defective parts being mixed with good parts. It was found out with preliminary analysis that they need transparency in shift wise rejection scenario, to minimize the mixing of good and defective parts

Solution: To resolve this problem, stations were interconnected with server to map the trend of internal rejections and poka-yoke validation. The validation of OK Master & Not OK Master was done at the beginning of every shift to ensure quality. SMS and emails were triggered to concerned stakeholders when rejections at a particular station go above acceptable limits. This trigger helped in taking right decisions at right time and recorded a collection of “reaction/correction plan” to be triggered according to the severity of error for future.
Due to this innovation, line managers were enabled to intervene at the right time and bring the situation under control. The system encouraged a due date to be set for each of the reaction plans and a reminder was sent to ensure corrective action.

4.9 Smart Robots and Cobots

The shop floor of a factory in automotive industry traditionally has been labor intensive and the challenge is to reduce rejection rate and possible reworking on parts /components due to inaccuracies while doing identification of parts, picking, loading and unloading. The nature of work is complex in nature and robots have limited functionalities. However, with AI and connectivity, robots can be programmed to work flexibly and intelligently – Collaborative Robots. Cobots are helping big and small automotive vehicle and component manufacturers to become competitive in both quality and price. It can offer all the advantages of advanced robotic automation and used where high quality and precision are critical.

The technology is now required for extending the application from conventional handling to a range of operations /processes like – gluing, painting, cleaning and extending it beyond every day uses. Globally, the use of robots has been accepted by all leading manufacturers. However, Indian manufacturers are hesitant to adopt this due to the relatively large initial investments. Continental Automotive[90] in Spain

[90] Universal Robots – Case Stories

introduced Cobots to perform the tasks of handling and validating PCB boards and components during the manufacturing process. PCB boards handling was a monotonous and repetitive task that required great precision and delicacy in handling. Introduction of Cobots provided benefits like control & flexibility, safety, cost reduction, time savings and less burden on the workforce for the organization.

Globally the introduction of robots is deemed as a component of skill-up-gradation and the same needs to be done in India as well to accelerate the introduction of robots and their benefits.

Case Study on Use of Cobot for Eliminating High Volume Repetitive Task at Manufacturing Line

Human capacities have always been limited because of inherent limitations. But robots have advantage of unlimited capacity by collaborating with human and does marvels. An Electronics Manufacturer Xymox Technologies Inc was facing problem of repetitive tasks performed by its operators. The company used robotic automation solutions and identified Cobots to resolve this problem.

Challenge: Xymox tests every product before it leaves the manufacturing facility. This means, every membrane switch and touch sensor are plugged in, all LEDs are lit up, and every button is pushed. Every part they produce needs to be 100% functionally tested, which leads to millions of buttons being pressed by assembly technicians.

Solution: They looked into cobots, which would work safely alongside their operators without the need for caging. So, if a person bumps into it, it would stop. The 'OB7' cobot used to press these millions of buttons. This allows the assembly technicians to focus on other value-added operations and relieves potential hand fatigue.

Setting up the job for OB7 was all done internally. Xymox created fixtures for each part that had grids to align the parts exactly to where OB7 would run the testing of every button. They also developed their own customized end effector, which controlled the amount of pressure to touch each product.

Locating the fixtures directly off the robot, OB7 helped run the electrical testing process by pushing down on each button. By doing so, it helped reduce the number of buttons that an operator would have to press. The operator just needed to plug in and unplug the parts.

Robots Operated ASRS Parking for Automobiles

Despite the infrastructure changes planned and under execution, there is still an issue of last-mile connectivity for the citizens. This gives rise to need for huge stacked parking facilities in principal nodes in the towns. Robot operated Automatic Storage and Retrieval System (ASRS) for vehicles at such nodes will help to reduce idle and avoidable movements consequently saving a lot of energy.

Figure 18: ASRS Parking for automobiles

This in conjunction with the IOT will popularize the optimized commuting. By using IoT, the movements can also be monitored by the involved parties. The need is to identify and approve safety certified designs and its manufacturing.

Considering the volume of structural materials to be used and its bulkiness, this will be of special interest to MSMEs as they can specialize in their respective locations.

4.10 Augmented Reality and Virtual Reality

Augmented Reality and Virtual Reality are technologies that superimpose computer generated designs or images on a real-world view of the user. It is an enhanced version of a real world with elements from digital world. Virtual reality refers to an immersive experience of complete virtual world for the user. There is an increasing trend towards usage of AR and VR in the automotive industry.

Augmented reality is being used across the value chain from designing and prototyping to maintenance and production lines. Still in its nascent stages, major automotive companies such as Volvo, Airbus, and Ford, etc. have tied up with technology firms to implement AR and VR in their processes.

Technical drawings and product designs can be integrated with model prototypes to provide visualization and understanding of products in the development phase. Manual and instructions can be integrated with wearable devices for assembly line staff to refer to while working. Voice instruction can be enabled to devices to update the manuals without the need to do it manually. AR and VR can help to design and view components, product designs, and prototypes without the need to make clay models during prototyping. More design concepts can be explored through AR and VR technologies. This will reduce the effort and time taken to create them.

The entire flow of production and assembly can be viewed virtually without needing to physically run the production process. Once, confirmed the data flow can be integrated with smart robots during the manufacturing phase. OEMs can have greater participation from suppliers and component manufacturers in the development phase and the integration of new products would be more efficient.

Honeywell Introduces AR/VR simulator to train the industrial workforce to close the skills gap

Honeywell in 2018 has introduced a cloud-based simulation tool that uses a combination of augmented reality (AR) and virtual reality (VR) to train employees on critical industrial work activities. It was estimated that 50 percent of industrial plant personnel were due to retire within the next five years. Hence, the Honeywell Connected Plant Skills Insight Immersive Competency was designed to bring new industrial workers up to speed quickly by enhancing training and delivering it in new and contemporary ways.

Honeywell's advanced training solution combined mixed reality with data analytics and Honeywell's 25 years of experience in worker competency management to create an interactive environment for on-the-job training. It uses Microsoft's HoloLens, the world's first and only self-contained holographic computer, and Windows Mixed Reality headsets to simulate various scenarios for Honeywell's C300 controller such as primary failure and switchovers, cable and power supply failure; that train and test personnel on their skills [91].

Figure 19: Implementation of AR/VR solution at Honeywell

Simulating specific job activities through virtual environments, which was accessed through the cloud, Honeywell's solution offers a natural way to interact and communicate with peers or a trainer. Similar to a flight simulator, trainees can safely experience the impacts of their decisions. This approach improves skill retention versus traditional training methods by up to 100 percent and reduces the length of technical training by up to 150 percent. Additionally, the employees' training progress is tracked as part of a formal competency management system.

Honeywell Connected Plant turns data into insight that enable plants and businesses to run better. Honeywell delivers this capability through its unmatched domain expertise and advanced analytics capabilities to connect processes, assets, people, and enterprise to maximize performance. Honeywell's breadth of cyber-security solutions ensures data stays secure from increasing external threats.

[91] Honeywell website, 19 May 2020

4.11 Predictive Analytics

Predictive analytics refers to software that can predict situations and scenarios based on historical and current data, and of providing corresponding recommendations for action. Predictive intelligence is being used more and more in relation to human behavior, except in large, holistic systems that are used to predict the maintenance intervals of machines. Application of predictive analytics can precisely categorize persons likely to buy a vehicle in the near future analyzing consumer purchase trends. Moreover, predictive quality analytics is particularly useful in the development of prototypes, quality management, supply chain optimization, and recall management[92].

4.12 Light Weighting - Shift to Magnesium from Steel and Aluminum

A major challenge faced by the automotive industry, in the current scenario, is to improve fuel efficiency to conform to European Union (EU) and Corporate Average Fuel Economy (CAFÉ) norms. The prevailing EU and CAFÉ standards have compelled the auto manufacturers to look for more fuel-efficient cars. The aim is to achieve an efficiency of 25 miles per gallon, a target also set up by leading manufacturers in the US, from the current 13.5 miles per gallon. This automatically leads to the usage of lighter and stream-lined dynamically balanced vehicles. Therefore, there has been a constant effort to find lighter materials than Steel and Aluminum for the manufacturing of automobiles.

A major shift is likely to happen to replace Aluminum and steel parts by Magnesium, which is 75% lighter than steel, 50% lighter than Titanium and 33% lighter than Aluminum and is also abundantly available. Magnesium is more durable and stronger than Aluminum. It dampens vibration and is good in resisting electromagnetic radiation. All the Aluminum parts can be converted into Magnesium. It can be machined, and injection molded. However, shifting to Magnesium has its weaknesses such as it poses problems in machining due to flammability. Also, its cost is twice that of Aluminum and 8 times that of Steel. Ductility, joining and corrosion are other major issues to be considered in shifting to Magnesium.

Different parts that can be manufactured using Magnesium are engine blocks, bed plates, transfer cases, clutch housings, cradles, and interior components. Many auto manufacturers are already converting auto parts to Magnesium. Converting to Magnesium requires prototyping facility, endurance, and life testing facilities largely and economically.

4.13 Electric Vehicles (EV) – Emerging Technologies and Capacity Building Activities

The Indian electric car market size was valued[93] at $71.1 million in 2017 and is projected to reach $707.4 million by 2025, witnessing a CAGR of 34.5% during the forecast period. Government schemes and subsidies are playing a major role in the growth of EV market in India. In addition, the growing environmental concerns owing to high pollution levels in major cities of the country are also positively affecting the market growth. There are various emerging technologies being developed in EV sector focusing on battery and its charging.

S. No.	EV Area for Emerging Technologies	Possible Interventions	Way Forward for TC
1.	Battery charging systems and stations	Design, fabrication, installation, and maintenance	It is relevant to MSMEs as these stations should be located, maintained, and serviced pan India. The high numbers and relatively low cost involved make this of interest to MSMEs. TCs can develop its capacity in suggested possible interventions.

[92] Deloitte report - Big data and analytics in the automotive industry

[93] India Electric Car Market Overview, Prescient & Strategic Intelligence, 23 October 2020

S. No.	EV Area for Emerging Technologies	Possible Interventions	Way Forward for TC
2.	Localised production of EV components, parts and sub-assemblies. The components relate to the electromechanical sub-assemblies used in EV.	Design, prototype, test and supply in small batches to OEMs for trial and testing	TCs are fully qualified to work on this area. TCs shall have the following facilities: • A 3 D printing facility for prototype production • Testing and certification facility for parts produced
3.	Battery swapping technology	Design, fabrication, installation, and maintenance	This technology can be taken up after achieving above capacities and considering core competencies of TC.
4.	Batteries for EV especially Lithium Ion batteries	Manufacturing	This technology can be decided for capacity building considering high cost involvement at later stage.
5.	Battery disposal, recycling procedures and safe disposal	Design and plan the details for recycling and disposal	This technology can be decided for capacity building considering core competency of TC at later stage

TC can provide following support in developing emerging technologies in EV sector:

Sl. No.	TC Intervention Area	Possible Interventions	Capacity Building Activities at TC
1.	Skill development	Training the staff and operators for the EV technology	The entire industry has been geared for petrol and diesel vehicle production, servicing. Exposure to EV is happening at its pace. To give this exposure more vibration, TCs can conduct training programs for all levels and all aspects of EV. Training and skill development being the core competency of TC they must gear up by designing training programs, syllabus and delivery of the same.
2.	Innovation centre	Optimize EV life and performance, reduce the overhead and peripheral costs and help in achieving a better return on investment.	The TC should have an innovation centre to support new experimentation and try outs.
3.	Incubation centre	Several components must be designed and tried out to suit the Indian terrain and conditions. This warrants new development.	Business models focused on EVs can be developed and encouraged by starting an incubation centre for EVs or focusing on EV in existing incubation centre.

4.14 Energy Storage Solutions

Energy Storage Solutions covers the area of intelligent storage technologies that can store energy in the long term. The challenges here lie in increasing storage capacity, charging and discharging performance, storage efficiency, and storage duration. Particular attention is paid to the storage of electrical energy using expandable supercapacitors made of graphene and the storage of electrochemical energy using redox flow batteries, for example. Storage technologies such as these are particularly attractive for the fields of e-mobility and telecommunications, since charging times are rapidly shortening, and usage times are greatly extended.

The automobile industry is exploring ways to innovate and develop efficient automobile batteries thereby limiting its impact on the environment. BEVs run an automobile by using electricity stored in a battery pack made up of lithium-ion, sodium (zebra), etc., to power an electric motor. EV OEMs are targeting to address challenges such as higher cost, safety, durability, performance, energy density, and charging time to improve battery technologies. There is huge potential for solid-state electrolyte lithium-ion batteries for EV application[94]

4.15 Trends in Tooling Technology

In the changing auto market scenario, the customers expect frequent newer versions, at affordable costs, with better energy efficiency. This has put tremendous pressures on OEMs, and they are compelled to come up with frequent model changes with improvements in features, performance, and efficiency. This in turn has put greater expectations on tooling manufacturers. They are now expected to supply tooling in short time. The turnaround time has become extremely critical for competitiveness and that the time lag between when orders are placed and when customers expect the orders to be filled has shrunk considerably. In the past, turnaround time used to be in months, but they are now in weeks and in some cases days. Keeping in need for these market expectations newer technologies, processes and materials are being introduced in tooling sector. This is of great relevance to the TCs, as one of their core strengths is tool development, try outs and pilot production.

Currently the entire cycle for tooling manufacture is undergoing a transformation and each stage is using newer tools and supports to meet the market needs. The trend is depicted in figure 20.

The various future technology trends that form part of the tooling design and production cycle are summarized below:

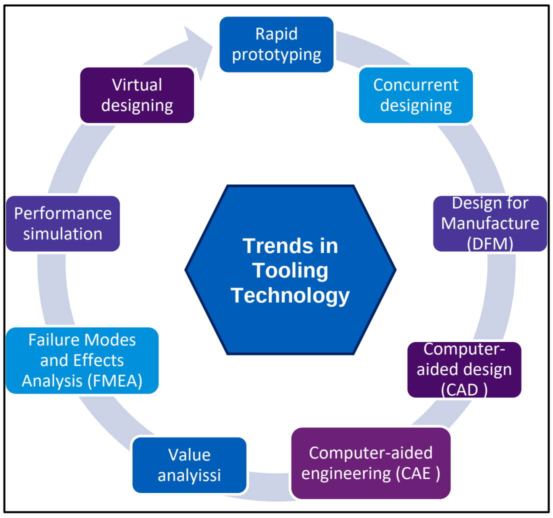


Figure 20: Trends in Tooling Technology

A. LM/AM technology for manufacturing of components for tooling:

The LM and AM technology – especially 3 D printing - have been in practice in the industry for almost a decade. However, these have remained primarily high cost alternatives /solutions especially for the auto industry. But in the last decade, constant research and development has taken place in making the RM used in these technologies economical and hence the overall solution would become implementable for the auto and tooling industry. The development trends are summarised below:

LM (Layer Manufacturing) technologies are also often referred to as RP (Rapid Prototyping) technologies. In this the final component for tooling is generated directly from a geometry file, in a near net shape quality. The two major methods are 3D printing and additive layer manufacturing.

[94] Energy storage - Primary Focus Area of Automotive Industry, Future Bridge

The 3 D printing technology is practiced for metal and polymer components used in the tooling. This technology is already in practice and is undergoing improvements in the materials used – especially metals and polymers.

Newer method is coming into practice for making specialised automotive seals using EPDM. of ethylene propylene diene monomer (EPDM) exterior automotive seals. Till recently prototype components can be manufactured through production tooling platforms by either injection moulding or extrusion. Consequently, tooling is expensive and has long lead times. Now viable additive layer manufacture method for producing tooling used in injection moulding of exterior automotive seals in EPDM. Under this method a novel rapid tooling can be made combining additive layer manufacture (ALM) with epoxy reinforcement. This would drastically reduce both costly and environmentally detrimental pre-manufacturing processes.

B. Rapid tooling technology for tooling components:

Rapid tooling technology is regarded as an important method of reducing the cost and time to market in a new product development process. Silicone rubber mold and epoxy-based composites mold are frequently used in the indirect tooling. Based on green manufacturing, a green rapid tooling technology is developed. This technology provides a new and simple approach for producing the green silicone rubber mold and the green epoxy-based composites mold without appreciable loss of surface roughness. The savings in costs of development in the green silicone rubber mold and green epoxy-based composites mold are about 35.6% and 52.5%, respectively. The saving in cost of development in the large-sized silicone rubber mold fabrication is up to 66.4%.

C. Use of AR/VR for tool design and try outs:

AR makes it possible for a new product to be visualized in a real-life setting, such as the factory floor, at scale. The way that designers view products has seriously evolved: from 2D drawings on paper to 3D CAD models on a desktop screen, designers are always looking for an easier way to accurately view a product before a prototype has been built.

With AR, there is an ability to superimpose the digital representation onto a physical asset once it has been produced to compare the configurations of the product through its evolution— whether that's "as-designed," "as-built," "as-manufactured," or "as-serviced." Once there, stakeholders can interact with the data, view the product from perspectives that are not easily accessible in 2D or 3D visualization.

D. Tools for the use of Intrinsic hybrid composites:

In the modern vehicles several hybrid parts are used to make the lightweight designs. Under the existing technologies, hybrid parts are mainly made in separate followed by subsequent forming and joining processes. By using the concept of an intrinsic hybrid, the shaping of the part and the joining of the different materials are performed in a single process step for shortening the overall processing time and thereby the manufacturing costs. To this end a forming tool, which combines the thermo-forming and the metal forming process, is developed. This is the development that is under progress[95]. The main challenge by designing the tool is the temperature management of the tool elements for the vario- thermal forming process. The process parameters are determined in basic tests and finite element (FE) simulation studies With the concept of intrinsic hybrids, the shaping and forming of the part is combined with the hybridisation in the same process step and thereby the same tool.

E. Impulse forming technologies:

[95] Journal of Physics: Conference Series, Volume 896, Issue 1, article id. 012043 (2017).

With impulse forming technologies like electrohydraulic and electromagnetic forming[96], the punch in a stamping process is replaced by an impulse that acts in a short period and provides high strain rates of over 1000 s-1. In this method a capacitor bank is loaded with electrical energy. The exploding wire initiates a shock wave in a fluid. This shockwave and electromagnetic pulse are used for forming. Improved formability and reduced spring back ca be achieved in this process. The flexibility covers different aspects like intrinsic geometrical adaptability of the punch, reduced demand for mechanical stiffness, rapid manufacturing of the dies due to the usability of alternative tool materials, modular dies, and the opportunity of consecutive or parallel process combinations. The proposed techniques can also be used for cold forming of small series or even single parts more cost and time efficiently.

F. Incremental sheet forming:

Incremental sheet forming (ISF)[97] is a relatively recent technique that allows solving many problems of the conventional sheet forming process. ISF is a die less forming process suitable for small batches and has demonstrated its great potential to form complex three-dimensional parts with using a relatively simple and low-cost tools. Potential application areas of ISF include the aerospace industry, biomedical applications, rapid prototype production, and metal forming in the automotive industry. ISF processes are characterized by much less forming force compared to conventional stamping, with no need to manufacture the dies, a higher value of the sheet deformation in relation to die-forming, and the ability to shape elements on a conventional computer numerical control (CNC) milling machine. A schematic of Two-point incremental forming[98] is depicted in figure 23.

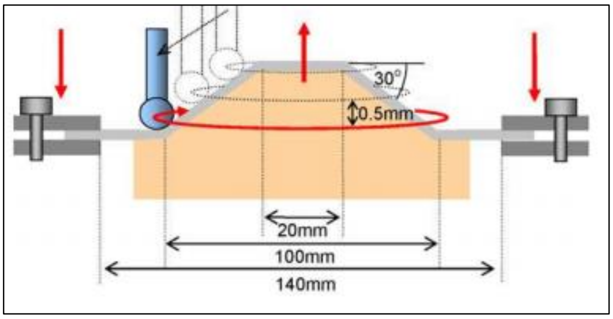


Figure 21: Schematic of Two-point Forming

G. Thermal spray forming technology:

Thermal spray forming[99] technology has the origins in the union of spray forming concept and new rapid tooling technologies to produce near-net shapes and thin-walled complex forms of different materials, using thermal spray equipment. Under this method coat is applied on a mandrel or body, reproducing their shape, and after spraying, to release the coating thus obtaining a self-standing part. Though this technology has been used in the past to produce complex and expensive parts in aerospace and rocket applications, it is now being used for tooling.

Under this method, a mold is fabricated by providing a matrix having a shape to be molded, and spraying molten metal from a spray gun. The spray gun is moved so that the spray gun makes successive passes over the surface of the matrix in a movement direction, shifts in a step direction transverse to the movement direction between passes and turns between passes so that during at least some successive passes metal is deposited from two spray directions in a crisscross pattern. Metal is deposited on the matrix, forming a shell which is removed from the matrix and used as a mold.

[96] L.. Langstadtler , University of Bremen . Science Direct 2018

[97] Recent Developments and Trends in the Friction Testing for Conventional Sheet Metal Forming and Incremental Sheet Forming Tomasz Trzepiecinski 1,* and Hirpa G. Lemu 2,*

[98] Incremental Sheet Forming Swapnil Deokar1 , Rahul Warghane2 , Abhyudaya Pathak 3 , Vikram Sawant4

[99] HVOF Forming: A New & Promising Tool J.M. Guilemany, J. Nin CPT (Thermal Spray Centre). Dept. de Ciència dels Materials i Enginyeria Metal·lúrgica. Universitat de Barcelona. Spain

H. Conformal cooling:

Increased part quality and cooling time reduction are the objectives of many designers and molders. conventional cooling lines can provide fail to achieve these two needs easily. The goal of cooling is to remove heat quickly and cooling lines should be economical to construct. At times, these two attributes can conflict with each other. Improvement in cooling line design is needed to get further reductions in cooling time. Conformal cooling channels are such improvement needed to get an additional reduction in cooling time.

These cooling lines are optimized to follow the part geometry in the mold and they provide near uniform cooling of the parts. In Conformal cooling, lines follow the part geometry in the mould. Optimum placement will make for uniform mold temperatures. Conformal cooling lines can be machined, but that will increase the build time and the cost. Although this creates more time in the design cycle, it reduces the time from when the first trials are run on a mold to when the actual production starts.

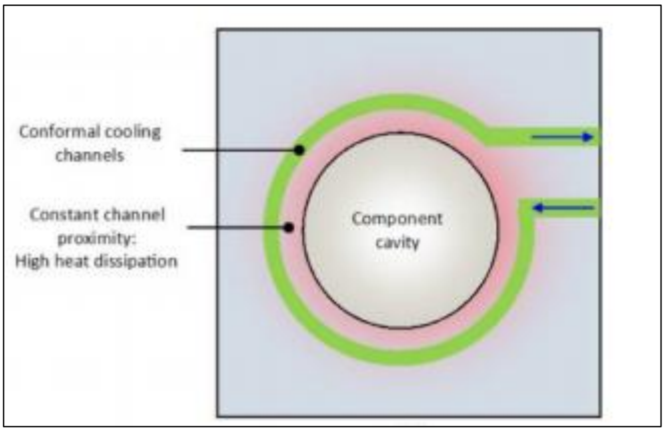


Figure 22: Conformal Cooling

This design and technology feature though known is not popular among the manufacturers due to the time taken to manufacture such parts. This is now simplified by 3 D printing and is now likely to become the trend in the industry.

5 Recommendations

The growing aspirations of the Indian market for better comfort, value for money, focus towards safety features, variety and customization of the automobiles – LCVs, HCVs and two wheelers - have been the driving force behind the evolving trend of the Auto and Engineering industry in the current decade. In the coming decade, automotive players may have to embrace new technologies and trends, driven by growing customer needs and government regulations regarding safety and environmental concerns. Conservation of scarce carbon-based energy resources and the reduction in effluents causing pollution are pointing towards the newer dynamics on the future of the automotive industry. In the Indian market, the price-sensitivity of the consumer could drive critical changes in the industry and may require innovations in both products and processes. This White Paper dwells in detail on the various aspects and the broad conclusions are as under:

- Going forward, the automakers will be compelled to lean more towards "large batch production" and at the same time **reduce the costs** from all angles. Under such circumstances, the manufacturers' search for newer technology to reduce wastage and optimize batch size has given a new impetus to "additive manufacturing" and "**automation based on robotics**".

- The **additive manufacturing** area is now striving to increase the availability of the **variety of materials for 3D printing** to meet with the variety of demand, that too with a lid on their cost. The focus over the coming 10 years would be in finding newer materials and making them available in the open market at comparable prices to conventional materials and efforts to finding newer process technology for enhancing the productivity of the 3D printing process.

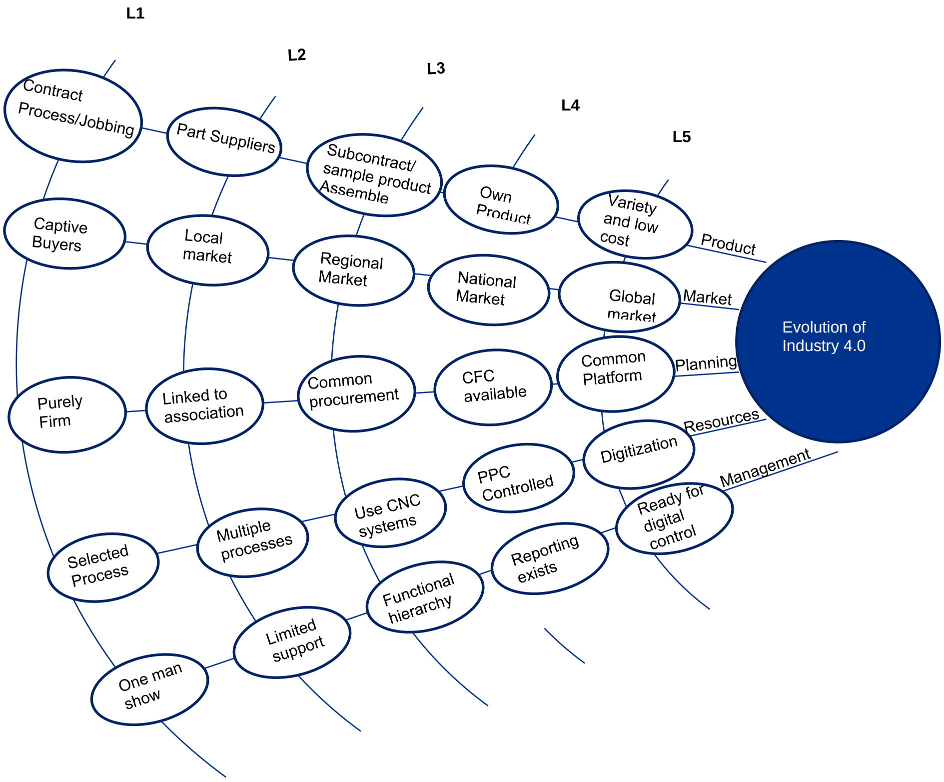
- Greater **reliance on robotics** will be good for minimizing rejection and a step towards achieving committed delivery times. Apart from the mere quantitative indicators on outputs, the introduction of robotics will automatically elevate the workforce to go in for better value jobs, which is also a larger social objective.

- The existing carbon-based vehicles need to improve their performance by going for **lighter material** and reducing the cost in all areas, especially on the supporting items – like tooling, casting accessories such as cores, patterns, etc. This poses a challenge to the industry & tool rooms including the Technology Centres (TCs). Efficient tool making and that too at bare minimum cost will be the guiding light for the industry and TCs engaged in tooling. Improving operational efficiency, short delivery time and capacity utilization will be of prime importance in the future for these support industries.

- Another major activity that would gain momentum in the coming decade will be the introduction of the **Electrical Vehicles** (EVs) and enhancing their "market share" by familiarizing the technology, servicing, and charging facilities. The EV introduction and the huge existing population of carbon-based vehicles will give rise to a demand for **conversion kits (Diesel / Petrol to EV)** over the coming years. The auto markets over the last few decades have been focusing on carbon-based fuels. Now with the need for the creation of the infrastructure facilities spread all over the country for "**servicing and repairing the EVs**" will generate new activity. It will be prudent to meet this sudden surge for infrastructure and know-how - by setting up the TCs or its arms at remote centers and simultaneously developing MSMEs to meet with the demand for charging, servicing, repairing stations, parking facilities, etc.

- The need for optimizing the energy consumed from the conventional carbon-based transportation, along with foreseen technological & skill advancements would facilitate the introduction of newer methods for transportation - like a **blend of private and public transportation** – as a good alternative.

- With the coming in of **Industry 4.0**, a newer concept of less supervision, if not supervision-less production will gain its true place in the industry. The newer manpower trained in Industry 4.0 aspects and benefits like digitization, real-time data collection & action, and IoT (Internet of Things) will help the industry to further reduce the costs – both through higher productivity even in smaller batch size production and economization through design improvements. Below is the shuttlecock diagram for mapping MSME readiness for adoption of Industry 4.0



Examples of Level:

Level 1: Fixed customers, with available resources

Level 2: Trading with local markets and limited resources

Level 3: Sub-contract with regional markets with CNC machining

Level 4: Own products and sell to national markets with Planning tools following standard management

Level 5: Flexible manufacturing, digitized, with low cost aiming

Figure 25: Shuttlecock diagram for mapping MSME readiness

5.1 Recommendations for TCs and MSMEs

On the basis of interpretation of opportunities and inherent challenges in the Indian automobile industry, a framework for adoption and implementation of the eight emerging technologies which has relevance to TCs and MSMEs is represented in the table below[100].

[100] India's readiness for industry 4.0. A focus on automotive sector by CII and Grant Thornton, BCG report 2015: Industry 4.0, The Future of Productivity and Growth in Manufacturing Industries

S. No.	Technology	Results of newer technology	Challenges faced: job losses/ skill shortages/ changes in the existing value chain	Initiatives to bridge the gaps in access and adoption	The role the TC can play to fill in the gap and ease of adoption/BDS need
1.	Additive manufacturing (AM) and incremental forming (for tools and an off-component production)	▪ Feasibility of consolidation of multiple parts into a single component. ▪ Lighter parts can be made. ▪ Complex/customized shapes can be developed, which is difficult to achieve in conventional tooling. ▪ Reduces the prototyping time and facilitates small batch production of tooling and parts. This enables the "Just-in-time" movement of components of the final product giving comparative advantages of different locations. ▪ It will result in producing components at a location where the assembly of the final product takes place. ▪ More localized manufacturing and delivery ▪ Warehouse space requirement reduction	▪ Will require up-skilling of resources (existing operatives, designers) on CAD drawings, 3D product design etc. ▪ Orientation programs would be required for MSME, which are not exposed to such technology yet. ▪ Unavailability of raw material required for AM. Also, resulting in high cost of production.	▪ Development of separate training courses for AM machine operation. ▪ Orientation programs to SMEs/ clusters on long term benefits of the technology through cost-benefit analysis. ▪ Reduction in production cost ▪ Government policies to avoid copyright infringement for digital design templates ▪ To address certification and liability of 3D printed parts	▪ TC can develop courses and training for creating awareness and capacity building of MSME employees for implementation of the technology. i. CAD design usage at operator level ii. 3D printer technology – operation details iii. Raw material handling in 3D operations iv. Cost analysis of 3 D printed parts v. Design for 3D operation (for design engineers) ▪ Consultants/ Subject Matter experts can be engaged by TC to carry out feasibility study at different stages of value chain for implementation of additive manufacturing.

S. No.	Technology	Results of newer technology	Challenges faced: job losses/ skill shortages/ changes in the existing value chain	Initiatives to bridge the gaps in access and adoption	The role the TC can play to fill in the gap and ease of adoption/BDS need
					▪ The TC can develop a separate team or collaborate with a BDS provider (on revenue sharing) to implement these services for MSMEs
2	Digital Factory: the whole manufacturing process is created virtually before it is implemented physically	▪ Enables designers, engineers to understand and rectify the issues that could arise. Similarly, the impact of changing the tooling, machines etc. can be studied prior to actual physical implementation ▪ Availability of real time machine data would reduce dependency on personnel for supervision, chasing and follow up in production area. ▪ Ready to use unmanipulated performance data would improve output efficiency of the operatives. ▪ Analytics for quick decision making both on machine working and output is possible. This helps to reduce RM wastage. ▪ Higher asset uptime for all equipment leading to higher production volume. ▪ Virtual designs using CAD CAM modelling, simulations	▪ Training to operatives to the digital methods. Skill up-gradation needed at various levels are depicted in diagram placed at Annexure I.	▪ Extensive training of the factory floor personnel. ▪ The operator should be Trained for a new mind set of "as self-supervisor" ▪ The engineers need to be trained on data analytics. ▪ An initial investment will be needed in data collection and management.	▪ The TC has big role to play in creating a graded syllabus for the various personnel across the board: i. digitization principles, its advantages ii. Factory automation and data collection methodology iii. The factory "order processing cycle "starting from enquiry to delivery of Finished goods shall be streamlined and documented and systematized. ▪ The TC can setup a "factory automation

S. No.	Technology	Results of newer technology	Challenges faced: job losses/ skill shortages/ changes in the existing value chain	Initiatives to bridge the gaps in access and adoption	The role the TC can play to fill in the gap and ease of adoption/BDS need
		and virtual process mapping helps to get the most optimized designs.			lab" to train the personnel in automation, its methodology and working. ▪ Development of new age entrepreneurs and skilled manpower in automotive industry for delivery/ service/ renting and riding,
3	Use of Magnesium for parts in place of Steel and Aluminum	▪ Reduction in component weight ▪ Lead to fuel efficiency	▪ Use of magnesium is fire hazard if not properly handled. ▪ Magnesium is limited by its extraction costs, which make the metal about 20% more expensive than Aluminum. Since an equivalent part is 33% lighter compared to Al and 75% lighter than steel, the net cost of a magnesium part is still competitive (See Annexure II).	▪ Newer designs of machines under selective laser melting (SLM), paste extruding deposition (PED), friction stir additive manufacturing (FSAM) and laser additive manufacturing (LAM) techniques to fabricate Magnesium alloy-based 3D printed parts are being developed.	▪ The TC shall assist the MSME to develop their prototypes using magnesium alloys and get the approval of parts to OEMs. Once this is done the MSMEs will buy their own 3D machines. ▪ TCs shall endeavor the needed hand holding, till use of magnesium is fully adopted by MSMEs.
4	Use of robots and cobots in manufacturing lines: Materials can	▪ High precision and accuracy of output ▪ Can replace humans for all repetitive tasks.	▪ The existing line operation shall be streamlined to ensure continuous flow. ▪ High initial capital cost.	▪ Funding to be provided to MSMEs to adopt use of robots and cobots.	▪ TCs can have in house Robotics lab where in people can be trained on the use and benefits of robots.

S. No.	Technology	Results of newer technology	Challenges faced: job losses/ skill shortages/ changes in the existing value chain	Initiatives to bridge the gaps in access and adoption	The role the TC can play to fill in the gap and ease of adoption/BDS need
	be transported across the factory floor via autonomous mobile robots (AMRs), avoiding obstacles, coordinating with fleet mates, and identifying where pickups and drop offs are needed in real-time	▪ Very high productivity in manufacturing is realized. ▪ Cost comes down drastically.	▪ Programming & managing skill to be developed.	▪ Benefits to be explained to MSMEs by taking examples of situation such as COVID-19, wherein robots would have proved useful.	▪ They can conduct special programs to appraise the MSMEs on benefits of using robots. ▪ TCs can undertake cost-benefit analysis ▪ Consultants/ Subject Matter experts can be engaged by TC to carry out feasibility study at different stages of value chain for implementation of additive manufacturing.
5	IoT	▪ Will give real time machine data even from a remote location. ▪ Helps to project unmanipulated performance details. ▪ Helps analytics for quick decision making ▪ Helps to realize higher asset up time for all equipment. ▪ With IOT, it is possible to have a system of interrelated computing devices, mechanical and digital machines, objects and people that are provided with unique	▪ The factory operation shall need to be digitized to some level to get the best benefits. ▪ An initial though small financial involvement in setting up the system and linking to portable handsets.	▪ The government is engaged in creating an IoT industry within India. It is expected to result in an increase in the connected devices from around 200 million to over 2.7 billion by 2020. ▪ To develop IoT products specific to Indian needs in the domains of	▪ TC can undertake capacity development (Human & Technology) for IoT specific skill sets for domestic and international markets. ▪ TC shall set up a full-fledged IOT lab to train the students and the industry. ▪ The TCs can aim to become a COE for Industry 4.0 with IoT as the core stream.

S. No.	Technology	Results of newer technology	Challenges faced: job losses/ skill shortages/ changes in the existing value chain	Initiatives to bridge the gaps in access and adoption	The role the TC can play to fill in the gap and ease of adoption/BDS need
		identifiers and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction. ▪ IoT can be embedded in vehicles for Improving the infrastructure and analyzing the vehicles in the long run for stability and road conditions. This will help vehicles in automatic fault detection, automate maintenance schedules, maintenance history analytics, health check up on dashboards etc. ▪ Eventually, will give the managers enough time to focus on their specialization and at the same time have control on routine follow ups/ supervision.		agriculture, health, water quality, natural disasters, transportation, security, automobile, supply chain management, smart cities, automated metering and monitoring of utilities, waste management.	
6	AR/VR	▪ Improves plant performance, uptime, reliability and safety ▪ Improves skill retention versus traditional training methods by up to 100 percent and reduces the length of technical training by up to 150 percent ▪ Employees' training progress is tracked as part of a formal competency management system	▪ Identifying use-cases, which are feasible to implement ▪ Shortage of in-house expertise and insufficient back-end infrastructures	▪ Government support to develop AR/ VR lab and get trainers trained from institution such as Harvard Innovation lab. ▪ Facilitating creation of programs in AR/ VR in Indian	▪ TC can set up a full-fledged AR/VR lab to train the students and the industry. TC can prepare models based on AR/VR to improve customer's buying experience

S. No.	Technology	Results of newer technology	Challenges faced: job losses/ skill shortages/ changes in the existing value chain	Initiatives to bridge the gaps in access and adoption	The role the TC can play to fill in the gap and ease of adoption/BDS need
		▪ Turns data into insight enabling plants and businesses to run better[101] ▪ Advance experience may be created for sales and marketing of new vehicles and to showcase process of vehicle manufacturing.		institutions/ universities.	
7	HALT: Allows newer products to be tested and certified for road worthiness or commercial use	▪ It is possible to predict in this testing procedure on how a product would behave in its life (over the years) due to the design and material limitations. The result of this test helps to reduce warranty claims. ▪ With this the time required to test is reduced substantially.	▪ The test needs to cover several parameters such as temperature, vibration, thermal cycle, environment, wind to name a few. Only the most important ones can be tested. ▪ Special test rigs need to be designed to consider all the likely variability in working condition of the product.	▪ A few standard methods have been identified to test the parameters. The actual working condition can be very closely simulated close to reality.	▪ TC can design the test rigs, to suit Indian conditions. They can also fabricate them and offer the testing services to the MSMEs and OEMs at a cost.
8	Electric vehicle components manufacturing	The introduction of EV has created the demand for a series of new products not currently in use in petrol/diesel vehicles. This relates to products and sub-assemblies which are part of the EV per se like a. Motor LEV, MEV & HEV b. Magnets and Battery	The volume of items needing prototyping, HALT and productionising is very large and all need to be done simultaneously.	The service institutions shall go in for Industry 4.0 techniques to allow small batch production and using 3D printed tooling's and dies/fixtures.	▪ TCs can help MSMEs in prototype production ▪ Once the prototypes at TCs are ready and the products can go in for batch production, the MSMEs around the geographical location of these TCs

[101] Honeywell Introduces AR/VR Simulator to Train the Industrial Workforce and Help Close Skills Gap – 28 March 2018

S. No.	Technology	Results of newer technology	Challenges faced: job losses/ skill shortages/ changes in the existing value chain	Initiatives to bridge the gaps in access and adoption	The role the TC can play to fill in the gap and ease of adoption/BDS need
		c. Power Electronics included BMS (Battery Management System) and Connectors d. Sensors & Misc. Components e. Charging stations A demand for HALT for the new products/components introduced The operatives across the board at all level need orientation to this product range – relating to manufacture, service, testing. A demand for Training courses for new entrants and existing operatives. With the coming in of EVs, substantial standardization and acceptance procedures and standards must be worked out at component and sub assembly level.	The training and orientation needs have multiplied all of a sudden. It may become necessary for the training institutions to establish an outlet right at the OEMs location. While this is an opportunity, this peak also creates a need to establish the sustainability.	Establish the syllabus for training the various levels and organize a team of trainers to focus on each OEM.	can be roped in as a “consortium”. ▪ TCs can explore the introduction of “up skilling” programs. They can train the new entrants (fresh engineers, diploma holders) and make them “ready for employment”. This can be further developed into a “finishing school” model. ▪ TC can provide a thrust to entrepreneurship in EV sector by focusing on skill development for developing high efficiency components/parts and charging solutions.

Table 14: Adoption Framework for implementation of emerging technologies

5.2 Technology Adoption Roadmap for SMEs

The adoption of emerging technologies for SMEs can play a significant role in making them competitive with new era of industrialization and associated opportunities and benefits. MSMEs need the following technologies coming under Industry 4.0 in the order of suggested priority. The priorities may slightly differ from cluster to cluster and for that matter from one MSME to another. However, the following indicates the overall linkage of Industry 4.0 technologies along with needs and priorities of MSMEs:

Needs	Priority		
	High	Medium	Low
Production Efficiency	Through Automation & Robotics		
Prototyping for New Product Development	3D Printing & Prototyping Lab		
Skilling of Manpower	AR/VR & Digitization		
Quality Assurance		Through Digitization & AR/VR	
Inventory Management		Supply Chain Analytics for Material Planning	
Energy Conservation		IIoT & Real Time Optimization	
Inspection Automation			AR/VR & IIoT
Improving Machine Reliability			IIOT & Analytics

Table 15: Alignment of Industry 4.0 Technologies with Needs and Priorities of MSMEs

Milestones:

To adopt these technologies SMEs will have to follow a certain structure and the roadmap will have the following key milestones:

1

Make the cluster and MSMEs see the benefits through demonstration:

- The cluster shall have a demonstration on the applicability and use and benefits of newer technologies falling under Industry 4.0. The need of the cluster is to know and to assure itself that Industry 4.0 is not merely for large units.
- Establish a "Model Cell" within the existing facility of the TC to implement IIOT, AR/VR, Digitization and Lean concepts. Demonstrating in existing machines will give confidence for the cluster units to see the benefits and adopt the same. This will give a new vision to manufacturing units in the cluster about smart factories.
- The TC can link 6 to 7 machines to demonstrate and avail the benefits for their production within the "Model Cell". This will help as a platform for collaboration between researchers, students (trainees) and cluster units. It will also give a real time depiction of the various processes and advantages to the cluster.
- The TC can use the existing machines like 3axis. 5 axis machine, 3D printer, CMM, robots (coming under planned CIM lab) , storage unit.
- **Hardware:** They need to invest in interconnecting conveyor lines, sensor on the machines, and IT infrastructure.
- **Software:** Digitization through dashboards and the integrating softwares.

2 Use of Model Cells facilities by MSMEs and Upskilling of their man power:

- Make the facilities in the model cell available for the MSMEs to make critical parts and pilots. Let the MSMEs know and experience the cost and value benefits .
- Training modules for each of the technologies mentioned above under Industry 4.0. (labs for robotics, CIM and automation are to be established either in the TC or in the cluster)

3 Assisting SMEs by TC with Cluster Body:

- TC along with the cluster body to assist the MSMEs in implementing the applicable areas of Industry 4.0 by offering the needed consultancy services.
- Handholding support in the initial period for nominal service charges to use Industry 4.0 and other technologies introduced.
- Conduct regular training program to the operatives in partnership with the cluster bodies.

Budgetary Indications: It is appropriate to mention that setting up this "Model Cell" at any TC will cost in the region of 60 lakhs using existing machines. Based on this, Smaller cluster units can emulate the relevant portions applicable to themselves with a smaller budget of 20 lakhs.

Roadmap for Adoption:

The adoption roadmap along with indicative timelines are shown below:

Activity	Timelines	T Month	T+3	T+6	T+9	T+12	T+15	T+18	T+21	T+24
Kick Off the implementation Process										
Create a Model Cell either in TC or cluster unit										
Demonstrate benefits of technology to the cluster units										
MSMEs avail services of Model Cell										
Upskilling of MSME employees										
Cluster units experience the real benefits										
TC to offer consultancy services to MSMEs for implementation and handholding support										
Cluster units start operating using industry 4.0 technologies										

Figure 26: Technology Adoption Roadmap for MSMEs

5.3 Suggested Policy Interventions

Capital good modernisation support: The immediate need for the MSMEs engaged in Auto component production is to upgrade their equipment to enable their quality assurance level to fall in line with the global expectations. It is recommended that the government shall support modernisation of the capital goods by giving special subsidies and policy support to those MSMEs.

Support for procurement of designs and drawings: MSMEs need drawings and specifications to make and offer the components – for potential buyers. This will enable them to proactively offer high quality components instead of waiting for enquiries. For this they need to buy the drawing and specification so that prototypes can be made offered to the buyers in the supply chain. Under the existing policies, such procurement of drawings is allowed by the government. However, the MSMEs are not able to avail this as they must remit the fees prior to the procurement of the drawing etc. Government can support this initiative from the MSMEs by granting such costs. Normally such cost is in the order of say 5 lakhs per component. This intervention from the government will make a visible impact among the MSMEs.

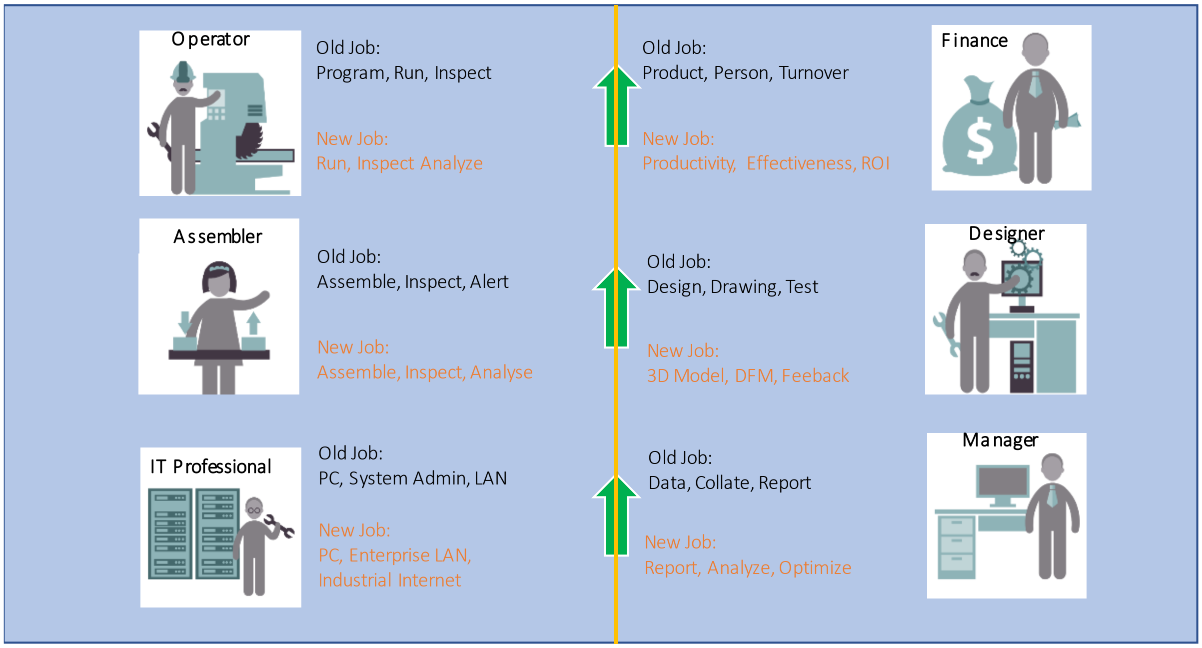
Common marketing platform: The cluster needs to put up a common marketing platform to compete in the supply chain needs – both in terms of quantity and cost. While the clusters have felt the need for such a CMP (common marketing platform) they are not able to implement considering the initial costs and hand holding assistance needed. The cluster shall be given some policy support in terms of covering their legal and formation cost and initial pre-operative expenses. In order to ensure effective implementation of the marketing platform, TC can be given the authority to oversee such formation and disbursal of the financial support.

Prototype production support for global supplies: Some of the TCs have established full prototyping facilities**.** The cluster units are not availing the same and thereby benefitting in exporting their product. This is primarily due to the cost involved in the prototype production. There is a definite time delay in getting in such prototypes approved by OEMs. Currently MSMEs are reluctant to take this risk. The government can kick start this process by offering support in getting the prototypes made in the TC or approved centres. The policy could give the needed financial support through the TC or the approved centres. Suitable repayment plans can be prescribed for the MSMEs once the prototypes lead to a firm order.

Incentives on Indigenisation: Incentivising the establishment of production facilities in the country is critical, not just for assembly, but for raw materials, too. The need of the hour is a calibrated incentive plan, depending on the level of indigenous production. Certain curbs against the import of cheaper produce, from other countries, might be necessary while ensuring that the local produce is cost-competitive and sustainable.

6 Annexures

6.1 Annexure I



6.2 Annexure II[102]

Metal	USD/lb	USD/kg	Cost vs. Steel
Al (Primary)	$0.97	$2.13	**3**x
Mg (primary)	$2.14	$4.71	**7**X
Steel (Primary)	**$0.29**	**$0.64**	
Ti (Sponge)	**$3.64**	**$8.00**	**12X**

Table 15: Annexure II - Skill up-gradation in Digitization & Industry 4.0

[102] 2016 U.S. spot Western, dollars per pound, average, USGS

6.3 Annexure III

Major centers of automobile production across the globe

#	Location	Country	Companies
1.	Great lakes	USA, Canada	FCA; GM; Toyota; Honda, Kia, Renault-Nissan, Daimler; Tesla
2.	South East	USA	Daimler; BMW; VW; Honda; Renault-Nissan; GM; Toyota
3.	Mexico	Mexico	Toyota, Ford, Hyundai, Kia, GM, Renault-Nissan, FCA, Honda, Mazda, VW, AUDI
4.	Sao Paulo, Rio de Janerio	Brazil	Renault-Nissan; PSA; VW; Tata; Daimler; GM; Ford; BMW; Honda; Toyota; Hyundai; Chery; AUDI
5.	Santa-Fe	Uruguay, Argetina	FCA; GM; Honda; Toyota; Daimler; PSA; Ford; VW; Geely; Ligan; Hyundai; Kia; GM
6.	Germany	Germany	BMW; GM; VW; AUDI; Daimler; PSA; Ford; Porsche
7.	Italy	Italy	FCA; PSA; Lamborghini; Ferrari; Maserati; PSA
8.	France	France	Renault-Nissan; PSA; Toyota; Daimler
9.	Spain	Spain	PSA; Renault-Nissan; Daimler; VW; Ford; AUDI; Seat
10.	North America	Algeria, Egypt, Marocco	Renault-Nissan; Dacia; Dongfeng; Daimler; BYD; GM; Isuzu; KingLong; SAIC; Suzuki; Chery; FCA; Geely; Honda; Hyundai; Toyota; BMW; Brilliance; Great Wall
11.	Eastern Europe	Poland, Czech Republic, Hungary, Austria, Slovenia, Slovakia	Toyota, PSA; Skoda; Hyundai; GM; FCA; VW; AUDI; Seat; Suzuki; Daimler; Tata; Renault-Nissan
12.	Turkey	Turkey	Ford; Isuzu; Hyundai; Kia; Renault-Nissan; PSA; FCA; Toyota; Honda
13.	UK	UK	GM; Tata; Toyota; VW; SAIC; Honda; BMW; Proton; Aston Martin; Renault-Nissan
14.	South Africa	South Africa	BMW; Renault-Nissan; Tata; Ford; Mazda; BAIC; Hyundai; Kia; Toyota; Daimler; VW; GM
15.	Greater Beijing	China	Chery, Renault-Nissan, Shungang, GM, Hawtai, Brilliance Auto, CNHTC, Sichuan Yema, PSA, Toyota, VW, Geely, Hyndai/Kia, Lifan, SAIC-GM-Wuling, Ford, Dongfeng, Suzuki, Changan. BAIC, Weichai Power, Brilliance, SWM, Izusu, Hainan Automobile, FAW
16.	Greater Shanghai	China	Chery, Renault-Nissan, Shungang, GM, Hawtai, Brilliance Auto, CNHTC, Sichuan Yema, PSA, Toyota, VW, Geely, Hyndai/Kia, Lifan, SAIC-GM-Wuling, Ford, Dongfeng, Suzuki, Changan. BAIC, Weichai Power, Brilliance, SWM, Izusu, Hainan Automobile, FAW
17.	Greater Chongqing	China	Brilliance Auto, CNHTC, Sichuan Yema, PSA, Toyota, VW, Geely, Hyundai/Kia; Lifan, SAIC-GM-Wuling, Ford, Dongfeng, Suzuki, Chanan, BAIC, Weichai Power, Brilliance, SWM, Isuzu, Hainan Automobile, FAW

#	Location	Country	Companies
18.	Japan/South Korea	Japan, South Korea	GM; Hyundai; Kia; Mahindra& Mahindra; Renault-Nissan; Mazda, FCA, PSA; Toyota; Fuji Heavy; Honda; SWM; Daihatsu; Daimler
19.	Malaysia/Indonesia	Malaysia, Indonesia	BMW; Hyundai; Kia; MAZDA; Perodua; Great Wall; Fuji Heavy; Renault-Nissan; Mitsubishi, PSA; Honda; Toyota; Geely; Proton; Daimler; VW; Isuzu; GM; SAIC; Suzuki; AUDI; Daihatsu
20.	North India	India	Tata; Suzuki; Honda; Ford; Mahindra& Mahindra
21.	Western India	India	GM; VW; AUDIL Skoda; Bajaj AUTO; FCA; premier; Mahindra& Mahindra; BAIC; Daimler; Force Motors; Ssangyong; Piaggio
22.	South India	India	Mahindra& Mahindra; Tata; Ashok Leyland; Toyota; Isuzu; BMW; Ford; Hyundai; Renault-Nissan; Mitsubishi
23.	Iran	Iran	Iran Khodro; Renault-Nissan; SAIPA; PSA; Dongfeng; Great Wall; BAIC; Brilliance; BYD; Changan; Chery; FAW; FCA; Hyundai; Kia; Isuzu; Jianghuai; Lifan; Mazda; Sollers; Zhongying; Changan; FCA; Hainan Automobile; Suzuki

Table 16: Annexure III- Major Centers of automobile production across the globe

6.4 Annexure IV

Details of eleven key factors supporting 6 megatrends

A. **Social responsibility:** Years of hedonistic materialism and increased prestige thinking are being followed by a slow but steady shift towards more environmentally and socially compatible lifestyles and consumer habits as a result of the intensification of environmental problems, coupled with a growing awareness of one's own overall social responsibility. The purchasing decisions of wealthy Indian or Chinese consumers, for example, are increasingly influenced by working conditions in production plants or by the effects of product use on the environment and society[103].

B. **Change in value-added:** In Europe, a high probability of establishing legal standards for the disclosure of working conditions in suppliers' production facilities will be observed. In addition, smaller European suppliers are increasingly being bought up by larger Chinese competitors. In the USA, the enforcement of binding guidelines will be established to establish transparent supply chains. California will remain an incubator for start-ups and groundbreaking innovations with an IT focus. In China, there will be high government subsidies, especially for suppliers in the field of electric mobility. Consolidation among suppliers is massively supported by the government's policy of forming large corporations. The development of know-how through massive M&A activities is being pushed in Asian countries.

C. **Powertrain changes:** In the overall vehicle market, a slow transition from conventional technologies to alternative technologies is taking place. In the medium term, diversification of drive technologies is becoming apparent[104].

D. **MaaS (Mobility as a Service) and new competitors:** In addition to today's core value creation, new value creation stages for individual mobility are developing. These new business areas (such as electric mobility, car-sharing models, mobility subscriptions, online purchasing of vehicles with door delivery ,data-based value creation) must be (further) developed strategically in order to secure the existing core business. In this context, new companies, possibly from outside the industry, become relevant as

[103] Global Sensor 2011-2013
[104] Knappe 2015

competitors or possible cooperation partners for automobile manufacturers. In particular, new players from China and India are causing increasing competitive pressure. OEMs from the triad choose direct cooperation with their new competitors from emerging markets or mobility providers from outside the industry as their preferred strategy for adapting to the highly competitive market environment. Many of the new mobility providers come from the ICT, transport, or energy supply industries.

E. **Multimodal and seamless mobility:** In order to integrate the various modes of transport and mobility services both technically and organizationally, data service providers such as Google and IBM will establish themselves as integrators on the mobility market in the coming years. With the help of sophisticated technical applications - which are easy and convenient to use for users - they are creating a breakthrough for seamless mobility. Different offers are bundled, standardized, and marketed, so that there are only a few customer interfaces. The individual providers and modes of transport cooperate under the roofs of these integrators, disappearing behind them, as it were. Overall, the diversity of players is gradually diminishing, so that dynamics and competition are diminishing, but the effectiveness of the offerings is increasing. The heterogeneous landscape of Car-Sharing providers is changing through consolidation, which also increases their efficiency. The proportion of journeys and distances covered by public transport and Car-Sharing is increasing.

F. **Data management:** The availability of data will increase very strongly in the coming years. This will also increase the importance of data-based value creation for many sectors of the economy. In particular, the possibility of actively selling data to third parties - in addition to pure collection and analysis - will lead to a real boom and the emergence of a variety of new business models. This development is made possible by the fact that many people around the world are generally free to handle their personal data. However, it is important to note that there is a varying degree of sensitivity regarding the use of data depending on the life situation. The legislation is responding to this development by laying down minimum requirements for data protection in certain areas.

G. **Sustainable transport infrastructure and energy system transformation:** Transport infrastructure includes existing and planned land-based infrastructure for passenger transport - transport routes and the supply of energy sources (H2, e-Fuels, CNG, BEV infrastructure). In 2025, the infrastructure of urban areas will be networked, thus enabling intelligent traffic flow control (Transportation Demand Management). This will be accompanied by the promotion of public transport. This applies to both developed and emerging markets (leapfrogging effect). The global demand for energy is increasing. Renewable energies are being expanded. In order to change the energy system from fossil to non-fossil primary energy sources, considerable progress in production, storage, and distribution are required. There is innovation potential in the areas of intelligent networking (smart grids) and storage technologies. In 2025, a steadily growing share of the energy supply will be provided by wind parks/hydropower, decentralized combined heat and power plants, or private photovoltaic systems. Industrial nations will drive global change in this area.

H. **Availability of resources:** The availability and prices of raw materials for the production and operation of automobiles (e.g. fossil fuels, rare metals), especially in view of the increasing demand pressure from emerging markets and the growing price volatility is becoming more and more crucial. In order to secure the supply of raw materials, the focus in the industry is on resource conservation and development of both new (renewable, recycled or bio-based) materials and material & material substitutes (concerns both mineral and energy raw materials). Recycling is becoming increasingly important in order to close important material cycles and to conserve primary resources. The use of secondary raw materials can lead to lower environmental pollution but requires resource-efficient product design from the outset.

I. **Organizational ambidexterity and R&D process:** There is an equal focus of innovation strategies on incremental and radical innovations. A robust and well-balanced innovation portfolio will guarantee success in order to meet volatile customer needs and increasing uncertainties. There will be increased use of open innovation methods (incubators, accelerators, etc.). In order to achieve a balance between traditional and digital business models, i.e. new world (speedboat) vs. the old world (tanker), the development of digital structures and competencies, e.g. IT architecture, or availability of employees (digital natives) is becoming more and more important. In addition, we are seeing more and more divisions of business units, e.g. Delphi splits into Aptiv for Mobility and Delphi Technologies for Powertrain solutions[105].

J. **Rising protectionism and regulations:** The influence of governments on entrepreneurial activity is increasing in many regions, i.e. restrictions on imports (customs duties, non-tariff barriers, import limits, tax regulations) and local content requirements, as well as health and employee protection regulations, are becoming stricter. This is particularly true for the USA and the emerging markets in Asia, Russia, and Latin America, which are seeking to protect and develop their industries. Patent legislation is improving as local industrialization in the emerging markets increases. At the same time, the problem of product piracy cannot be effectively combated, and the number of legal disputes is rising. Legislators are more often guided by technological innovation. In cooperation with manufacturers and transport providers, visions such as automated, accident-free driving, CO2-free, or CO2-neutral vehicle fleets are becoming established. The legislative framework for autonomous mobility gets better, nevertheless, legislation is still a limiting factor for automated driving. Ethical discussions often hampering the legislation process, especially in Europe. In addition, increasing awareness of massive capital requirements with uncertain payback periods to achieve L5[106].

K. **Cost Savings:** Increased margin pressure along the value chain will lead manufacturers to look for increased cost-saving solutions. Coherently, OEMs have announced large cost-saving programs, which have a major material-cost-reduction component and high improvement targets in total: GM 4.5 bn. US$ by 2020, Porsche 6 bn. US$ by 2025, Mercedes-Benz 4.0 bn. US$ by 2025 and Jaguar/Land Rover 2.5 bn. US$ by mid-2020. As a result, there is a high-cost pressure for suppliers due to increased R&D investments, higher raw material prices, and special tools. Many SMEs can neither produce the required quantities nor simply follow the corporations abroad. The high pressure for efficiency through shorter product life cycles: "Faster and more flexible with the same quality “as well as unilateral bidding rounds and disclosure of the CBDs forces high psychological pressure.

[105] Guffarth and Knappe 2019
[106] Roland Berger 2019

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