International Journal of Engineering, Business and Management (IJEBM)
ISSN: 2456-7817
[Vol-9, Issue-1, Jan-Mar, 2025]
Issue DOI: https://dx.doi.org/10.22161/ijebm.9.1
Article Issue DOI: https://dx.doi.org/10.22161/ijebm.9.1.11

Emerging Trends in the Automotive Industry Driven by Sustainable Technological Innovation

Suman Sharma, Jitendra Singh, Jinendra Rahul, Bharat Modi, Garvit Gupta, Md. Yusuf Sareef

Department of Electrical Engineering, Swami Keshvanand Institute of Technology, Management & Gramothan, Jaipur
Jitendra.singh@skit.ac.in, jinendra.rahul@skit.ac.in, suman@skit.ac.in, bharat.modi@skit.ac.in, garvit.gupta@skit.ac.in, yusuf.sharif@skit.ac.in

Received: 27 Feb 2025; Received in revised form: 21 Mar 2025; Accepted: 25 Mar 2025; Available online: 31 Mar 2025

Abstract— *Sustainable technological innovation has become increasingly critical to balance profitability, environmental protection, growth and prosperity of the automobile ecosystem. Grid integration of electric vehicles (GIEVs) and renewable energy (RE) integration are vital components towards sustainable innovation. Variability and intermittency of RE and uncertain mobility behavior makes the operational planning challenging. The paper identifies and discusses diverse technologies and trends shaping automotive industry and electric mobility. The leading technologies are: connectivity, electrification, autonomous driving and shared Mobility. Feasibility of these trends is justified from advancements of underlying technologies such as 5G & edge computing, vehicle-to-everything (V2X), Internet of Things (IOT), public clouds, data analytics, artificial intelligence, digitalization, connected car platforms, analytics platforms, cyber security and so on. This paper highlights driving experience enhancement through technologies and glimpse of possible issues of automotive industry.*

Keywords— ***Connected cars, Digital twin, aggregator, G2V, net-zero, machine learning, trends.***

I. INTRODUCTION

Present economies are vigorously fluctuating, provoked by growth in evolving markets, the fast-tracked upsurge of innovative technologies, viable policies, and varying buyer desires about tenure. Digitization, enhancing automation, and novel trading models have transformed almost all industries including automobile sector [1]. Such reinforcing factors leads to trends in automobile segment: divergent driving behavior, autonomous ride, electrification, and associated network connectivity. Net Zero scenario [2] investigates a potential route to carbon neutrality across all segments of road transport as represented in Figure 1.

Vital aspects of automobile revolt are targeted at offering set-ups anxiety what type of reforms are upcoming and how they will impact conventional automobile manufacturers and dealers, prospective new stakeholders, policy makers, consumers, market operations, and the automobile value chain. The predictions must be reflected as a projection of the most possible uppositions across all four trends, depending upon natural acceptance. They are inherently stochastic but must assist stakeholders for dealing with uncertainty by deliberating probable future states.

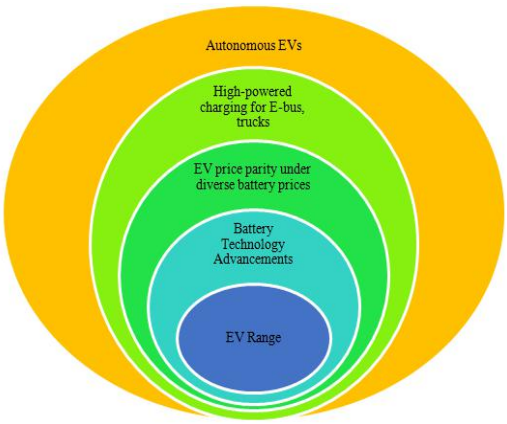

Fig.1: Net-zero Scenario of Automotive Industry

1.1 Motivated by pooled transportability, connectivity services, and aspects promotion

Connectivity, and advanced automation mechanism, will boost the vehicle to be a platform for EV users to utilize their available entertainment/media and services during travel time or devote leisure time to other personal tasks accomplishment [3]. The accelerated innovation, specifically in software-based networks, will necessitate vehicles to be advanced. As pooled transportability elucidations with smaller life cycles will be more public, consumers will be persistently conscious of technical progresses, which will additionally upsurge demand for upgradability in private vehicles as well.

1.2 End user dynamic drivingpattern results into Fit-for-purpose tailored driving solutions

Fluctuating consumer choices, compressing regulation, and technological advances amounts to an ultimate paradigm shift in individual trip behavior [4]. End users enhance usage of diverse means of conveyance to accomplish their trip; belongings and facilities are provided prior to be drawn by them. As a consequence, the conventional commercial prototype of selling vehicles will be supplemented by a variety of ambitious driving solutions, particularly in densely populated urban atmospheres that proactively encourage public transport usage. End consumers nowadays employ their cars as flexible vehicles, whether they are travelling alone to work or taking family to enjoy weekend-picnic. In the future, they may wish the adaptability to select the optimal solution for a particular target, on demand and through their smartphone apps. End consumers' different practice of employing adapted solutions for each target results into new sectors of dedicated vehicles projected for very precise prerequisites. For example, the sales market for a vehicle specially made for e-hailing services—that is, a vehicle manufactured for extraordinary usage, strength, further range, and commuter contentment.

1.3 Viable and competitive Electrified vehicles' adoption

Harsher emission protocols, decreased battery costs, more extensively accessible charging set-ups, and cumulative consumer approval will build new and robust drive for integration of electrified cars (hybrid, plug-in, battery electric, and fuel cell) in the future [5]. The rate of acceptance will be determined by the coordination of consumer attraction (partly motivated by total cost of ownership) and regulatory impulse, which will fluctuate intensely at the provincial and local level.

Electrified cars' acceptance rates will be maximum in industrialized dense cities with harsh emission protocols and consumer incentives (tax interruptions, exceptional car parks and driving privileges, promotional electricity rates, etc).Trades circulation will be sluggish in rural areas with lesser levels of charging set-ups and more reliance on driving range.

1.4 Inside additional complicated and differentiated automobile industry ecosystem, involved entities will be enforced to compete concurrently on manifoldfaces and collaborate with rivals

A pattern swing to mobility as a service, accompanied by new players, will unavoidably enforce customary car manufacturers to strive on manifold faces [6]. Mobility suppliers, tech giants, and domain Original Equipment Manufacturers (OEMs) upsurge the complication of the competitive ecosystem. Conventional automobile stakeholders that are under uninterrupted pressure to decrease costs, increase fuel efficiency, lessen emissions, and turn out to be more capital-efficient will feel the squash, probably resulting into transition of market locations in the developing automobile industries, leading to amalgamation or new customs of conglomerates among involved entities.

In alternative game-mutable progress, software competency is progressively fetching one of the most significant distinguishing features for the business, for numerous field areas, containing ADAS/active safety, connectivity, and infotainment. Further on, as vehicles are more and more penetrated into the linked world, auto manufacturers will have to participate in the innovative driving landscapes that evolve as a consequence of technical and end user drifts.

1.5 Prepare for uncertainty; Drag cooperation & transformative alteration; Reform the value proposal

Success requires automobile entities to transit to a uninterrupted course of deliberating new market drifts, discovering substitutes and accompaniments to the customary commercial model, and exploring novel mobility trading prototypes ensuring their cost-effectiveness and consumer sustainability [7]. This will necessitate an eruditegrade of scenario planning and swiftness to recognize and scale new smart business models. The business is altering from rivalry among peers toward new competitive collaborations, but also conglomerates and open, scalable landscapes [8]. To prosper, automobile manufacturers, suppliers, and service providers must form coalitions or partake in landscapes—for example, about set-ups for autonomous and electrified cars. Novel manufactured items' value is enhanced by software, OEMs mustline up their proficiencies and practices to deal with new threats like software-empowered end consumer value characterization, cyber security, data confidentiality, and uninterrupted product

modernization [9]. Vehicle manufacturers should further distinguish their offers products/services and alter their value proposal from customary vehicle sales and repairs to unified mobility provisions [10]. This will place them in a robust position to sustain a part of the worldwide growing automobile revenue and profit pool, with new business prototypes such as online sales and mobility offers, and cross-fertilizing the prospects among the core automobile-industry and new mobility-business prototypes.

II. EVOLUTIONARY AUTOMOTIVE INDUSTRY

The automobile segment is the technological leader amid corporations in the manufacturing industry. It is emerging catalytically and is a dragger of the digitalization era. The Digital Enterprise elucidation proposing assistances to the automobile industry transform its ideas into successful vehicles rapid and efficient.

2.1 The most holistic digital twin

The all-inclusive method of the Digital Enterprise for building digital twins in the automobile sector provides appreciable advantages: substantial reduction of the numeral of models required in manufacturing process of new vehicles [11]. It turns out to be promising to predict the performance parameters of the manufacturing plant and the products themselves. It guarantees manufacture in terms of end consumers'expectancy depending on individualization and drive aspects.

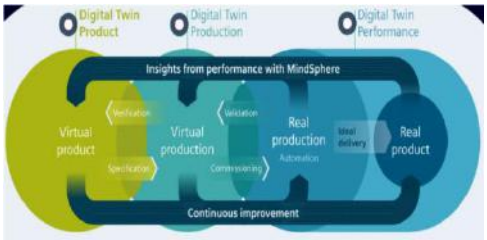

Fig.2: Digital Twin in Automobile Sector

The digital twin in the automobile sector is the detailed computer-generated model of a car or a manufacturing unit. It exhibits their progress during the whole lifecycle and permits operators to predict performance, improving realization, and device insights from preceding design and manufacture experiences. Holistic aspect of digital twin comprises tri-practices: digital twin of item, digital twin of manufacturing to be optimized, and digital twin of performance parameters of item and manufacturing process as shown in Fig.2.

2.2 Compelling autonomous cars to the fast track

Autonomous cars will transform the transport industry drastically. Building autonomous cars demand active, prototype-based advances along with incorporated data flows and a substantial reliability from software-based simulation potentials [12]. It necessitates a whole set of autonomous car solutions for all vital technical areas – from chip design to full carauthentication.

Autonomous cars and features can be deployed successfully only when they are safe, secure, and certified. However, teaching a computer to drive as safe as or safer than humans is more complex than anyone predicted. Deeper into the realm of advanced driver assistance systems (ADAS) and autonomous vehicles (AVs), a customized solution must be provided to help innovation, optimization, and validation of designs. With robust tools, the functional digital twin, simulation, real-world recordings and critical scenario methodology can be leveraged to accelerate the delivery of safe, secure, high-performing and compliant autonomous driving.

III. RECENT SUSTAINABLE TRENDS

3.1 Connected car

Now-a-days there is inherent need to remain connected; be it at home or in office and on the go [13]. There are number of connectivity features in following categories: navigation, remote control, safety and security, convenience, vehicle management, AI voice command, smart watch connectivity etc. Almost all players in India have some form of connected car apps. Some of these are Hyundai (BlueLink), Kia (Kia Connect), Tata Nexon (iRA/Intelligent Real-time Assist), MG Hector (i-Smart connected car technology), Jeep (Uconnect), Ford (FordPass Connect), Maruti (Suzuki Connect), and many more. Many OEMs in India are offering 30-70 connected car features. Now-a-days connectivity features is one of the buying decision as it provides differentiation. Key challenges are high price and affordability, security of the system, privacy of the data being gathered. Technologies being used to address are IOT, Cloud, AI, Data Analytics, Embedded, Telematics etc. Future tech trends may be additional 5G based use cases, additional AI related use cases etc.

3.2 Electrification

This trend shows different types of Electrical Cars in the market are Battery Electric Vehicle (BEV), Hybrid Electric Vehicle (HEV) such as mild and full hybrid [14]. Types of Electric yet to pick pace in India are Plug-in Hybrid Electric Vehicle (PHEV) and Fuel Cell Electric Vehicle (FCEV). Key players are Tata, MG and more. Key challenges of Electrification trend are charging network, EV range anxiety, relatively high price. Key solutions are

Public Private Partnership (PPP) model, standard APIs, connectors, stronger implementation of Faster Adoption and Manufacturing of Electric Vehicles (FAME) 3.0. Future tech trends include battery life prognostic, Fast charging, standard APIs, connectors, battery swap, more accurate range calculations to reduce range anxiety.

3.3 Advanced Driver Assistance System (ADAS)

Level 1/Level 2 features are available in Indian Cars including lane maintain support/lane departure stoppage/lane departure cautionary/lane variation support, blind spot revealing, rear cross traffic aware, adaptive cruise governor, front/rear collision threatening, automatic emergency decelerating, speed assist system, intelligent head lamp control/high beam assist, door open alert [15]. There are many passengers' cars supporting given features as MG Astor, Tata Harrier, Tata Safari, Kia Seltos, Mahindra SUV 700 etc. Technologies used are long range radar, LIDAR, camera, short medium range radar, ultrasound, AI, ML etc. Future trends involve advanced Level 2 features/ Level-3 features, driver distraction warning, drowsiness detection warning, integration with heath sensors (stress sensors)/cognitive load.

3.4 Shared Mobility/Fleets

This trend indicates focus shifting from car ownership to shared mobility for number of reasons such as consumers' preference of access over ownership, convenient scheduling by Smart phone, incentives for corporations and consumers, urban congestion, parking issues, trendy products offer provided by shared mobility etc [16]. Usage of number of fleets is increasing as Uber, Ola, Blue: Electric Vehicles only. Shared Mobility/Fleets has its own challenges such as safety/security, personalization, predictability/reliability etc. Future trends involve MaaS concept of Mobility-as-a-service is also picking up. In this through a single digital platform, access to various transportation modes is provided public transit, car-sharing, bike-sharing and more EV fleets.

3.5 5G enabled V2X services

There are many services which are possible now due to launch and availability of 5G network [17]. V2X services are categorized as Vehicle to Vehicle (V2V), Vehicle to Infrastructure (V2I), Vehicle to Pedestrian (V2P), and Vehicle to Network (V2N). Various use cases of V2X involves situational awareness VRU, vulnerable road users alerts such as pedestrian alert, by-cycle alert etc. This trend involves various use cases of V2X such as increased fuel efficiency (mileage) due to traffic light efficiency, Time to Green (TTG), Red Light Violation Warning (RLVW), and Green Light Optimized Speed Advisory (GLOSA). Keeping traffic flowing reduces emissions and fuel consumption by displaying speed recommendations based on real-time data.

3.6 *Software Defined Vehicle (SDV)*

Software is eating the world but services are eating software [18]. This trend features involve faster development and integration of new features and capability to upgrade the vehicle throughout the vehicle lifecycle, flexible and scalable architecture. This disruption is same as Smart Phones vs. feature phone. Key components involve 1 GB/Sec Ethernet network, high performance computing, unbundled hardware and software, and layered architecture. Layered architecture exhibits vehicle abstraction layer, car operating system, management services layer and application layer. This trend uses several technologies such as OTA, App Store, cloud, IOT, digital twin, micro services etc. Challenges associated with trend are security, automotive grade application, agility but stability.

3.7 Safety and wellbeing focused on driver/passengers health monitoring and controls

During Post COVID era, safety trend is on the rise [19]. Key features of this trend are driver distraction warning is displayed through observations from driver facing inferred camera, visual and mental load detection, eye gaze zone detection, eyelid, blinking and head position analysis. Driver drowsiness warning is provided through observations from interventions in terms of HVAC settings, Audio settings, vehicle lighting, etc. Vital sensing is executed via camera and radar based sensors' records of heart rate, inter-beat intervals, breathing rate.

3.8 In car-Augmented/Mixed reality

In car-Augmented/Mixed reality combines AR-HUD (Augmented reality-Head up Display), navigation, ADAS and AI/ML to offer innovative solution [20]. This trend can reduce the cognitive load on Driver. It can handle ADAS events, navigation, and infotainment. ADAS events involve collision warning, blind spot warning, lane departure, lane change assist. Navigation deals with AR destination/address.

Infotainment provides information regarding points of interest or Interactive information or entertainment zone. There is provision for 3D object detection and AR perception through integrated computer vision and machine learning algorithms. It can pose 6D0F based on sensor fusion of vehicle speed, angle, momentum, location, etc. Key technologies behind these evaluation trends are Internet of Things, 5G Connectivity, Cloud technologies, embedded technologies, Artificial Intelligence, Machine Learning, Edge and Cloud analytics, Mobile apps (Android & iOS), Digital Twin, and Security etc [21].

In the forthcoming era of grid-integrated EVs, EVs can perform pivotal role in maintaining supply-demand equilibrium by serving as mobile energy storage technology termed as "vehicle to grid" as depicted in Figure.3. Flexibility aggregator/EV aggregator has the potential to inject surplus power into the grid during peak periods, avoiding brownouts and rolling blackouts [22]. EVs also have the potential to help keep isolated parts of the grid operating during blackouts. They could also synergize penetration of intermittent and variable renewable energy resources. Demand response programs can be implemented for EV users that encourage their active participation in V2G/G2V operations [23].

Fig.3: G2V/V2G through Home Area Network (HAN)

IV. CONCLUSION

With so many disruptive technologies like SDV, 5G, AI and more; automotive industry is probably at the same disruptive juncture as transition from Feature Phone to Smart Phone happened decade+ before! Stakeholders' Imagination, learning and experience would decide the automotive journey. The Smart Grid permitseffectivepackages to function in more sophisticated manner, leading to increased energyefficiency with less discomfort to stakeholders. Some examples involve time-of-use rates, advanced metering infrastructure, and reward programs for connected EVs. Smart Grid will provide new opportunities to utilities andtheir end consumers to attain targets in cost-effective manner. The fiscal incentives offered could motivate a wide range of new consumer choices. End consumers may be agreeable to pay a bit extra for anintelligentmachine for a new source of revenue for them. Aggregator incentives could also motivate them to install rooftop solar panel and transform to prosumers. The result is a win-win for all involved entities.

REFERENCES

[1] https://about.bnef.com/electric-vehicle-outlook 2023/

[2] M.S., Hossain, Y.R., T., Ma,Fang, C.Huang, and H., Dai, "The role of electric vehicles in decarbonizing India's road passenger toward carbon neutrality and clean air: A state-level analysis", *Energy*, 273, p.127218, 2023.

[3] J., Kottig, D.Macke, and M., Pielen, "Connectivity Design Considerations for a Dedicated Shared Mobility Vehicle", In *Advanced Microsystems for Automotive Applications 2018: Smart Systems for Clean, Safe and Shared Road Vehicles 22nd* (pp. 162-172), Springer International Publishing, 2019.

[4] M., Gkeli, K., Apostolopoulos, G., Mourafetis, C.Ioannidis, and C., Potsiou, "Crowdsourcing and mobile services for a fit-for-purpose Cadastre in Greece", In *Fourth International Conference on Remote Sensing and Geoinformation of the Environment (RSCy2016)* (Vol. 9688, pp. 390-399). SPIE, August 2016.

[5] J., Archsmith, E.Muehlegger, and D.S., Rapson, "Future paths of electric vehicle adoption in the United States: predictable determinants, obstacles, and opportunities", *Environmental and Energy Policy and the Economy*, 3(1), pp.71-110, 2022.

[6] N.K., Goel, A.Chatterjee, and K., Kumar, "Corporate Acquisition In Automobile Sector: A Growth Driver and Challenges", *ClearInternational Journal of Research in Commerce & Management*, 7(10), 2016.

[7] J., Singh, A.B.A. Hamid, and J.A., Garza-Reyes, "Supply chain resilience strategies and their impact on sustainability: an investigation from the automobile sector", *Supply Chain Management: An International Journal*, 28(4), pp.787-802, 2023.

[8] I., Stuart, P., Deckert, D.McCutcheon, and R., Kunst, "A leveraged learning network", *MIT Sloan Management Review*, 1998.

[9] K.Felser, and M.G., Wynn, "Digitalization and IT Backsourcing: Towards a Transformational Model for the German Automobile Industry", In *eKNOW 2020: The Twelfth International Conference on Information, Process, and Knowledge Management* (pp. 7-16). IARIA, March2020.

[10] G., Fournier, "The new mobility paradigm. Transformation of value chain and value proposition through innovations", *The Automobile Revolution: Towards a New Electro-Mobility Paradigm*, pp.21-47, 2017.

[11] E.Glaessgen, and D., Stargel, "The digital twin paradigm for future NASA and US Air Force vehicles", In *53rd AIAA/ASME/ASCE/AHS/ASC structures, structural dynamics and materials conference 20thAIAA/ASME/AHS adaptive structures conference 14th AIAA* (p. 1818), April 2012.

[12] J.E., Naranjo, C., Gonzalez, R. Garcia, and T., De Pedro, "Lane-change fuzzy control in autonomous vehicles for the overtaking maneuver", *IEEE Transactions on Intelligent Transportation Systems*, 9(3), pp.438-450, 2008.

[13] R.Coppola, and M., Morisio, "Connected car: technologies, issues, future trends", *ACM Computing Surveys (CSUR)*, 49(3), pp.1-36, 2016.

[14] Z., Yin, X., Lu, S., Chen, J., Wang, J., Wang, J., Urpelainen, R.M., Fleming, Y.Wu, and K., He, "Implication of electrification and power decarbonization in low-carbon transition pathways for China, the US and the EU", *Renewable and Sustainable Energy Reviews*, 183, p.113493, 2023.

[15] F., Jiménez, J.E., Naranjo, J.J., Anaya, F.,García, A.Ponz, and J.M., Armingol, "Advanced driver assistance system for road environments to improve safety and efficiency", *Transportation research procedia*, 14, pp.2245-2254, 2016.

[16] H., Becker, M., Balac, F.Ciari, and K.W., Axhausen, "Assessing the welfare impacts of Shared Mobility and Mobility as a Service (MaaS)", *Transportation Research Part A: Policy and Practice*, 131, pp.228-243, 2020.

[17] C., Zoghlami, R.Kacimi, and R., Dhaou, "5G-enabled V2X communications for vulnerable road users safety applications: a review", *Wireless Networks*, 29(3), pp.1237-1267, 2023.

[18] Z., Liu, W.Zhang, and F., Zhao, "Impact, challenges and prospect of software-defined vehicles", *Automotive Innovation*, 5(2), pp.180-194, 2022.

[19] S.E., Peters, H., Grogan, G.M., Henderson, M.A., López Gómez, M.Martínez Maldonado, , I.Silva Sanhueza, and J.T., Dennerlein, 2021. Working conditions influencing drivers' safety and well-being in the transportation industry:"on board" program. *International journal of environmental research and public health*, 18(19), p.10173.

[20] https://www.nokia.com/about-us/newsroom/articles/augm-ented-reality-hud-the-next-step-up-for-smart-vehicles/

[21] Sharma, Suman, Jitendra Singh, and Jinendra Rahul. "Digital Twin Technology as Facilitator to Sustainable and Energy-Efficient Ecosystem." *International Conference on Signal, Machines, Automation, and Algorithm*. Springer, Singapore, 2024.

[22] https://www.smartgrid.gov/the_smart_grid/consumer-eng-agement.html

[23] Singh, Jitendra, et al. "Review of Microgrid Energy Management in Smart Grid Environment." *2024 IEEE Third International Conference on Power Electronics, Intelligent Control and Energy Systems (ICPEICES)*. IEEE, 2024.