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# Influence of Artificial Intelligence in Automotive Design

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**Abstract:** Artificial Intelligence (AI) is revolutionizing the automotive industry by enhancing manufacturing efficiency, optimizing design processes, and enabling innovation. In manufacturing, AI-powered robotics and automation streamline production lines, improving precision, reducing costs, and minimizing errors. Predictive maintenance and quality control systems leverage machine learning to detect defects and optimize performance. In design, AI-driven generative models assist in creating lightweight, aerodynamically efficient, and sustainable vehicle structures. Additionally, AI enhances safety features, facilitates autonomous vehicle development, and accelerates prototyping. This paper explores the transformative role of AI in automotive manufacturing and design, highlighting its benefits, challenges, and future prospects.

**Keywords:** Artificial Intelligence, automotive, design, Sustainability, Smart Manufacturing

## I. INTRODUCTION

Artificial Intelligence (AI) is transforming the automotive industry, revolutionizing both manufacturing and design processes. From optimizing production lines with predictive maintenance and robotics to enhancing vehicle design through generative algorithms and virtual simulations, AI is driving efficiency, innovation, and cost reduction. Automakers are leveraging AI-powered systems to improve quality control, automate repetitive tasks, and accelerate the development of next-generation vehicles. Additionally, AI-driven design tools enable engineers to create more aerodynamic, lightweight, and sustainable vehicles. As the automotive industry moves toward smarter, more autonomous solutions, AI continues to play a pivotal role in shaping the future of mobility.

## II. CONTEXT OF THE STUDY

The automotive industry is undergoing a significant transformation driven by the rapid advancement of Artificial Intelligence (AI). AI-powered technologies are increasingly being integrated into various aspects of vehicle production, from design conceptualization to manufacturing automation. This study explores the role of AI in reshaping the automotive sector, enhancing efficiency, reducing costs, and fostering innovation in vehicle design and production.

## III. INDUSTRY BACKGROUND

Traditionally, automotive manufacturing has relied on human expertise and mechanical automation. However, the rise of AI-driven systems, such as machine learning, computer vision, and robotics, has revolutionized production lines. Companies are investing in AI to streamline operations, improve precision, and predict maintenance needs.



Figure 1: Human Expertise



Figure 2: AI – Driven Systems



#### IV. TECHNOLOGICAL ADVANCEMENTS

AI applications in automotive design include generative design algorithms that optimize vehicle aerodynamics and performance. AI-driven simulation tools enable engineers to test prototypes virtually, reducing the reliance on physical prototypes. Additionally, AI-powered predictive analytics help manufacturers anticipate equipment failures and optimize supply chains.



Figure 3: AI for designing and Virtual simulations

#### V. RELEVANCE AND JUSTIFICATION

With increasing consumer demand for smarter, safer, and more sustainable vehicles, AI plays a crucial role in advancing automotive innovation. Self-driving technology, predictive maintenance, and AI-assisted quality control are reshaping how cars are built and designed. This study aims to analyze the impact of AI in these areas and its implications for the future of the automotive industry.

#### VI. APPLICATIONS OF ARTIFICIAL INTELLIGENCE IN AUTOMOTIVE DESIGN

Artificial Intelligence (AI) is revolutionizing the automotive design industry by improving efficiency, enhancing safety, and enabling innovative vehicle designs. Here are some key applications of AI in automotive design:

##### A. Generative Design & Optimization

AI-driven generative design uses algorithms to create optimized vehicle structures, reducing weight while maintaining strength. Engineers input design constraints, and AI suggests multiple optimized design alternatives.

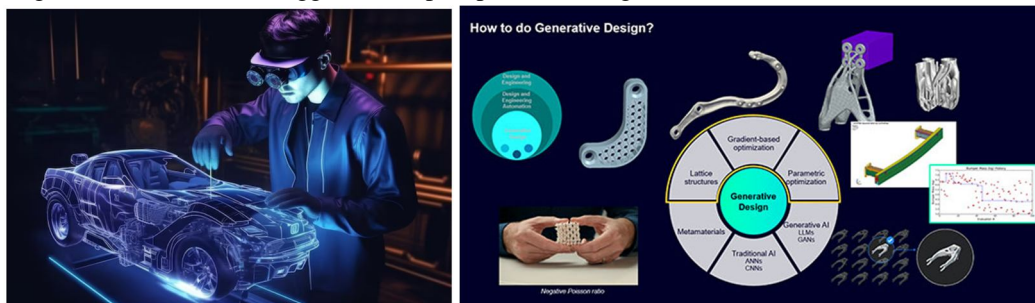


Figure 4: AI-Driven generative design

##### B. Aerodynamics & Performance Enhancement

AI-powered simulations improve vehicle aerodynamics by analyzing airflow and suggesting shape modifications. Reduces drag, increases fuel efficiency, and enhances overall performance.

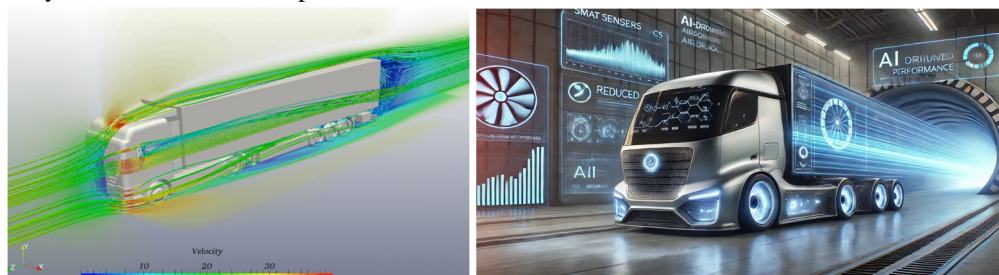


Figure 5: AI-driven simulations

### C. Material Selection & Sustainability

AI helps identify lightweight and durable materials to improve fuel efficiency and reduce emissions.

AI-driven predictive analysis ensures materials are cost-effective and sustainable.

### D. Autonomous Vehicle Design

AI assists in designing and testing self-driving car systems, including sensor placement and integration.

Simulations help refine autonomous driving algorithms before real-world testing.

### E. Virtual Prototyping & Crash Simulations

AI speeds up crash testing through virtual simulations, reducing reliance on physical crash tests.

Predicts vehicle behavior under different impact scenarios, improving safety designs.

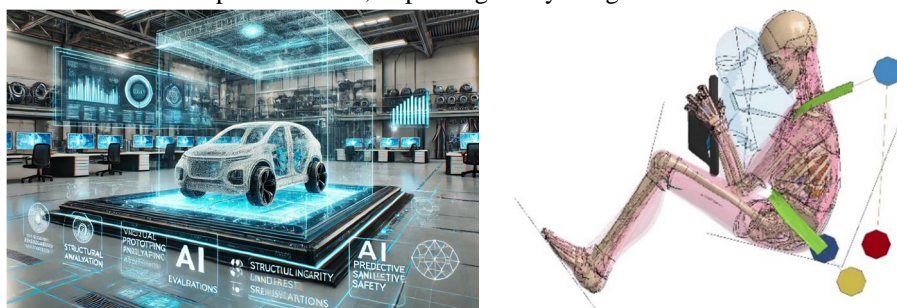


Figure 6: AI driven Virtual Prototyping & Crash Simulations

### F. AI in User-Centric Interior Design

AI enhances ergonomic designs by analyzing human factors, improving comfort and accessibility.

Personalized in-car AI assistants adjust seating, climate, and entertainment preferences.



Figure 7: AI-Driven ergonomic designs

### G. Smart Manufacturing & Quality Control

AI-powered robots assist in assembling vehicle parts with high precision.

AI-based quality control systems detect defects in real-time, reducing production errors.

### H. Predictive Maintenance & Lifecycle Optimization

AI predicts potential failures in automotive components, leading to proactive maintenance.

Extends the lifespan of vehicles and enhances reliability.



Figure 8: AI-Driven Proactive maintenance.

### I. AI in Electric Vehicle (EV) Design

Optimizes battery placement, efficiency, and thermal management.

Enhances regenerative braking and energy efficiency through AI-driven algorithms.



Figure 9:AI- Driven Electric Vehicle Design

### J. Human-Machine Interface (HMI) & Infotainment Systems

AI-powered voice assistants and gesture controls improve driver interaction.

Adaptive interfaces adjust based on driver behavior and preferences.

## VII. ARTIFICIAL INTELLIGENCE IN VEHICLE STYLING AND AESTHETICS

Artificial Intelligence (AI) is revolutionizing vehicle styling and aesthetics by enhancing design processes, optimizing aerodynamics, and personalizing user experiences. Here's how AI is making an impact in this field:

### A. AI in Concept and Design Development

**Generative Design:** AI-powered tools, like generative adversarial networks (GANs) and deep learning models, help designers explore multiple design variations quickly.

**Automated Sketching & Rendering:** AI converts rough sketches into high-quality 3D models, speeding up the ideation process.

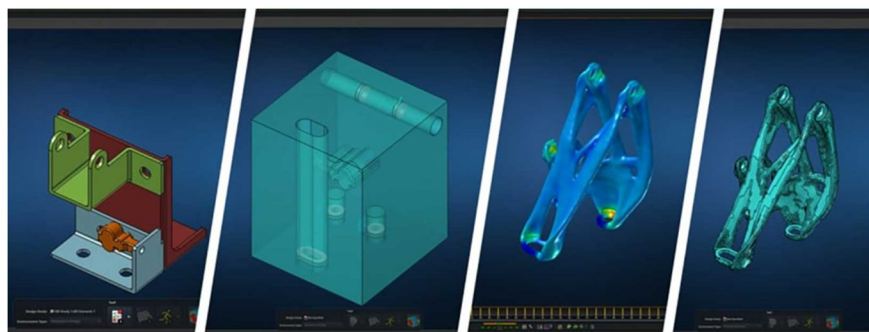


Figure 10:AI- Driven Generative Design

**Style Prediction & Trend Analysis:** Machine learning analyzes past and current design trends to predict future styling preferences.

### B. AI-Driven Aesthetic Enhancements

**Surface Refinement & Proportions:** AI refines vehicle body contours for better aesthetics and aerodynamics.

**Lighting & Color Optimization:** AI suggests optimal color schemes and lighting placements based on brand identity and market trends.

### C. AI in Personalization & Customization

**User-Specific Design Adaptations:** AI tailors vehicle interiors and exteriors based on individual preferences, offering customizable dashboards, ambient lighting, and exterior styling.

**AI-Generated Trim and Material Choices:** AI suggests fabric, textures, and materials that align with sustainability goals and user preferences.



#### D. AI in Aerodynamic and Performance Optimization

Virtual Wind Tunnel Testing: AI simulates airflow over different vehicle designs to improve efficiency and aesthetics simultaneously.



Figure 11: AI-Driven Virtual Wind Tunnel Testing

Smart Materials & Shape Adaptation: AI-assisted materials can adjust vehicle surfaces dynamically for better aerodynamics and visual appeal.

#### E. AI in Smart Manufacturing & 3D Printing

AI-Assisted Prototyping: AI optimizes 3D printing for faster, more precise, and cost-effective manufacturing of concept models.

AI in Quality Control: AI-powered visual inspection ensures high aesthetic and functional standards during production.

#### F. AI in Human-Centered Design

Emotion Recognition in Design: AI analyzes user emotions to suggest styling cues that evoke desired feelings (e.g., aggressive, sporty, luxurious).

Enhanced Human-Machine Interaction: AI-driven voice assistants and smart displays offer personalized experiences, enhancing the car's aesthetic and usability.



Figure 12: AI-Driven Human-Centered Design

#### G. Future Prospects

AI will continue to push the boundaries of vehicle styling by integrating real-time user feedback, enhancing sustainable design practices, and leveraging augmented reality (AR) for design visualization.

### VIII. ARTIFICIAL INTELLIGENCE VEHICLE PERFORMANCE OPTIMIZATION

Artificial intelligence (AI) is revolutionizing vehicle performance optimization by enhancing efficiency, safety, and overall driving experience. Here are some keyways AI is applied in this field:

#### A. Predictive Maintenance

AI-powered predictive analytics help detect potential failures before they occur by analyzing sensor data from the vehicle. This reduces downtime and maintenance costs.



Figure 13: AI-Driven Predictive Maintenance

#### B. Fuel Efficiency & Energy Management

AI optimizes fuel consumption by analyzing driving patterns, traffic conditions, and engine performance. In electric vehicles (EVs), AI helps manage battery life and charging strategies.



Figure 14: AI-Driven Energy Management

#### C. Advanced Driver Assistance Systems (ADAS)

AI improves safety through systems like adaptive cruise control, lane-keeping assist, and collision avoidance. Machine learning (ML) enables these systems to adapt to different driving conditions.

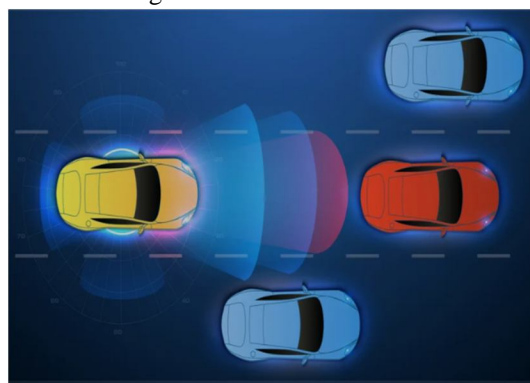


Figure 15: ADAS

#### D. Aerodynamics & Structural Design

AI-driven simulations optimize vehicle aerodynamics and structural components to reduce drag and enhance stability, leading to better performance and efficiency.

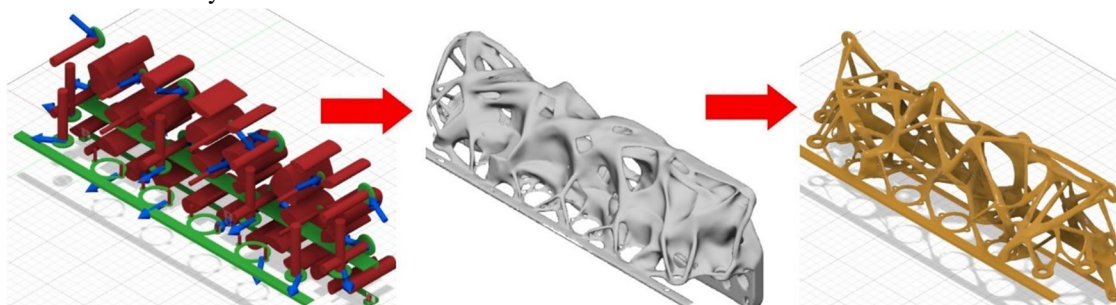


Figure 16: AI-driven Structural Design

#### E. Powertrain Optimization

AI fine-tunes engine parameters for better power output and efficiency. It helps in hybrid and electric powertrains by dynamically adjusting power distribution.

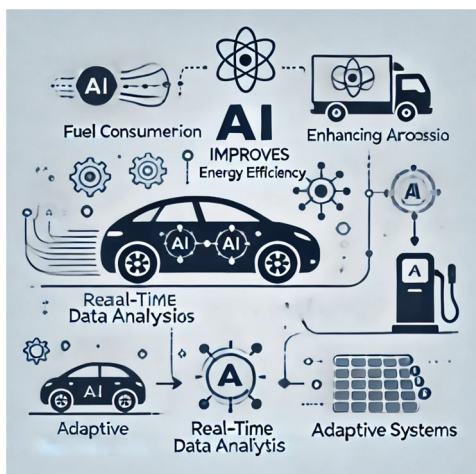


Figure 17: AI-Enhanced Powertrain Optimization

#### F. Autonomous & Semi-Autonomous Driving

AI enables self-driving features through computer vision, deep learning, and sensor fusion. Vehicles can make real-time decisions to improve safety and efficiency.

#### G. AI-Enhanced Navigation & Route Planning

AI-based navigation systems optimize routes based on real-time traffic, weather conditions, and historical data to improve travel efficiency.

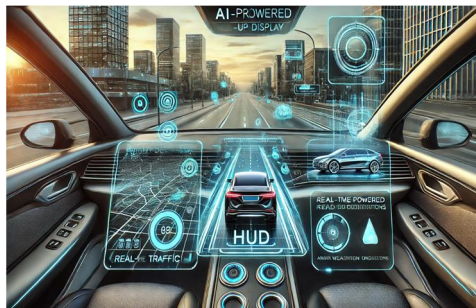


Figure 18: AI-Enhanced Navigation & Route Planning



## IX. ARTIFICIAL INTELLIGENCE IN SAFETY AND CRASH TESTING

Artificial Intelligence (AI) is revolutionizing safety and crash testing in the automotive and transportation industries. It enhances the accuracy, efficiency, and predictive capabilities of crash simulations and safety assessments. Here's how AI is being applied in this field:

### A. Crash Simulations & Predictive Modeling

AI-powered simulations can predict crash outcomes by analyzing vast amounts of real-world and experimental data.

Machine learning (ML) models can refine crash test dummies' responses and improve injury prediction accuracy.

AI reduces the need for physical crash tests by enabling digital twin technology, saving time and costs.



Figure 19: AI-Driven safety testing

### B. Autonomous Vehicle Safety Testing

AI is used to test and validate autonomous vehicle (AV) systems under various conditions.

Simulated environments train AVs to respond to hazards, pedestrians, and other vehicles.

AI-powered scenario generation helps create rare but critical crash situations.

### C. Real-Time Safety Monitoring & Risk Assessment

AI processes sensor data (LIDAR, radar, cameras) to detect potential hazards in real-time.

Predictive AI models assess driver behavior, fatigue, and distraction to prevent crashes before they happen.

Connected vehicle technology allows AI systems to share safety data across a network.



Figure 20: AI-Driven Safety Monitoring

### D. Crash Test Data Analysis & Optimization

AI enhances traditional crash test analysis by detecting patterns in injury and impact data.

ML algorithms optimize vehicle design for crashworthiness by analyzing materials, structures, and impact dynamics.

AI refines safety features like airbags, crumple zones, and seatbelt tensioning systems.

### E. Human Injury Prediction & Biomechanics

AI models simulate human body responses in crashes more accurately than traditional methods.

AI-driven virtual crash test dummies (finite element models) improve injury risk assessment.

Medical AI applications help predict post-crash injury outcomes for better emergency response.

### 1. Regulatory Compliance & Crash Test Automation

AI automates compliance testing to meet global safety regulations. AI-based robotic systems execute precise and repeatable crash tests.

Automated reporting streamlines regulatory documentation and certification.

Future of AI in Safety & Crash Testing

Integration with 5G and IoT for real-time safety alerts.

Enhanced AI-augmented crash dummy models for more accurate testing.

Use of quantum computing for ultra-fast crash simulations.



Figure 21: Regulatory Compliance

## X. ARTIFICIAL INTELLIGENCE IN USER EXPERIENCE AND HUMAN MACHINE INTERACTION

Artificial Intelligence (AI) in Human-Machine Interaction (HMI) is transforming how humans engage with technology. HMI refers to the ways in which humans communicate and interact with machines, including computers, robots, and other devices. AI enhances this interaction by making machines more responsive, intuitive, and capable of understanding human behavior.

### A. Few keyways AI impacts HMI

- 1) Natural Language Processing (NLP): AI enables machines to understand, interpret, and respond to human language. Virtual assistants like Siri, Alexa, and chatbots are prime examples. Through NLP, these systems can process speech or text input and provide meaningful responses, making communication feel more human-like.

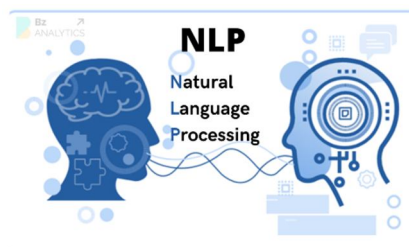


Figure 22: HMI

- 2) Computer Vision: AI-powered systems can see and interpret the world through cameras and sensors, allowing for tasks like facial recognition, object detection, and gesture control. This makes it possible for machines to respond to visual cues and interact with humans in a more dynamic way.
- 3) Emotion Recognition: AI can be trained to detect human emotions based on voice tone, facial expressions, and body language. This ability allows machines to adapt their responses depending on the user's emotional state, creating a more empathetic interaction.



Figure 23: Emotion Recognition

- 4) **Autonomous Systems:** AI enables machines, like self-driving cars or robots, to interact with their environment without direct human control. These systems rely on AI to make real-time decisions, navigate obstacles, and optimize tasks, offering a seamless human-machine collaboration.
- 5) **Personalization:** Through machine learning algorithms, AI can adapt to individual user preferences, behavior patterns, and needs, enhancing the user experience. This can range from content recommendations on platforms like Netflix to more personalized health recommendations in fitness apps.
- 6) **Predictive Interaction:** AI can predict human needs and behaviors, offering proactive suggestions or interventions. For example, smart home devices might learn your routines and automatically adjust lighting or temperature for comfort.



Figure 24: Predictive Interaction

- 7) **Haptic Feedback:** AI is used in conjunction with touch-sensitive technology to provide haptic feedback, allowing users to “feel” virtual interactions. This is seen in gaming, virtual reality, and remote-controlled robotic systems.

AI in HMI is revolutionizing many industries, including healthcare (e.g., virtual doctors and robotic surgery), customer service (AI-powered chatbots and virtual assistants), and entertainment (e.g., interactive games and VR experiences).

The integration of AI into HMI not only improves user experience but also paves the way for new opportunities in automation, accessibility, and even human augmentation

## XI. CHALLENGES AND LIMITATIONS OF ARTIFICIAL INTELLIGENCE IN AUTOMOTIVE DESIGN

Artificial Intelligence (AI) is transforming the automotive design process, but it faces several challenges and limitations. Here are some key factors:



Figure 25: Limitations

### A. Data Dependency

AI models rely heavily on large volumes of high-quality data to function effectively. In automotive design, gathering such data can be challenging, especially in areas like user behavior, real-world driving conditions, and vehicle performance in various environments. Additionally, ensuring that data is representative, accurate, and diverse is difficult, which can limit AI's ability to generate optimal designs.



### *B. Complexity of Automotive Design*

Automotive design involves numerous interconnected systems, such as aerodynamics, material science, safety standards, electrical systems, and human factors. AI algorithms may struggle to account for all these variables simultaneously, leading to suboptimal designs or unexpected results. The complexity of balancing these aspects while maintaining regulatory compliance is a significant challenge for AI.

### *C. Integration with Traditional Design Tools*

Automotive design has been traditionally based on tools like CAD (Computer-Aided Design) and CAM (Computer-Aided Manufacturing). Integrating AI with these tools and ensuring smooth interaction between AI-driven and traditional methods can be difficult. AI-based solutions may not always work seamlessly with legacy systems, leading to a longer implementation time and potential resistance from established teams.

### *D. Interpretability of AI Decisions*

AI algorithms, particularly deep learning models, can often act as a "black box," meaning their decision-making processes are not easily understood or interpretable by humans. This can be a major drawback in automotive design, where engineers and designers need to justify their design choices for safety, regulatory, or consumer satisfaction reasons. Lack of transparency can be a barrier to wider adoption in critical areas like safety design and autonomous systems.

### *E. Ethical and Legal Concerns*

AI's use in automotive design, especially in areas like autonomous driving, raises ethical and legal issues. How should AI systems make decisions in emergency situations? What if a design flaw is caused by an AI algorithm? These unresolved questions create challenges in adopting AI for certain aspects of vehicle development, especially when public safety is involved.

### *F. Limited Creativity*

While AI can optimize existing designs and explore various possibilities within predefined constraints, it still struggles with true creative design thinking. The human ability to innovate and think outside the box, especially when it comes to aesthetic or revolutionary design elements, remains a challenge for AI systems.

### *G. Regulatory and Safety Standards*

Automotive design is highly regulated, with strict safety standards that must be met. AI must be programmed to ensure that designs comply with all safety regulations and pass rigorous crash tests. Achieving this level of precision and validation with AI models, especially when designing new components or systems, can be difficult.

### *H. Adaptability and Flexibility*

AI systems can be quite rigid, especially when dealing with rapid changes in the market, consumer preferences, or unexpected technological advancements. The automotive industry is constantly evolving, and AI must be adaptable to these changes. Building AI systems that can quickly pivot and evolve in response to such shifts remains a challenge.

### *I. Cost of Implementation*

Developing, training, and implementing AI solutions in automotive design requires significant investment. The cost of acquiring large datasets, setting up specialized hardware, and developing customized AI models can be prohibitively expensive, especially for smaller manufacturers or startups.

### *J. Human-AI Collaboration*

AI is often seen as a tool to augment human designers, but the dynamics of human-AI collaboration are still evolving. There can be a gap in trust between human designers and AI systems, with some designers hesitant to rely too heavily on AI. Establishing effective communication and collaboration between humans and machines is a challenge that needs to be overcome for AI to become a truly integrated part of the design process.

## XII. FUTURE TRENDS AND INNOVATIONS IN ARTIFICIAL INTELLIGENCE AND AUTOMOTIVE DESIGN

The intersection of artificial intelligence (AI) and automotive design is transforming the future of transportation, leading to more efficient, safer, and innovative vehicles. Here are some key trends and innovations to look out for:

### A. Autonomous Vehicles (Self-Driving Cars)

**AI and Machine Learning for Navigation:** AI systems are being developed to enable vehicles to drive themselves with minimal or no human intervention. Advances in computer vision, sensor fusion, and decision-making algorithms will improve the accuracy and safety of autonomous driving.



Figure 26: Self-Driving Cars

**Predictive Safety Systems:** AI will enhance vehicle safety by predicting potential hazards in real-time and taking corrective actions. These systems will evolve beyond traditional collision avoidance to consider complex real-world environments.

### B. AI-Driven Vehicle Design

**Generative Design:** AI-powered tools are helping designers create more efficient and sustainable vehicle structures. These tools use algorithms to optimize designs based on performance criteria such as weight, strength, and aerodynamics.



Figure 27: Generative Design

**Personalized User Experience:** AI will continue to improve in creating personalized in-car experiences, including tailored infotainment systems, adjustable driving modes, and climate control, all based on real-time analysis of the driver's behavior, preferences, and even mood.

### C. Connected Vehicles (V2X)

**Vehicle-to-Everything (V2X) Communication:** AI-powered V2X systems enable vehicles to communicate with each other and infrastructure (traffic lights, road signs, etc.). This allows for smoother traffic flow, accident prevention, and optimized route planning.

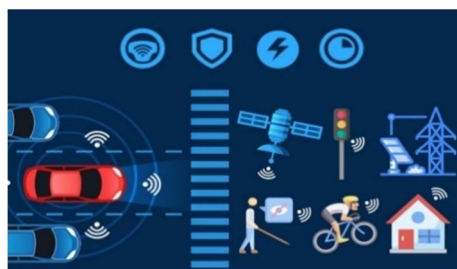


Figure 28: Connected Vehicles

**5G Integration:** With the rollout of 5G networks, cars will be able to process and transmit data more quickly, improving the responsiveness of autonomous systems, infotainment, and safety features.

#### D. AI in Manufacturing and Production

**Smart Manufacturing:** AI-powered robots and machines are improving vehicle manufacturing processes by enhancing precision, efficiency, and safety. These systems can self-monitor and adjust operations to ensure quality control and reduce waste.

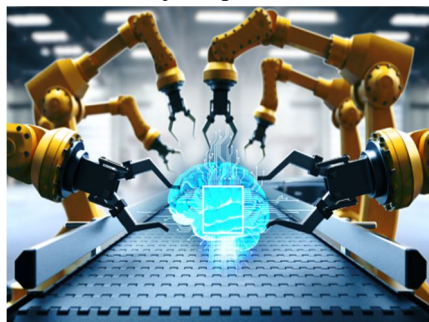


Figure 29: Smart Manufacturing

**Supply Chain Optimization:** AI algorithms can predict demand and optimize the supply chain to ensure timely delivery of parts, reducing costs and inefficiencies.



Figure 30: Supply Chain Optimization

#### E. Electric and Sustainable Vehicles

**AI for Battery Management:** AI will optimize the performance of electric vehicle (EV) batteries, improving their lifespan, charging speed, and energy efficiency.



Figure 31: AI - Battery Management

**Sustainability in Design:** AI is being used to design more sustainable and eco-friendly vehicles, not only in terms of emissions but also in the materials used. Advanced AI models can help identify new ways to recycle vehicle components, reduce waste, and improve energy efficiency.



#### F. Augmented Reality (AR) and AI Integration

**AR Dashboards and Navigation:** AI-powered augmented reality systems will revolutionize in-car dashboards by providing drivers with contextual information such as navigation instructions, real-time hazard alerts, and vehicle performance data.

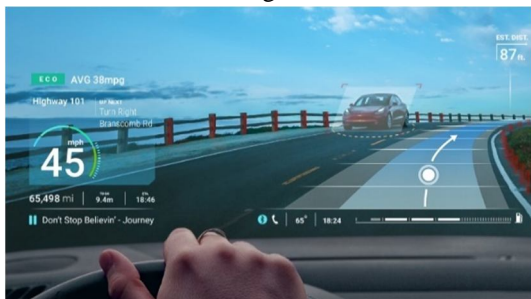


Figure 32: AI Driven – Navigation

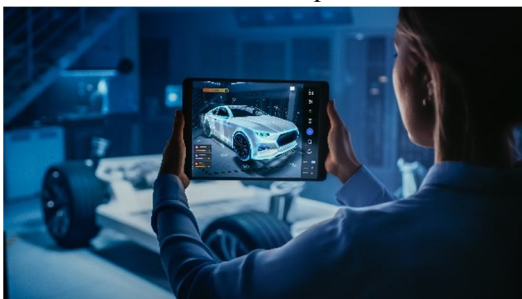


Figure 33: Augmented Reality

**Maintenance and Repairs:** AI and AR can assist with vehicle maintenance by overlaying step-by-step instructions and diagnostics onto a technician's view of the car, speeding up repairs and reducing human error.

#### G. Human-Machine Interaction (HMI)

**Natural Language Processing (NLP) Systems:** Future vehicles will have more intuitive voice-activated assistants, allowing drivers and passengers to interact seamlessly with their car. NLP systems will improve by understanding more complex commands, emotions, and even context.

**Emotion Recognition:** AI systems will be able to analyze facial expressions, voice tone, and body language to understand the emotional state of the driver and passengers. This will enhance safety, driver well-being, and the overall experience.

#### H. AI in Traffic Management

**Smart Traffic Systems:** AI will help manage traffic flow in cities by using data from sensors, cameras, and GPS to optimize traffic light timings, reduce congestion, and predict traffic patterns.

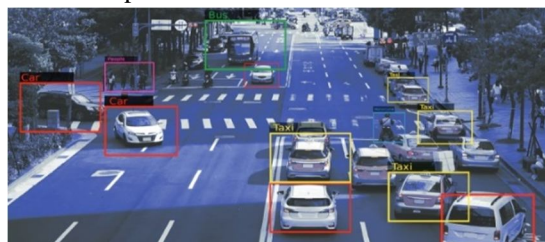


Figure 34: AI - Traffic Management

**Fleet Management:** AI will optimize fleets of autonomous vehicles, improving scheduling, maintenance, and routing to reduce costs and improve efficiency in areas like ridesharing and delivery.

#### I. Ethical AI in Automotive Design

**Bias and Safety Concerns:** As AI plays a larger role in vehicle design and driving, there will be increased scrutiny on how algorithms make decisions, especially when it comes to safety. Automakers and developers will need to ensure that AI systems are designed ethically and do not perpetuate biases.

**Regulation and Standards:** Governments and regulatory bodies will create frameworks to ensure that AI in automotive systems meets safety, privacy, and accountability standards.

#### J. AI for Predictive Maintenance

**Predictive Analytics:** AI-powered systems will monitor vehicle components in real-time and predict when maintenance is needed. This will allow owners to fix issues before they lead to breakdowns, improving vehicle longevity and reducing overall maintenance costs.



The convergence of AI and automotive design is reshaping how vehicles are built, driven, and experienced. These innovations are not only focused on enhancing performance but also improving safety, sustainability, and the overall driving experience. As AI continues to evolve, its role in the automotive industry will become more integral, driving both technological and societal change.

### **XIII. CONCLUSION**

AI is not only revolutionizing the way vehicles are manufactured but is also driving the evolution of automotive design. As AI technologies continue to advance, their role in the industry will expand, leading to further innovations that enhance vehicle performance, safety, and sustainability. However, this progress must be balanced with considerations regarding job displacement, ethical concerns, and data privacy to ensure the responsible development and integration of AI in the automotive sector can contribute significantly to global environmental goals while meeting the demands of a more eco-conscious market.

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