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Faculty of Business Economics

Master of Management

Master's thesis

Artificial Intelligence In The Automotive Industry: Whats Next?

Petra Yaacoub

Thesis presented in fulfillment of the requirements for the degree of Master of Management, specialization Strategy and Innovation Management

SUPERVISOR :

Prof. dr. Jean-Pierre SEGERS

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Acknowledgment

Completing this Master's thesis has been an enriching journey, marked by growth, challenges, and invaluable support from numerous individuals whose motivation and guidance made it possible. I want to express my genuine appreciation to everyone who has contributed to my journey towards completing this Master's thesis.

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Petra Yaacoub

Executive Summary

1. Research Purpose

The automotive industry is facing a significant transformation which is fueled by the integration of Artificial Intelligence (AI); this transformation promises to revolutionize innovation processes and reshape the future of mobility. This research examines how AI and automotive innovation intersect together to help automotive companies strategically exploit AI-driven approaches and hence overcome the challenges they face while capturing new opportunities for upgrading innovation. By extensively exploring AI's potential influence and strategic utilization, this study draws attention to the transformative impact that AI can have specifically on innovation initiatives and approaches within the automotive sector. Several companies are ahead in this revolution and considered to be at the forefront naming Stellantis, Mercedes-Benz, BMW, Microsoft, Volkswagen, Waymo, Ford, and McLaren. The mentioned companies leverage AI to improve overall safety, enhance manufacturing processes, create and develop intelligent vehicle systems, and even revolutionize top sports like Formula One. Certainly, the automotive industry will have a future innovative state which will be marked by the rise of Electric Vehicles (EVs), with Tesla leading innovation in both EVs and autonomous driving technology through its integration of AI, particularly evident in its Autopilot technology.

Big data analytics, predictive modeling, natural language processing (NLP), and generative AI-enabled design tools are just a few of the ways in which AI applications are being utilized in the automotive industry to improve vehicle design, manufacturing processes, and user experience. These applications not only enhance vehicle performance and safety but also enable personalized optimization, innovative design support, and efficient manufacturing processes, ultimately driving efficiency, quality, and competitiveness in the automotive sector. Considering the challenges and opportunities that AI offers in this particular industry, this thesis provides helpful insights for automotive companies seeking to drive and benefit from the evolving landscape and profit from the technological advancements of AI if they were to look at long-term growth and competitive advantage, answering the research question: How can automotive companies exploit AI-driven approaches to overcome key challenges and capture opportunities to upgrade innovation?

2. Research Methodology

This study is a qualitative research where two different questionnaires were created; one for an academic professor to explore on a deeper level the economic relevance of AI and another unified questionnaire addressed to experts in this industry. To collect data for AI in the automotive industry the preferable method was conducting semi-structured interviews. The unified questionnaire was structured into three main parts targeting the main research question and the two sub-questions. In total, seven respondents were interviewed, holding diverse positions including an academic professor, directors, AI/ML developer, CEO, and COO. One of the respondents was from the United States (California) and the rest were all based in Belgium. Various perspectives on how artificial

intelligence can tackle the challenges and support opportunities were provided by these experts who constitute the players in the automotive ecosystem. Due to different geographical locations, all interviews were conducted online except two interviews conducted face-to-face together. Furthermore, all interviews were conducted in English. Additionally, one respondent submitted a written report along with the interview.

3. Findings

After interviewing seven respondents and collecting the data, several significant findings were underlined and further discussed. The findings shed light on the fact that the integration of AI applications into the automotive industry presents both opportunities and challenges. Challenges include cultural differences, regulatory complexities, ethical concerns, data collection from real-world experiments, road and user safety, and who is to blame during an accident. It is safe to say that cultural differences can affect the adoption of AI technologies, while on the other hand, regulations pose some complexities and impede the development and implementation of autonomous vehicles. Because AI algorithms are unpredictable, ethical issues arise and consequently make it difficult to determine blame in accidents. Data collection and safety concerns also pose challenges, along with ethical considerations regarding privacy and bias mitigation.

However, despite these challenges, AI offers numerous benefits to the automotive industry. These benefits are varied and include several aspects such as accelerated decision-making and research processes, enhanced safety through simulation, personalized maintenance, and improved user interaction. AI can transform various aspects of the industry, from self-driving technology to marketing tactics and customer behavior analysis. To evaluate the impact of AI technologies on business outcomes, automotive companies refer to key performance indicators (KPIs); mainly focusing on metrics such as patents, collaboration with universities, customer value, and product integration.

In the future, AI is expected to play an even larger role in the automotive industry, moving from managing specific tasks to overseeing entire workflows. This will lead to safer, more efficient, and more intelligent vehicles, ultimately revolutionizing transportation and vehicle operation.

In the field of automotive innovation, the effective integration of artificial intelligence (AI) is determined by robust management of data quality and availability. This necessitates careful procedures to ensure the accuracy, reliability, and accessibility of the vast amounts of data generated by sensors, cameras, and other sources. Some strategies could be used to ensure robust management by the utilization of reliable and safe hardware for data collection, preprocessing pipelines to address noise and occlusions, and cloud-based solutions for efficient data storage and retrieval.

It is crucial to address the bias in AI datasets since it poses a critical concern for companies and more specifically in autonomous vehicles where skewed data could lead to incorrect localization,

mapping, and decision-making. Hence, less safety. To reduce bias in AI development, automotive companies must rely on regulatory measures, technical solutions, and proactive monitoring. Moreover, managing privacy and security concerns surrounding AI applications in the automotive setting demands strategies such as user consent, data anonymization, and the adoption of privacy-preserving technologies like federated machine learning and data clean rooms.

AI technologies offer faster data analysis which in turn will alter traditional data analysis procedures, enabling swift extraction of insights and patterns from extensive datasets. Automotive companies must seek a successful implementation of AI by strategically employing core competencies, making use of well-structured business models, and initiatives to attract and retain AI talent while upskilling employees and fostering diversity. Collaboration and partnerships between government, academic institutions, and automotive organizations are crucial for closing the AI-talent gap and fostering innovation, competitiveness, and efficiency within the automotive industry.

4. Critical Considerations and Recommendations

Considerable key recommendations emerge to decipher the full potential of AI in the automotive industry. First, addressing the shortage of AI talent through offering extensive training programs and workshops is key for promoting innovation and maintaining industry leadership. Secondly, companies must retain skilled workers given the competitive landscape by adopting a comprehensive and careful strategy, deepening collaboration, empathy, and creativity alongside competitive compensation. Additionally, research and development (R&D) is proven to play a crucial role in enhancing innovation. Therefore, it is important to invest in R&D to drive the next wave of automotive innovation.

Furthermore, fostering collaborative relationships within the automotive ecosystem players such as suppliers, customers, government agencies, and academic institutions is vital. Joint R&D initiatives can elevate the integration of AI technologies to the next level and ensure scalability for large-scale manufacturing by thoroughly merging collective skills and resources. Moreover, taking advantage of a variety of AI techniques, including simulation tools and big data analytics, can enhance notable aspects of the automotive industry, from supply chain management to vehicle development.

Additionally, prioritizing the development of human-AI interface systems, particularly for semi-autonomous vehicles, is pivotal. By focusing on improving interaction between humans and AI systems, automotive companies can ensure user acceptance, safety, and usefulness as the industry transitions toward semi-autonomous driving technology. This entails investing in user-centered design approaches and providing personalized interaction mechanisms tailored to individual preferences and driving styles. Overall, these recommendations aim to enhance the integration of AI in the automotive sector and drive innovation while ensuring user satisfaction and safety.

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Opening Quotation

Coming together is the beginning.

Keeping together is progress.

Working together is success.

— Henry Ford

Motivation

Since my earliest admiration for automobiles and Formula One racing, I have been captivated by the intersection of technology and automotive innovation. This passion has naturally extended to the rapidly growing field of artificial intelligence (AI), which promises to revolutionize every aspect of the automotive industry. As a Formula One fan, I have witnessed firsthand the relentless pursuit of performance through cutting-edge technologies, and this has inspired me to delve deeper into the transformative potential of AI within the automotive sector.

Choosing to explore the integration of AI in the automotive industry for my thesis was an obvious decision for me. It represents the convergence of my interests in automotive engineering and AI technologies, offering a platform to delve into a field that has fascinated me for years. Furthermore, the opportunity to undertake this research at Hasselt University provides access to invaluable resources and expertise, enabling me to gain a comprehensive understanding of this rapidly evolving domain.

Through my research, I aim to unravel the intricate ways in which AI is reshaping the automotive landscape. From autonomous vehicles and predictive maintenance to intelligent driver assistance systems, AI is poised to redefine the way we interact with automobiles. By examining the latest advancements, challenges, and prospects in this field, I aspire to contribute to the collective knowledge base while elevating my expertise in both automotive innovation and AI.

Moreover, by engaging with experts and industry professionals, I seek to gain insights into real-world applications and explore potential avenues for collaboration and innovation. By fostering conversations and sharing expertise, I hope to contribute to the ongoing dialogue surrounding the integration of AI in the automotive sector and pave the way for future advancements in this dynamic field.

In essence, my motivation for choosing this topic stems from a genuine passion for automotive, AI technologies, and the continuous pursuit of innovation. Through rigorous research and exploration, I aim to deepen my understanding of this fascinating intersection while contributing to the advancement of knowledge in the field. Ultimately, I am driven by the opportunity to be at the forefront of a transformative industry, where the possibilities are as limitless as the open road.

1. Problem Statement

The automotive industry faces notable challenges in steering the complexities of innovation while capturing opportunities made possible by artificial intelligence-driven approaches. Having in mind that AI can ultimately transform the future of mobility, this research explains Innovation, Innovation in the Automotive Industry, Artificial Intelligence, AI in the Automotive Industry, the Automotive Ecosystem, the Old and Future State of the Automotive Industry, AI-driven Approaches, Leadership in the Age of AI, Challenges and Opportunities, and Economic Relevance. Given the rapidly evolving industry, automotive companies strive to stay ahead of the competition. The role of artificial intelligence is not limited to but goes by overcoming challenges and capitalizing on emerging developments. Therefore, it is highly important to understand its role in this specific industry. The integration of AI in the automotive sector offers a promising strategy for tackling these barriers by enhancing driver safety, optimizing sustainability for green innovation, creating new job opportunities, and increasing automation and efficiency. However, the effective deployment of AI in the automotive industry requires a coordinated attempt that acknowledges the unique specifications of individual vehicles. Thus, the focus should be on the multiple AI-driven approaches that are efficient, effective, and safe in designing autonomous vehicles which pose a key challenge to automotive companies to upgrade innovation. Moreover, according to Porsche Consulting, the automotive industry is currently shifting toward electrical vehicles, pushed by technological advancements, signifying a dramatic change in perspective. Surprisingly, some learnings from the automotive industry can be effectively adapted to the pharmaceutical industry. This shows a great example of how the automotive industry can have an impact on society by driving innovation and cross-industry learning (Porsche Consulting).

Central to this inquiry are questions surrounding the influence of data quality and availability of AI-driven approaches such as AI-driven predictive analytics, machine learning algorithms, natural language processing, and more (Atalay et al., 2013). The quality and availability of data can impact the effectiveness and success of AI within automotive companies (Smith, 2020). High-quality data sets, serve as the basis of AI algorithms, enabling precise analysis, predictive modeling, and well-informed decision-making (Johnson & Lee, 2018). However, automotive companies often encounter challenges such as data fragmentation, inconsistency, and incompleteness, making AI-driven approaches less successful (Brown & Jones, 2019). Moreover, the diverse array of data sources, such as vehicle sensors, customer feedback, and market trends, presents additional complexities in ensuring relevant data availability (Garcia et al., 2021). Therefore, tackling the distinctions of data quality and availability is of great importance for automotive companies seeking to effectively implement AI-driven approaches in cultivating innovation (Taylor, 2017).

The successful implementation of AI requires a range of skills and expertise. Key competencies needed encompass proficiency in data analysis, programming languages, and specialized domain knowledge in automotive engineering and innovation management (Morris et al., 2020). However, the shortage of AI talent presents a considerable challenge for organizations seeking to use AI (Manyika et al., 2018). Automotive companies often struggle to recruit, retain,

and develop individuals with the necessary skills and expertise to lead AI-driven innovation projects (Hofmann et al., 2022). Closing this talent gap necessitates strategic interventions and planning targeted at improving workforce capabilities including specific training or internship models, educational alliances, and initiatives concentrated on talent development (Batra et al., 2021). Addressing these questions is highly crucial because it not only highlights the ways to exploit AI but also emphasizes the necessity for organizations to shorten the AI-talent gap to realize the full benefits of technological innovation (Peres et al., 2020). The implementation of Industry 4.0 solutions does not solely focus on manufacturing and logistics but extends to areas such as data quality management and innovation management (Stawiarska et al., 2021). Furthermore, in the big data era, science and engineering achievements thoroughly depend on the combination of artificial intelligence and high-performance computing (Huerta et al., 2020).

Another significant advantage of using AI in autonomous vehicles is the likelihood of improving road safety, reducing car accidents, and optimizing traffic management. Artificial intelligence empowers autonomous vehicles to make split-second decisions based on real-time data and predictive analysis, thereby increasing road safety (Grigorescu et al., 2019). Deep learning methods hold great promise as they enable cars to sense their surroundings, make decisions, and navigate complex situations (Grigorescu et al., 2019). By implementing AI algorithms for identifying and preventing accidents, autonomous cars have the potential to reduce risks caused by traditional human error (Tian et al., 2019).

Nevertheless, this research examines the challenges and opportunities of implementing AI while uncovering how automotive firms can strategically exploit AI-driven solutions to enhance innovation. By examining AI applications from companies, thorough research, and best practices, this research is designed to provide actionable insights for automotive companies to effectively and strategically deploy AI, thereby focusing on long-term growth and competitive advantage in a rapidly evolving industry. The thesis is divided into a Literature Review followed by a Research Methodology then the Findings based on conducted interviews, a Discussion of the findings, a Conclusion, and lastly Recommendations. The interviews will be conducted with various players in the automotive ecosystem. To do this, qualitative analysis will be used in the research.

2. Literature Review

2.1. Introduction

In the constantly changing environment, innovation is gaining a substantial interest attributable to the extensive development and fast growth of technology. With the aim of survival, companies must release novel products and services (Anderson et al., 2014). Firms that fail to embrace and benefit from innovative technologies find themselves at a disadvantage. Consumer and government involvement play a crucial role in driving the innovation process (Townsend et al., 2013). As consumer preferences change, products that were once leading, become outdated with the advancement of technology as well as the generation of new business models by startups (Venkatesh & Davis, 2000). Furthermore, one of the most significant innovations we are facing is Artificial Intelligence (AI). AI is revolutionizing how we interact, work, and live daily (Anifowose, 2021). Professor John McCarthy, one of the founding fathers of Artificial Intelligence, delineated AI as "The science and engineering of making intelligent machines, especially intelligent computer programs" (McCarthy, 2004). AI allows the analysis of vast amounts of raw data to detect patterns and trends. The latter may greatly reduce the time needed to develop and perfect new goods or services by automating processes like idea screening and prototyping (Tekic et al., 2019).

With AI's enormous array of subfields, the automotive industry faces a rapid transformation. AI is the key to a new era of value for the automotive industry (Chai et al., 2021). New competitors such as Tesla and Google make their move into the market influencing traditional automakers to adapt. According to McKinsey (2022), 50 to 60 percent of organizations use at least one AI application in a process or product (Chui et al., 2022). Mercedes-Benz, Toyota, Volkswagen, Tesla, Volvo, Bosch, and several large automotive companies are integrating AI at different levels. Automotive manufacturers are proactively embracing AI-based software development solutions to bring the dream of autonomous vehicles to fruition. This is demonstrated by the creation and development of internal AI frameworks by considerable chip and car manufacturers like Tesla's Full Self-Driving (Tesla, 2023). Furthermore, the widespread implementation of the Automotive Open System Architecture (AUTOSAR) framework by significant automotive manufacturers and electronic device suppliers is evident by the industry's dedication to exploiting software components for autonomous cars (Adaptive platform AUTOSAR, n.d.; Autotechdrive, 2023; Mutschler, 2023). Additionally, BMW has declared the launch of its autonomous iNEXT model, and Toyota plans to create its first driverless car (Home AUTOSAR, n.d., The Future is Now: Continental Innovates Mobility from the Road to the Cloud at CES, 2023).

AI can be applied for various developmental purposes. Considering the latest advancements in AI, new opportunities are emerging aimed at implementing productions more effectively, ethically, and with higher quality (Plorin, 2022). Therefore, reshaping the automotive industry. Even if AI offers several advantages and benefits, it still poses challenges and barriers for every new technology. Those challenges cannot be overlooked, and it is crucial to discuss them. Given the unintended crashes that may arise from autonomous vehicles or using AI in normal vehicles,

automotive AI necessitates a higher level of safety than other consumer segments (Juliussen, 2021). Consider a situation where your car detects your fatigue and assumes control of the wheel. Dustin Tran, a member of Google's AI team stated: "If a self-driving car doesn't know its level of uncertainty, it can make a fatal error, and that can be catastrophic." (Tran, 2019; Tran & Lakshminarayanan, 2015). It is imperative to emphasize research and development (R&D) while focusing on the strategies to create and develop new ideas.

Preceding research studies have explored the significance of AI in the automotive industry given its current prominence. However, they did not tackle how can automotive companies exploit AI-driven approaches to overcome key challenges and capture opportunities to upgrade innovation. In consideration of its extensive potential, AI could completely change the innovation processes within the automotive industry.

This research extensively explores how AI technology can be realizable to enhance innovation, delving into the captivating area where AI meets automotive innovation. It does not only investigate the potential influence of AI in the automotive industry but also explores strategically its utilization in reshaping tomorrow's drive. Therefore, shedding light on how automotive companies can take advantage of AI advancements to drive and capture innovation initiatives. Additionally, addressing the opportunities and challenges associated with the integration of AI along with the future of AI in the rapidly evolving automotive landscape and its potential impact on innovation.

2.2 Innovation

Innovation is considered an organizational competence that plays a pivotal role in companies' achievements and performance since it promotes a culture of competitiveness and successful performance (Lawson & Samson, 2001; Melendez & Dávila, 2022; Bayhan & Korkmaz, 2021). In brief, innovation is the process of converting innovative ideas from a concept to reality, making those ideas achievable. It is considered a critical system for businesses seeking for competitive advantage because when implemented effectively, can lead to new products, services, and solutions (Vzhuk, 2023). However, there is a fundamental difference between invention and innovation. The former refers to the process of creating a novel idea or new concept, while the latter involves turning the creative idea into a market or application (Ṣimṣit et al., 2014). On the other hand, innovation management comes into play by modifying the degree to which newly created technological information is converged into product innovation. Thus, enhancing technological innovation effectiveness (Heij et al., 2019).

Innovation is not confidential. Highly successful organizations do not possess a secret recipe for innovation; instead, they achieve their goals by excelling in one or multiple areas. There is a high correlation between innovation management and an organization's performance, highlighting the impact of innovation management on enterprise outcomes (Kraśnicka et al., 2017). To succeed and gain a competitive advantage, companies must excel in all aspects rather than focusing only on one (Murswieck, 2017). How can we classify a company as an innovative one? Maier (2013) considers

an innovative company one that adopts and welcomes creative ideas and has a positive view on change. In other terms, viewing change as an opportunity to grow rather than a threat (Maier, 2013). Unfortunately, managers still do not possess an accurate or correct definition of innovation. Furthermore, not every manager recognizes the need for innovation in business because they merely follow traditional business approaches. Therefore, without a systematic framework, companies must enhance their adaptive process through innovation to increase demands and performance standards (Maier, 2013).

In summary, innovation management reflects a dynamic process that opens to multiple facets and is vital for every organization. It is an urge for every company to adapt to the rapidly changing environment while driving technological advancements and achieving sustainable success ("Relationship Between Business Sustainability and Management Innovation", 2021; Vitezi & Vitezi, 2014).

2.3 Innovation in the Automotive Industry

Innovation is a key driver of the automotive industry, driving advancements in technology, design, and sustainability. A culture of continuous improvement requires automotive companies to implement innovation strategies. Barachini and Rankl in their empirical research highlight the importance of knowledge management and innovation in the automotive outsourcing industry to foster idea generation and innovation production (Neumann et al., 2011). These findings emphasize the need for a systematic approach to creativity in the automotive sector. In addition, open innovation has received considerable attention in the automotive industry, reflecting a cultural and social shift towards integrating collaborative innovation and external knowledge to promote organizational innovation (Ili et al., 2010).

There are various stages involved in innovation management including idea generation, evaluation, development, and implementation. Following these stages is crucial in effectively utilizing the potential of innovation in the automotive sector. Researchers have identified key partnerships that the automotive industry used to stimulate idea generation and innovation, especially customer engagement and collaboration, competitors, and suppliers (Massis et al., 2012). Furthermore, Winter and Lasch (2016), have shed light on the supplier innovation evaluation process, focusing on the need for structured criteria and methods to evaluate and select novel ideas from suppliers. Additionally, AI is also acknowledged for its contribution to innovation and knowledge management. Liu (2022) highlighted how AI may drive collaboration in knowledge and innovation management, stressing how important it is for promoting innovation spillover and the learning of new skills and expertise. The evolution of innovative designs has notably affected the concept of design phases in this sector, highlighting the industry’s emphasis on using novel technologies to enhance innovation and value creation (Paker, 2022). Neumann et al. (2019), have highlighted the engagement of startups in technological strategy planning to increase innovation in the automotive industry. This underscores the significance of diversification and external stakeholder integration in innovation management.

2.4 Artificial Intelligence

Artificial Intelligence abbreviated as (AI) is a broad term and is described as the capacity of a digital computer or computer-controlled robot aiming to mimic, expand, and enhance human intelligence such as visual processing, speech understanding, decision-making, and language translation (Joiner, 2018). AI dates back many years and was first introduced in the 1950s by John McCarthy as previously mentioned. Several notable people had an impact on the development of this field alongside McCarthy including Alan Turin and Marvin Minsky. The famous Turin Test was created by Alan Turin and is used to assess and evaluate a machine's intelligence. Marvin Minsky made a substantial impact in advancing AI research and had significant contributions (Toosi et al., 2021). AI refers to the machines' ability to undertake tasks that typically require human intelligence. The incorporation of human expertise into AI systems has also been remarkable, termed informed artificial intelligence, intending to enhance complex problem-solving tasks (Johnson et al., 2022). AI consists of several aspects such as understanding and analyzing the intelligent behavior of machines, and most importantly creating AI algorithms that enable robots to absorb a vast amount of data aiding in faster analysis. It also detects patterns and trends and autonomously makes informed decisions. The fascinating aspect of AI is that machines can learn from experience quickly and adapt to new inputs. This could not be done easily by humans. To identify meaningful and useful patterns, AI algorithms need a set of reliable data. Data can be presented in multiple forms including digital data, satellite imagery, visual content, and several more (West et al., 2018).

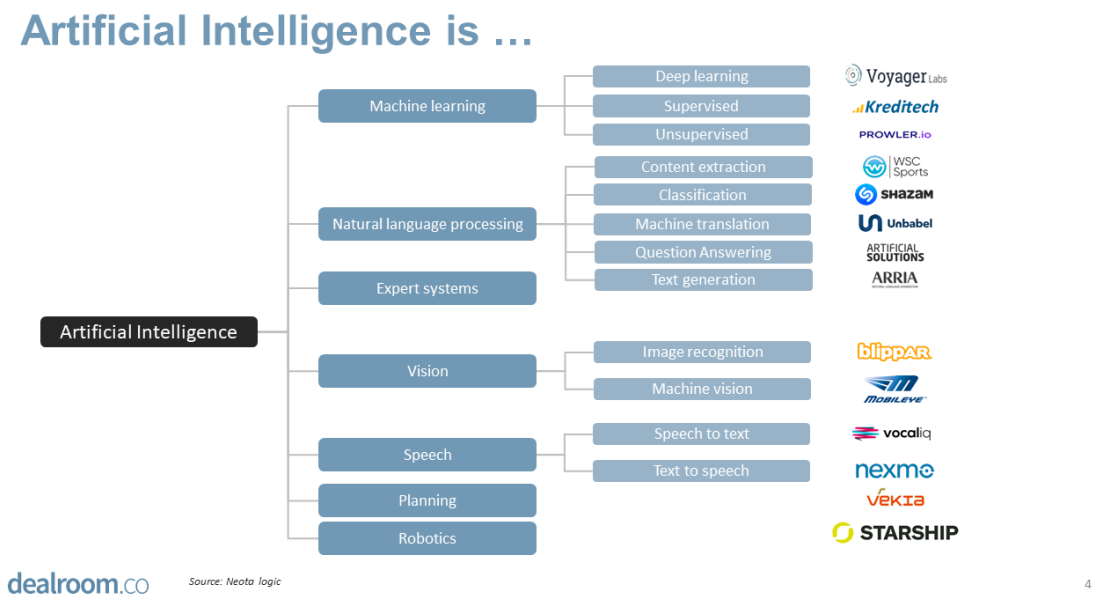

Figure 1: What is Artificial Intelligence (AI)? (Usmedia, 2020)

There are two critical disciplines within the field of AI namely Machine Learning and Deep Learning. Machine learning (ML) has a pivotal aim in its ability to handle a large amount of data effectively and extensively in a limited period (Bharadiya et al., 2013). Whenever a manufacturing machine is not performing optimally or in its desired way, a machine learning system has the

potential to send a message or signal and notify the decision makers, mainly the managers. Deep Learning (DL) stands as one of the most powerful techniques within AI. The notable availability of enormous computing capabilities and the integration of methods mainly based on statistical principles and AI have significantly progressed DL (Shawahna et al., 2019; Kotsiantis et al., 2006). Not only does it encompass the input of a vast amount of data into a prosperous neural network (Bharadiya et al., 2023) but can handle complex tasks such as fraud detection and even autonomous decision-making. With this approach, machines can now distinguish objects and images and accurately convert speech language into transcribed text in a short period (Knight, 2020). Businesses are actively identifying methods and seeking new opportunities to streamline daily tasks, stay connected with their customers, and therefore gain a competitive advantage. This will allow them to make a profit while being effective. When working with humans, the presence of uncertainty is higher; however, the integration of AI into business decision-making enhances the power of AI systems (Wu et al., 2020). This provides creative solutions when for resolving complex obstacles in entrepreneurship (Towsend et al., 2019). Wu et al. (2020) stated, "Stakeholders hold high expectations that AI can deliver excellent decisions. AI-enabled decision-making applications have enabled civilizations to enhance humans' quality of life". ML and DL enable AI to excel in the world of business making it a dynamic and crucial field.

AI has been notably implemented in numerous fields including business, computer science, and healthcare. Bryndin (2019) states "Artificial intelligence is a revolutionary technology that is designed to transform the life of the world community: to optimize business processes, to provide valuable information, to increase creative service to citizens". Furthermore, the structure and responsible use of intelligent systems pose a real concern which makes concerned companies put efforts to standardize AI (Russia, 2020). Overall, it is evident that artificial intelligence is advancing swiftly, especially when extensive research and ongoing development are focusing on areas such as quantum machine learning, de novo molecular structure modeling, and the intersection of AI with Industry 4.0. This emphasizes the dynamic and evolving nature of this field (Si et al., 2021; Kumpulainen & Terziyan, 2022; Li et al., 2015). However, the growth of AI has also raised striking conversations about its potential negative effect on society, specifically in the areas of management, social security, and the nature of employment in the future of work, stressing the implications of this technology (Schwendicke et al., 2020; Buczek et al., 2022).

2.5 Automotive Ecosystem

The automotive ecosystem is a complex and dynamic network involving interconnected elements including car ownership, maintenance, product development, and technological innovation (Jawi et al., 2012; Brown, 2019). The ecosystem includes a variety of operations, such as aftermarket services, sales, distribution, and vehicle design and manufacture (Jones et al., 2021). Stakeholders engage in this complex system with one another including service producers, distributors, suppliers, service providers, legislators, and end users (Smith & Johnson, 2020). Various factors affect this ecosystem like consumer preferences, regulatory standards, and technology improvements (Garcia & Lee, 2018).

The study by De Aragón and colleagues (2018) highlighted the significant changes in the automotive industry affected by connectivity and emerging technologies like the Internet of Things (IoT). Martinez (2021), also discussed the future of the automotive industry, emphasizing the pivotal role of engineering and physics in determining the trajectory of the ecosystem. Stakeholders must comprehend the complex dynamics of the automobile ecosystem to adjust to changing market needs and technology advancement (Aragón et al., 2018).

The automotive ecosystem involves several stakeholders, including conventional manufacturers such as Opel, Mercedes, and BMW, suppliers of components like Melexis, and government bodies that regulate the industry (Cataltepe et al., 2022).

- Melexis, a Belgian supplier for the automotive industry provides microelectronic solutions making cars smarter and safer (Melexis, n.d.). Marc Biron, the CEO of Melexis states "We design, develop, test and sell Integrated Circuits or ICs, mainly for the automotive industry. The goal is to make cars more comfortable, safer, and environmentally friendly." (Marc Biron, Melexis, 2023). He further highlighted that "In most cases, those customers are not the car manufacturers, but their suppliers such as Bosch or Valeo, who integrate our ICs into their products. We only deliver directly to newer car manufacturers like Tesla." Because of the necessity of regulatory monitoring and technical improvements in the automotive sector, the triple helix model which emphasizes collaboration between government, industry, and academia is especially pertinent (Chae et al., 2019). The automotive ecosystem has experienced a transformation due to the integration of AI and data centers, which has led to disruptive innovation and reshaped the sector (Wilhelm & Dolfsma, 2018).

- NVIDIA Corporation is the leading supplier of AI computing solutions to a range of industries, including the automotive one. AI-driven applications such as autonomous vehicles (AVD) and advanced driver assistance systems (ADAS) in the automobile industry are powered by NVIDIA's technology. The high-performance processing power offered by NVIDIA's platforms, such as the NVIDIA DRIVE platform, is essential for handling the massive volumes of data needed for intelligent car systems and autonomous driving (NVIDIA, n.d.). The NVIDIA DRIVE AGX™ platform, powered by the DRIVE OS™ SDK, provides the maximum possible computational performance. AI-defined vehicles can process massive amounts of camera, radar, and lidar sensor data over the air and make choices in real-time thanks to this centralized processing and software. According to Jensen Huang, the CEO of NVIDIA Corporation, "Our vision is to enable self-driving cars to be our companions, rather than just transportation machines". The company's dedication to using AI technology to revolutionize the automotive sector and improve the driving experience is emphasized by this goal. The AI computing solutions that NVIDIA Corporation offers to automotive industries facilitate the development and implementation of advanced AI applications, with a special focus on autonomous driving.

As the automotive industry grows rapidly, the concept of innovation as an ecosystem becomes increasingly important. This ecosystem includes the various stakeholders mentioned earlier, including established automakers, new entrants, suppliers, regulators, and technology providers, all of which work together to foster innovation and competitiveness (Liu et al., 2018). Battery technologies such as lithium-ion batteries are one of the key components of EVs for future electric transportation and sustainable transportation, therefore, they should be continuously developed and improved (Yang et al., 2020). Vehicle ecosystems can effectively cover disturbances, deal with emergency environmental issues, and give a new definition to the future of mobility by cherishing a culture of innovation and alliance (Lipu et al., 2020).

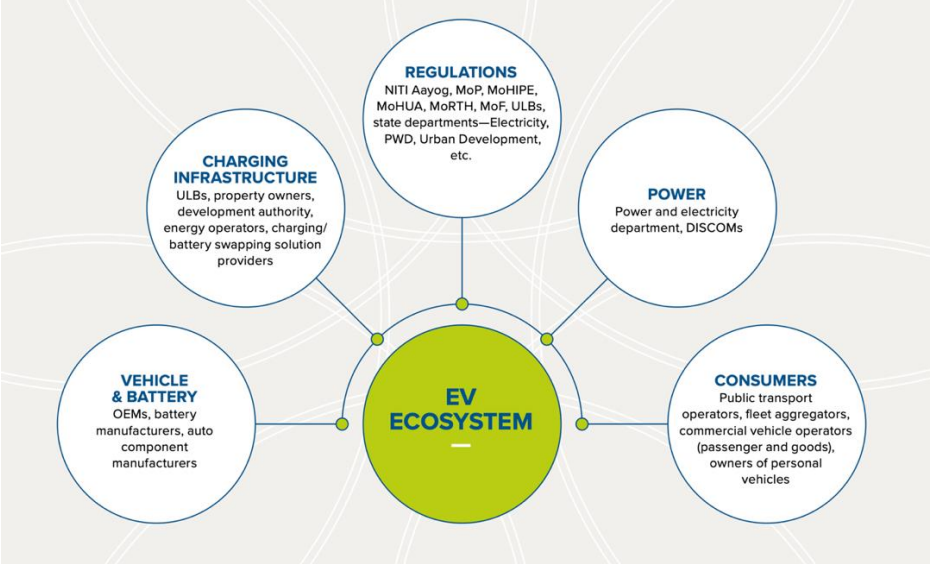

Figure 2: Key stakeholders and components of an Automotive EV Ecosystem (Rocky Mountain Institute & Ministry of Housing and Urban Affairs, n.d.)

Figure 2 provides an overview of the new EV ecosystem and its elements. The core of the automotive ecosystem will shift because of the vehicle's electrification. The eMotor, batteries, and power will be the three main components of the new ecosystem. The improvement of electric vehicle performance will be dependent on fresh research based on experiments or lessons learned from current vehicles. Effective manufacturing of performance batteries will be crucial for the advancement of vehicle electrification. According to Anuradha (2024), optimizing battery chemistry, power density, standardizing battery size, manufacturing process, and cost are necessary for high-performance battery configuration. To get the best battery performance, Original Equipment Manufacturers (OEMs) and battery makers must work together. An additional crucial element of the future automotive ecosystem will be the infrastructure for charging. The system needs to be modified to recharge batteries because it was designed for fossil fuels. The emergence of recharging infrastructure will disrupt the traditional fuel distribution model, including fuel processing companies and their retail distribution channels. The charging ecosystem will expand beyond the conventional distributor and retailer models to include personal home charging systems connected to the grid. Energy distribution companies will either replace or collaborate with fuel stations to offer retail

charging services for vehicles. Current legislation about electric vehicles needs to be modified, and new regulations may need to be created. Governmental organizations are collaborating now and will have to do so to guarantee a smooth transition. The new transportation ecosystem will alter consumer behavior. The adoption of electricity in public transit will be prioritized. Operators of fleet vehicles and individual drivers alike should anticipate more ecosystem modifications as a result of electrification, such as adjustments to servicing and charging networks (Anuradha, 2024).

2.6 Old State of the Automotive Industry

In the old state of the automotive industry, companies like **Opel** and **Mercedes-Benz** functioned without using artificial intelligence (AI). These firms heavily relied on traditional manufacturing methods. These firms depended on traditional production strategies and human abilities for the design and manufacturing of their cars. Mercedes-Benz and Opel, two well-known German automakers, have developed vehicles while focusing on mechanical engineering and guiding manual labor. The absence of AI meant that production strains operated without automation, and human workers mainly handled most of the tasks such as quality control and assembly (Moniz et al., 2022). This era emphasized the need for skilled workers which was essential for manufacturing processes as well as the need for mechanical expertise and precision and this could sometimes cause inconsistencies and delays in operations. Therefore, the automotive industry focused on the significant demand for routine manual tasks (Autor et al., 2001); Opel and Mercedes were dependent on human labor and mechanical equipment to drive their operational panorama. The supply chain network of the automotive industry was more localized, focusing on the areas where businesses were located (Ishida, 2020).

Stellantis, is a leading player in the automotive industry given that it has a long history of development and a rich track record that goes back even before the integration of intelligent technologies. It is distinguished by its broad range of emphasis on mass production and vertical integration to provide strategies and make the processes simplified (Santos & Paganotti, 2019). If AI is being used extensively today, especially in developing self-driving cars and in-car experiences (Kannally, 2023), Stellantis' past success can be tied to its ability to innovate and be revolutionary without relying highly on AI. What enabled this company to have a competitive advantage in a dynamic market was its strategic focus on sustainable value creation and efficient manufacturing processes (Valiyan et al., 2022).

With the introduction of the Ford Model T in 1908, Henry Ford's Ford Motor Company transformed the automotive industry (Tomac et al., 2019). When Henry Ford first began using horses, the operation required a lot of manual labor and was labor-intensive. However, Ford's innovative approach to production and handling led to significant improvements in manufacturing processes. The most prominent feature is the mass production methods introduced by Henry Ford in the early 20th century (Abolhassani & Jaridi, 2016).

Most cars today rely on data from the highly notable sport of **Formula One (F1)**. Years ago, Formula One was performed even before the introduction of Artificial Intelligence. The sport operated on manual analysis and human decision-making. Teams would use telemetry and sensors to collect data, but human engineers and strategists handled most of the data processing and interpretation. Engineers' and drivers' experience and expertise were of high importance considering that vehicle setup was based on them, with limited access to real-time data analytics. Historical trends and on-track observations were used and analyzed to make decisions regarding tire management, fuel consumption, and race strategy. However, those decisions often lead to deficient outcomes due to the inherent limitations of human cognition and manual data processing. Therefore, this manual approach often led to delays in decision-making and restricted the depth of analysis that could be performed in real-time during races. It is fascinating how Formula One (F1) has completely changed the sport on several levels by allowing teams to handle and process large amounts of data quickly and correctly by providing them with previously impossible insights. Today, AI algorithms are needed to predict results, adjust race tactics, and improve overall performance on the track (Olsen, 2007).

The automotive industry is presently undergoing a major shift with established players like Opel, Mercedes-Benz, and BMW transitioning towards new technologies. This shift has opened the door for new competitors such as Tesla, Geely, Volvo, and Stellantis to enter the market, challenging traditional automotive norms and disrupting the status quo (Lavon et al., 2011).

2.7 Future State of the Automotive Industry: The Automotive AI Revolution

Beyond our current awareness, AI is certainly already around us. For instance, AI technology is utilized in logistics planning, forecasting weather conditions daily, and banking services such as trading stocks. In addition to the aforementioned, AI is integrated into vehicles, aviation systems such as autopilot, and smartphones such as Apple's Siri (Luxton, 2016). Reim et al. (2020) further discussed the role of AI in shaping business models, highlighting its vast potential to create value and hence gain a competitive advantage over others.

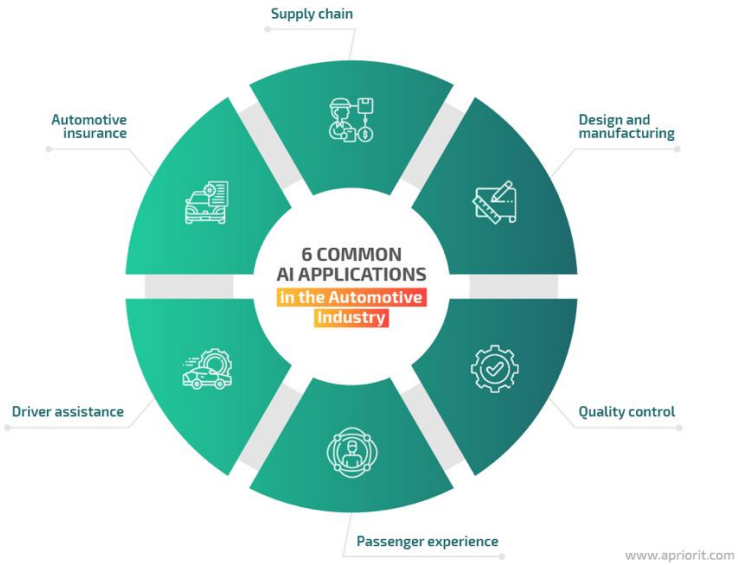

Figure 3: Rise of AI in Business and Industry (Bharadiya et al., 2023)

Artificial Intelligence plays a vital role in every organization, prompting drastic changes across industries (Schulze-Horn et al., 2020). The automotive industry is currently undergoing a major transformation with the integration of cutting-edge technologies like AI, big data, and the Internet of Things (IoT) (Cheng et al., 2022). The digitalization and automation of production environments characterize the fourth industrial revolution, or Industry 4.0, of which this revolution is a component (Krishna, 2021). From autonomous vehicles and predictive maintenance to advanced safety features and sophisticated infotainment systems, AI has emerged as a vital component in innovation, promising to reinvent the way we devise, design, and engage with automobiles.

AI technologies significantly improve the overall performance of the automotive sector by providing multiple benefits. These advantages include improved safety features like adaptive cruise control (ACC), lane departure warning (LDW), and autonomous emergency braking (AEB). Predictive maintenance utilizing Internet of Things (IoT) technology also helps vehicle management execute preventive measures (Srivastava, 2023). IoT is a network of interconnected devices that communicate and exchange data with each other over the internet, without the need for human involvement. Additionally, AI applications can greatly enhance the driver experience in several ways such as smart voice assistants in cars, autonomous driving, and lastly cost savings by improving supply chains and providing an early detection of vehicle defects (Breunig, 2017; Srivastava, 2023). In addition to manufacturing processes in the automotive industry, AI is being applied in the development of intelligent and connected vehicles (ICVs) (Li et al., 2023). Predicted to be the next revolution in transportation with autonomous vehicles reducing traffic congestion, lowering CO2 emissions, and preventing accidents, these ICVs represent a major change in the automotive industry (Higgins et al., 2023; Zhi et al., 2021).

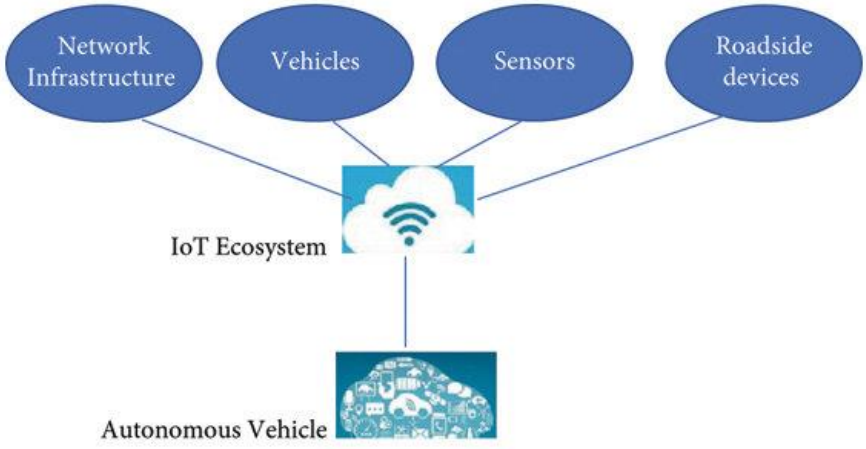

Figure 4: IoT ecosystem for AI-enabled autonomous vehicles (Bathla et al., 2022)

West et al. (2018) stated on Brookings that "Advanced software enables cars to learn from the experiences of other vehicles on the road and adjust their guidance systems as weather, driving, or road conditions change. This means that software is the key—not the physical car or truck itself" (West et al., 2018). Microsoft and Volkswagen teamed up with the purpose of delivering reliable automated driving solutions. Advanced Driver Assistance Systems (ADAS) and autonomous driving vehicles (ADVs) can significantly improve passenger safety, ease traffic congestion, and enhance the overall comfort of mobility (Microsoft News Center, 2021). Furthermore, the BMW Group has expressed that AI is facilitating the usage and management of data while providing unique and exceptional opportunities in business processes and optimizing their quality overall (BMW Group, 2023).

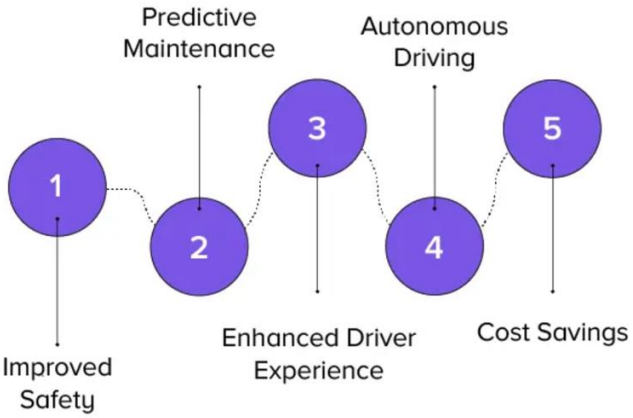

Figure 5: Benefits of AI in the Automotive Industry (Srivastava, 2023)

According to the European Automobile Manufacturers Association (ACEA), 2020, AI has a huge impact on the automotive industry's products specifically in production and manufacturing processes and, value-added chains. The deployment of AI will lead to a safe and effective mobility ecosystem within Europe.

The automotive sector stands at the forefront of the most innovative, intricate, and globally distributed industries in today's business landscape, being recognized as an early adopter of Industry 4.0 technologies (Mueller et al., 2022). AI-driven vehicles are reshaping the way we perceive the automotive industry. One of the most significant uses of AI in the automotive industry is perhaps autonomous driving. In 2024, self-driving cars are exploiting AI to analyze data from numerous sensors such as cameras and radar, enabling these cars to make informed choices when it comes to navigating the road.

Disruptive innovation in the automotive industry has been a central focus in recent years, with Artificial Intelligence advancements serving as an enabler for innovation. The integration of AI technologies has completely revolutionized traditional processes. AI is driving disruptive innovation by enabling new business models, enhancing manufacturing processes, and improving product quality. Furthermore, according to Rotjanakorn et al. (2020), AI is fostering the innovative skills necessary for the automotive sector to succeed. AI further facilitates the automotive sector's shift to open innovation by enabling competitors to work together and improve collective innovation systems through new technologies (Aalbers & Whelan, 2021). Businesses like Melexis, which provide innovative AI-based solutions to improve productivity and performance throughout the sector, are pivotal to this shift. Melexis has partnered with Multicoreware to develop face anti-spoofing AI using ToF by implementing custom neural networks on the Melexis MLX75027 VGA ToF sensor. "The goal is to achieve robust performance for a wide range of in-cabin applications such as driver authentication, drowsiness detection, driver attentiveness, etc" (Melexis, 2022). AI's integration into the automotive value chain is changing traditional methods and encouraging industry stakeholders to collaborate and be innovative (Iskandar & Ariffin, 2019).

As mentioned earlier, **Stellantis'** history in the automotive industry explains how important it is to innovate constantly and strategically to stay ahead of the competition. However, the application of Industry 4.0 principles, such as robotics and digital technologies, has completely transformed the production processes enhancing their efficiency and flexibility to align with the shifting market dynamics (Karabegović et al., 2021). Hence, Stellantis' focus on connectivity and intelligent vehicle technologies resonates with larger industry trends toward Intelligent and Connected Vehicles (ICVs) (Zhi et al., 2021). Currently, it is transforming into a mobility tech company. "Over a period of two years, starting in 2024, Stellantis will begin deploying three all-new, Artificial Intelligence (AI)-powered technology platforms across its four new global vehicle platforms" (Stellantis, n.d.).

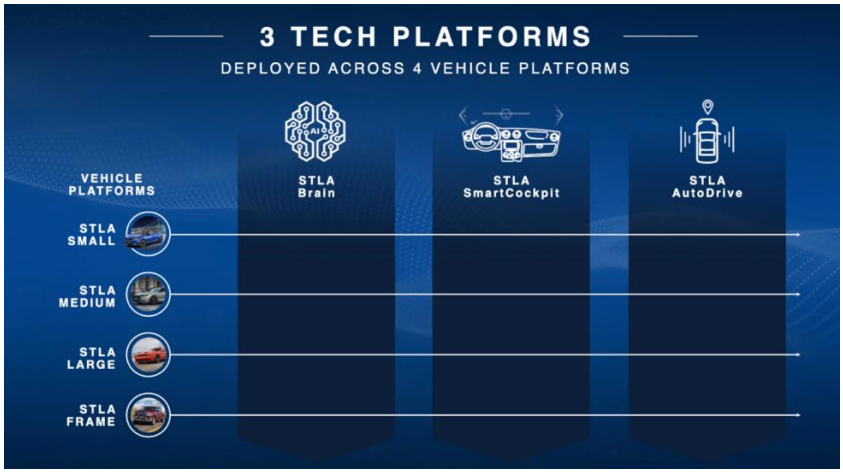

Figure 6: Intelligent Vehicle (Stellantis, n.d.)

1. **STLA Brain:** This is a novel software and electrical/electronic (E/E) architecture, that is at the center of the shift to customer-centric services. The hardware and software cycles are disconnected by this fully cloud-integrated, service-oriented design, making it possible to create and deploy features and services more quickly through over-the-air (OTA) updates without having to wait for the launch of new hardware (Stellantis, n.d.).

2. **STLA SmartCockpit:** Constructed on the STLA Brain, the STLA SmartCockpit will effortlessly integrate with the digital existence of car owners, converting the vehicle into a customized living area. Customer will engage with their car more naturally based on inputs ranging from touch and voice to glance and gesture. The STLA SmartCockpit, powered by the joint venture between Stellantis and Foxconn called Mobile Drive, will use artificial intelligence (AI) to provide a wide range of functions and services, including voice assistance, e-commerce, navigation, and payment services, using Amazon products and services. Stellantis illustrated how AI will be integrated into The STLA SmartCockpit Experience: Imagine commanding your vehicle to park with just a glance at an open space and then confirming your choice with a nod of your head. Imagine augmented reality capabilities such as the name of a famous monument appearing in the windows as you drive by or the names of constellations appearing as your passengers gaze through the moonroof at night".

3. **STLA AutoDrive:** created in collaboration with BMW, will provide Level 2, 2+, and 3 autonomous driving capabilities that will be updated over-the-air (OTA). The first Level 3 solutions are almost ready for release, and they are now offering the best Level 2 solution with semi-automated lane change. Stellantis and Waymo are collaborating for Level 4 and higher.

Mercedes-Benz has taken in-car voice control to a higher level by incorporating ChatGPT (Mercedes-Benz Group, 2023). Adding AI via the MBUX Voice Assistant's Hey Mercedes is an instinctive step into the future. Starting June 16, 2023, Mercedes-Benz in the United States initiated an optional beta program for more than 900.000 vehicles equipped with the MBUX system. The MBUX Voice Assistant has already established a benchmark in the automotive industry famed for its distinctive features, user-friendly and a large array of commands. Access to sports and weather updates has become more convenient while driving the car. Furthermore, drivers and passengers can obtain information and get instant answers regarding their surroundings and even control their smart homes. ChatGPT complements perfectly Hey Mercedes given its extensive understanding of several topics. The large language model it possesses can greatly enhance natural language and even conducting conversations such as suggesting a new dinner recipe and formulating complex answers. To ensure data privacy, Mercedes-Benz has collaborated with Microsoft for the integration of ChatGPT through Azure OpenAI service while keeping possession of data stored in the Mercedes-Benz Intelligent Cloud. Markus Schäfer, a chief technology officer in the Mercedes-Benz group stated, "The integration of ChatGPT with Microsoft in our controlled cloud environment is a milestone on our way to making our cars the center of our customers' digital lives. Everything is under one big goal: Redefining the relationship with your Mercedes" (Mercedes-Benz Group, 2023). Besides Mercedes-Benz, another leading company, **BMW**, has incorporated AI-powered voice assistants into most of its newest models to enhance both safety and drivability (BMW Group, 2023).

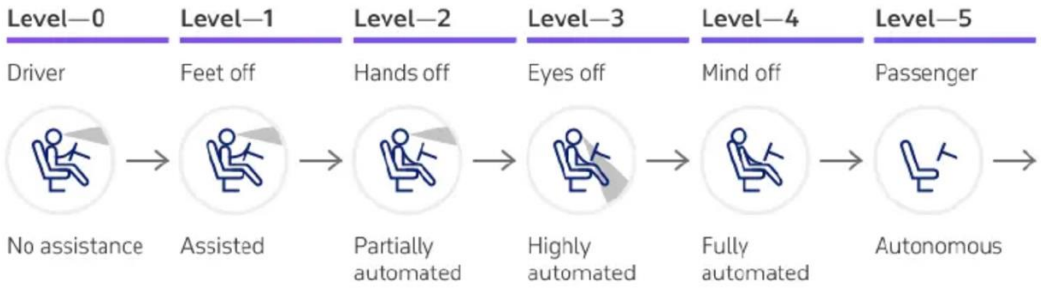

Figure 7: AI-assisted driving autonomy levels (Srivastava, 2023)

Microsoft, a technology giant, takes the leading position through its cooperation with Volkswagen Group intending to create and develop a distinct cloud-based platform for upcoming autonomous vehicle systems (Microsoft News Center, 2021). In partnership with Microsoft, the Group's software company Car.Software Organization will build the automated diving Platform (ADP) on Microsoft Azure. Microsoft Azure will leverage ADP faster given its compute and data capabilities. Car.Software Organization can significantly increase the productivity and development of advanced driver assistance systems (ADAS) and autonomous driving (AD) features for drivers and passengers across Volkswagen Group by employing ADP held on Azure. Scott Guthrie, executive vice president asserted that "The power of Microsoft Azure and its compute, data and AI capabilities will enable Volkswagen to deliver secure and reliable automated driving solutions to their customers faster" (Microsoft News Center, 2021).

Waymo, another prominent firm in autonomous driving formerly known as the Google Self-Driving Car Project, began allowing people to make payments for rides in its autonomous Jaguar vehicles in San Francisco (Mickle et al., 2023). Every day, the Waymo Driver successfully employs a combination of sensors and software to autonomously navigate actual city streets safely. It perceives and comprehends the outside world through a variety of sensors, such as external cameras, and multiple sensors linked with advanced artificial intelligence (AI) software. This process is known as "Sense, Solve, Go" (Google, 2023).

Ford Motor Company has been utilizing artificial intelligence (AI) in several applications, most notably autonomous driving systems. According to Rychtyckyj et al. (2017), the company has a history of implementing AI-based technologies to manage process planning in automobile assembly plants throughout the world. As the auto industry transitions to autonomous vehicles, Ford faces competition including from established manufacturers, tech giants like Google, and more recent entrants like Tesla (Eggers & Eggers, 2021). In the context of Ford's autonomous cars, Datasets like the Ford Multi-AV Seasonal Dataset, and the Ford Highway Driving RTK Dataset provide important insights for autonomous driving technology research and development (Houts et al., 2020; Agarwal et al., 2020). These datasets support the industry's transition to AI-driven solutions and enhance AI technology for autonomous vehicles (Li, 2022). Moreover, Latitude AI is a wholly owned company of Ford Motor Company that is dedicated to creating an automated driving system that allows millions of cars to drive without using their hands (Ford, 2023). With the founding of Latitude, Ford expanded its development efforts in automated driving technology, including improvements in Ford BlueCruise, which has already accumulated more than 50 million miles of hands-free driving. Ford also adds a top team of machine learning, robotics, software, sensors, systems engineering, and operations talent.

Presently, we will take a closer look at **Formula One** (F1), which stands as the most sophisticated and advanced sport in the world. The achievement of perfection of both humans and machines is the result of every victory. F1 is integrating AI using sophisticated algorithms and data-driven technology. The creation of AI-based cybersecurity systems to safeguard sensitive information and guarantee the reliability of racing technologies is one way that AI is being deployed in F1 (Riley et al., 2011). Moreover, advanced ablation index (AI) systems that monitor and improve the quality of ablation lesions during catheter ablation procedures for atrial fibrillation are prospering using AI to amend the performance of racing F1 cars (Papageorgiou et al., 2020; Hussein et al., 2017; Hussein et al., 2018).

Formula One pushes the boundaries for automotive advancement by using the most innovative technologies such as machine learning (ML) models and high-performance computing (HPC) to digitally revolutionize the sport. Each Formula One car is equipped with 300 sensors producing 1.1 million telemetry data points every second and sent from the vehicles to boxes. Since everything starts with data, to choose the winning race strategy on the track, this real-time data is coupled with over 70 years of enriching historical data stored on an S3 bucket allowing vital information (AWS, 2021). F1 can anticipate and predict race strategy outcomes for teams, cars, and

drivers with high accuracy by extracting historical data to train Amazon SageMaker complex machine-learning algorithms. Thus, with the help of AI and real-time data, the models can forecast future scenarios such as Grand Prix races. The graphic model below, Figure 8, shows how F1 uses a variety of AWS machine-learning services including AWS SageMaker, AWS Lambda, and AWS analytics services to provide and analyze crucial performance data.

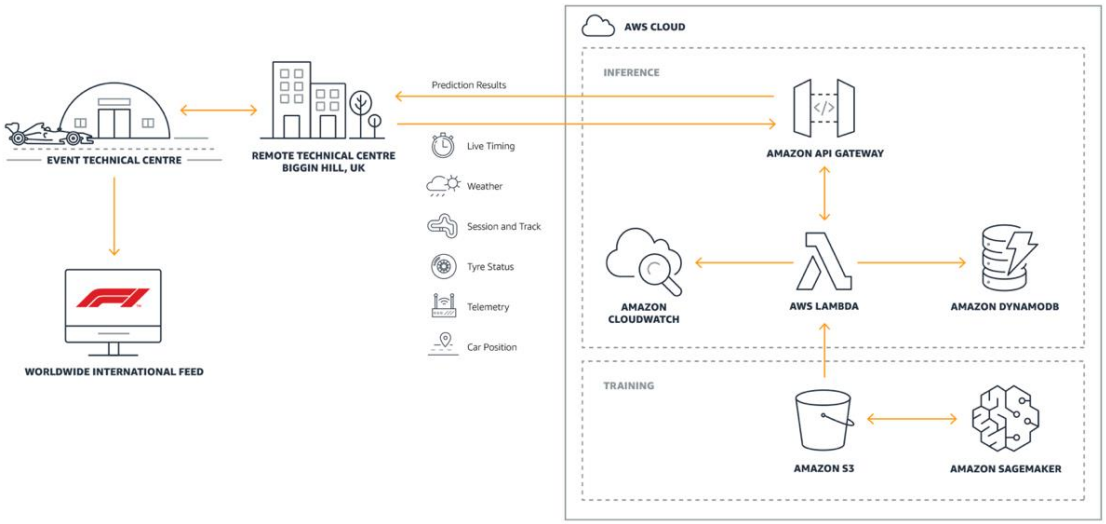

Figure 8: Machine Learning with F1 Data (AWS, 2021)

McLaren launched Formula E livery on the 60th anniversary using AI methods and claiming to be a "world first" to integrate AI. McLaren inserted six visions using AI tools into a text-to-text AI and then requested instructions for an image AI. Following the inputs, a text-to-image generated six distinct artworks, one per vision which then were integrated, combined, and enhanced into one single final scheme using an image-to-image AI to create "high-resolution graphics that McLaren Racing designers mapped onto the car" (McLaren, 2023). The benefits of integrating AI into this sport include the improvement of the accuracy of intraocular lens power calculations and providing drivers and team members with precise and customized lens power predictions (Nemeth et al., 2021; Ladas et al., 2021). The application of AI in F1 extends to the creation of innovative approaches for improving existing intraocular lens calculation formulae, enhancing AI to prosper, and developing hybrid formulae for improved certainty (Ladas et al., 2021). Collectively, these advancements show the multifaceted integration of AI in Formula One, encircling cybersecurity, vehicle performance expansion, and customized medical applications, thereby fundamentally changing the diverse aspects of the sport.

The integration of AI technology is deemed to cause a profound transformative revolution in the automotive industry. One of the biggest shifts in the future state of the automotive industry is the advent of **Electric Vehicles (EV)**. All major companies are heading in the direction of manufacturing EV vehicles since they are more sustainable than gasoline-powered cars, eco-friendly, and cost-effective. The **Tesla** Model Y rose to the top of the EV sales charts in 2022, selling 7.47 million cars globally (OMR, 2023). Particularly in the areas of electric vehicles and autonomous

driving technology, Tesla has led the way in innovation. Tesla has already embraced AI through the Autopilot technology, offering intelligent parking, steering, and acceleration abilities (Tesla, 2023). To ensure high capabilities, Tesla's camera suite is equipped with robust vision processing in each car. Architected by a deep neural network, Tesla's vision recognizes the car's surroundings with a high level of accuracy greater than that of classical and traditional vision processing methods. With the current state of autopilot functionalities, the car is not autonomous but, requires ongoing driver supervision. Tesla has introduced various elements in their electric cars. Navigate on Autopilot recommends lane changes and automatically adjusts to avoid getting stranded behind slow-moving cars or trucks on the road to optimize travel time. Additionally, it will automatically guide the car toward the highway interchanges and exists based on your specific destination. More important elements include autosteer and smart summon to navigate complex roads and environments. In the future, Tesla is promised to become a fully autonomous car in nearly all situations with the features it possesses. The system is engineered in a way to conduct both short and long distances (Tesla, 2023).

2.7.1 AI-driven Approaches

As a matter of fact, automotive companies are increasingly exploiting AI-driven approaches to upgrade innovation management processes. Innovation workflows rely on cutting-edge methods to improve and manage data more efficiently. These AI-powered tools optimize advanced techniques such as predictive analytics, natural language processing, and computer vision to design vehicles, automate certain tasks, analyze data, and detect patterns and trends. It is reasonable to conclude that the benefits of these tools offer a comprehensive view of the industry and help in better-informed decisions for upcoming trends and opportunities.

The integration of AI technology in design applications can help automakers enhance **vehicle designs**. For instance, AI can be applied to optimize **vehicle weight and improve fuel efficiency and clearness** (Khaligh & Düşmez, 2012). Gama and Magistretti (2023), stated that "General Motors is an automotive firm that adopted AI in generative design applications to optimize its materials, costs, and manufacturing methods, and make auto parts 40% lighter and 20% stronger" (Gama & Magistretti, 2023). AI can leverage knowledge management by providing sophisticated search and recommendation systems. Employees can effectively and swiftly access pertinent knowledge, best practices, and choices for implementation. The adoption of a design-driven innovation strategy within the automotive sector has the potential to provide a persistent competitive advantage by balancing customers' requirements, product significance, and technological opportunities (Farhana & Bimenyimana, 2015).

AI-driven predictive analytics can process and analyze vast amounts of data and help automotive companies forecast market trends and opportunities, consumer preferences, and potential innovative technologies (Johnson & Lee, 2020; Wang et al., 2021). Automotive firms can make well-informed decisions regarding product development and innovation strategies by examining market data, customer input, and internal research (Smith & Patel, 2019; Chen & Liu,

2022). The use of artificial intelligence, for instance, can be used to identify unmet customer needs and develop new products and services based on customer feedback (Gupta & Kim, 2020; Zhang & Wang, 2022).

A **machine learning algorithm and AI-driven engineering** for design optimization and engineering tasks is another way automotive companies can exploit AI's potential; enabling engineers to focus on more creative and strategic tasks (Chen & Wang, 2020; Gupta & Patel, 2021). For example, AI can generate design variations, optimize vehicle aerodynamics, and develop complex algorithms for autonomous driving systems (Lee & Kim, 2019; Zhang & Liu, 2022). The efficiency, safety, and performance of automotive systems and components can all be improved by using these algorithms to examine historical design data, spot trends, and make recommendations for changes (Smith & Johnson, 2020; Wang et al., 2021). Nonetheless, automotive companies may test and validate designs in a virtual environment by utilizing **AI-driven simulation and testing tools** to create advanced simulations and prototypes. This accelerates the invention process and reduces the time and expense of physical prototypes (Jones & Brown, 2018; Patel & Shah, 2020).

The pivotal role of **manufacturing and production** in the automotive industry cannot be overstated, especially in the development of a car. The efficiency, precision, and innovation exercised during the manufacturing process directly influence the quality, safety, and overall performance of the final product. A successful and competitive car is developed during the production phase, which includes everything from the assembly of complex components to the use of cutting-edge technologies. Additionally, the automotive industry’s rising interest in AI Inference Engines has been primarily influenced by the growing trend of autonomous vehicles, reflecting a remarkable shift in AI use in this sector (Grigorescu et al., 2020). Simultaneously, the employment of Industrial AI for achieving process optimization in manufacturing is gaining substantial traction, enabling faster and more reliable data-driven decision-making by using both historical and real-time data (Peres et al., 2020). In what manner does Artificial Intelligence contribute to the foundational aspects of this process? AI can be used to enhance quality control, reduce faults, and optimize manufacturing processes. AI can be used, for instance, to plan maintenance, anticipate machine breakdowns, and adjust production lines to match variations in demand. The ongoing pursuit of excellence is ingrained in this process since improvements in manufacturing techniques have a major impact on the development and progress of the automotive landscape.

In the automotive business, integrating **Natural Language Processing (NLP)** for consumer feedback analysis has become a strategic necessity (Ag Analytics, 2023). Automotive firms can obtain nuanced insights into customer preferences and concerns by deploying natural language processing (NLP) algorithms to analyze input that is distributed across diverse platforms, such as social media, reviews, and forums (Emerj Artificial Intelligence Research, 2020; Chowdhury, 2003). This advanced analytical approach provides a comprehensive understanding of customer sentiment and acts as a foundation for well-informed decision-making (Fang & Zhan, 2015; Das et al., 2022). Automotive companies can effectively customize their innovations to meet market

demands by identifying patterns and feelings in customer feedback, thereby promoting a customer-focused and responsive approach to product development (LinkedIn, 2023).

Additionally, several internal automotive companies, have executed the Lean, Agile, Resilient, Green (LARG) methodology, improving their competitiveness in the sector and performance sustainably (Aisyah et al., 2021). Besides, Zhu et al. (2021) point out that the complexity of automotive systems has driven the need for collaboration with Original Equipment Manufacturers (OEMs) and suppliers, emphasizing the interconnected aspect of innovation in this industry (Zhu et al., 2021).

To successfully integrate AI for innovation in the automotive industry, companies need a combination of skills and expertise. First, according to Changkajonsakdi and Kaewkuekool (2016), a strong foundation in STEM education is essential. This foundation should encompass knowledge, professional skills, soft skills, and qualities. Furthermore, to guarantee that staff members have the basic abilities required for the use of AI, a focus on workforce development and competency-based training is crucial (Changkajonsakdi & Kaewkuekool, 2016). Additionally, a thorough AI adoption plan depends on the implementation of Industry 4.0 technologies across various functional domains of automotive firms, including quality management, human resources management, and innovation management (Stawiarska et al., 2021). To address the AI-talent gap, organizations can invest in alliances and partnerships with educational institutions to develop the required competencies among pre-service instructors in automotive engineering. Effective training models such as Work-Based Learning and Partnership-Based Training can aid in achieving this target (Sudarsono et al., 2021; Suyitno et al., 2022). Nevertheless, enhancing employee involvement and empowerment is key to building essential organizational competencies that support the effective application of AI technology in the automotive sector (Roslin et al., 2019). Lastly, to close the AI skills gap, companies should prioritize interventions and frameworks for skill development, guaranteeing that employees possess the requisite expertise and necessary knowledge to properly use AI (Laseinde & Kanakana, 2017).

2.8 Leadership in the Age of AI: The Evolving Role of Top Managers

Leadership can be defined as the ability to impact individuals to attain certain goals while shaping their values, beliefs, and attitudes (Sun, 2018). With the rise of AI in various industries, a significant change in leadership has been remarkable. The evolution of this technology has pushed the boundaries for leadership dynamics and drawn attention to several aspects of businesses.

AI is recently being integrated with several domains such as writing, drawing, coding, and composing (FMJ; Carron, 2023). As AI technology continues to advance, leaders find themselves forced to adapt to this advancement while exploiting the full potential of the tools. Organizations are increasingly demanding their leaders to reshape their workforces to reallocate capital while still delivering profit. This demand emerges from AI's unique capacity to improve employee productivity through resource rebalancing, investments in labor force reskilling, the advancement of new models of education, and enduring acquisition (Fleming, 2020).

Top managers play a crucial role in gathering and organizing knowledge before AI usage. The growing use of artificial intelligence (AI) in businesses is causing major changes in the roles and duties of top managers. The role of top managers in dealing with AI involves gathering and organizing knowledge to ensure effective AI usage. To prepare human workers for working in teams with robots, Arslan et al. (2021) stress the significance of organizational support mechanisms including training opportunities and technological competence. The role of artificial intelligence (AI) in promoting knowledge sharing and learning is highlighted by (Arslan et al., 2021; Sundaresan & Zhang, 2021). This has resulted in the redesign of the responsibilities and procedures of AI-enabled knowledge workers. Additionally, Jarrahi and colleagues (2022) emphasize how important it is for people to contextualize knowledge generated via AI and assimilate it into organizational learning processes (Jarrahi et al., 2022).

As AI becomes more prevalent in organizations, top managers are required to adapt to these changes. According to Holmström and Hällgren (2021), to promote AI adoption and allay concerns, organizations must explicitly state the goal of using the technology. Furthermore, Baslom & Shu (2019) discovered that responsiveness, information acquisition, and dissemination all significantly and favorably correlated with AI awareness, highlighting the significance of knowledge management strategy in the context of AI. One important area in which senior managers are actively involved is the application of AI in human resource management. Tuffaha (n.d.) emphasizes the significance of educating HR managers and staff members on AI implementation procedures. Agarwal (2022) goes on to point out that the way upper management views the advantages of implementing AI affects how AI choices are decided upon and how effective HR systems are (Agarwal, 2022).

In conclusion, top managers are at the forefront of negotiating AI's inclusion into businesses. To increase AI awareness and acceptance across a range of organizational tasks, their responsibilities include educating human workers about AI cooperation, supporting knowledge sharing and learning using AI, and strategically managing knowledge.

Challenges and Opportunities of AI in the Automotive Industry

Challenges	**Opportunities**
Job loss	Job creation
Ethical concerns	Sustainability
Data security and privacy concerns	Reduced accidents
Bias in AI-algorithms	Data knowledge management
Regulations	

Table 1: Challenges and Opportunities (Author's own)

2.9 Challenges of AI in this Sector

Challenges and barriers arise when incorporating AI into organizations to enhance their innovation potential in the automotive industry. It is of utmost importance to guarantee the safety and reliability of AI-driven systems. For instance, autonomous vehicles require extremely advanced systems that have also undergone countless testing and verification to navigate complex and dynamic settings (Brown & Smith, 2021).

Artificial intelligence (AI) is causing a revolution in the automotive industry, which has many worried about possible **job losses**. There is a chance that some jobs in this industry will become automated as AI technology advances. Jobs that need a lot of manual labor, repetitive tasks, and regular decision-making are especially susceptible to automation by AI systems. This covers jobs in automotive firms such as assembly line workers, quality control inspectors, and certain administrative positions. Studies have shown that the use of AI in sectors like the automotive industry may result in job losses. Bakker and Demerouti (2017) argue about how some features of a job and its high demands might drain one's resources, possibly leading to job loss. Anaf et al. (2012) highlight that several variables, such as increased automation brought about by technology improvements, might lead to job loss. According to Morandini et al. (2023), artificial intelligence can automate tasks that are currently performed by people, which could result in job losses in industries that rely significantly on manual labor. While the precise percentage of job loss due to AI implementation in the automotive industry may vary, it is clear that there is a potential for a significant impact on the workforce. To adapt to the changing nature of the workforce, it is critical to prioritize employee upskilling and reskilling, as seen by the automotive industry's shift towards automation and artificial intelligence. Companies need to invest in training initiatives so that workers have the abilities needed to interact with AI systems and lessen the negative consequences of job displacement.

Data security and privacy concerns are intricate and progressively growing in the context of AI integration as vehicles become more associated and reliable on AI algorithms (Zöldy et al., 2020; Moniz et al., 2022). Vehicles generate and transmit vast amounts of data including driving patterns, diagnostics, and most importantly, personal information about the drivers and passengers (Smith & Johnson, 2019; Wang & Chen, 2021). The possibility of data breaches/leaks and cyberattacks is one of the major concerns. Hackers can manage to obtain access to this sensitive data, potentially causing a threat to personal safety by committing theft (Jones & Brown, 2020). Stealing identity could compromise the companies' security while posing serious consequences (Garcia & Martinez, 2020). It is an ongoing challenge for automakers and technology providers to certify protection against unauthorized access by ensuring strong encryption and cybersecurity safeguards (Gupta et al., 2021; Lee & Kim, 2022).

Bias in AI algorithms has become a striking risk as artificial intelligence is more widely adopted in the automotive industry to enhance vehicle safety, performance, and efficiency (Chen & Liu, 2020; Johnson et al., 2021). This bias can take many forms, including skew in data collection

and training practices, bias in decision-making, and lack of equity within different demographic groups (Wu & Wang, 2019; Patel & Shah, 2022). Artificial intelligence algorithms are constantly trained on historical data, and they may strengthen preexisting biases in the data set (Gupta & Smith, 2020). As such, if a self-driving car is previously trained on data that comprises photos of individuals from a certain racial or socioeconomic group, the AI system may not be able to recognize and respond to pedestrians from underrepresented groups correctly (Li & Zhang, 2021). Besides, autonomous vehicles deeply rely on AI algorithms to make decisions in real-time like when to brake, steer, or accelerate. These algorithms might contain bias ending up favoring certain groups over others (Kumar & Singh, 2022). This could impose safety and ethical implications, particularly in scenarios where the AI system needs to decide in complex surroundings involving foot passengers, cyclists, and other cars on the road (Zhang et al., 2020). The use of AI in the automotive industry raises significant ethical and legal questions such as who is held accountable? If AI-driven vehicles make biased decisions that result in a fatal accident, who is to blame and how might rules and regulations be created to guarantee accountability and mitigate these biases? (Chen & Wang, 2021).

Furthermore, another challenge that must be addressed is **ethical considerations** such as user consent and transparency in data collection and usage (Gao & Li, 2021; Zhang & Chen, 2022). Drivers and passengers may not be fully aware of how much their personal data is being collected, stored, and used and with which parties it is being shared (Wang & Liu, 2020; Patel & Shah, 2021). It becomes a complex task to find a balance between innovative services while respecting people's confidentiality (Smith & Johnson, 2020). To mitigate risks and guarantee uniformity in safety measures, it is necessary to ensure standardization and regulations in the field of AI-driven automotive technology (Gupta et al., 2021; Chen et al., 2022). Switching from conventional to AI-driven manufacturing could be of high cost since it requires significant investments in infrastructure and employee training. Therefore, displaying a financial strain (Jones & Brown, 2019; Lee & Kim, 2020). The shortage of talent in IT fields especially in the realm of AI is a significant concern (Loucks et al., 2018). Executives acknowledge that the development of intelligent automation provides several advantages. However, due to the shortage of talent, they also recognize that millions of workers would necessitate retraining and reskilling simultaneously (IBM, 2019).

The rise of Artificial Intelligence in recent years has captivated the attention of various debates among large businesses (Duan et al., 2019). For instance, Ginni Rometty, the CEO of IBM, contests that AI technologies are "technologies to augment human intelligence" (Duan et al., 2019). He argues that this intersection between the machine and the person could have of great impact on humans and offers a variety of opportunities. Conversely, Stephen Hawking and Bill Gates argue that Artificial intelligence could pose a threat to humans and therefore yield a downfall of mankind (Cellan-Jones, 2014; Rawlinson, 2015). With the progress of technology, some human jobs will be replaced and automated through AI and machine learning. However, Harvard Business Review suggests that solely 2.5 percent of current jobs consist of tasks appropriate to machine learning. These include jobs like lobby attendants and ticket takers which encompass main tasks such as checking credentials and authorizing access to a restricted space (Fleming, 2020). The majority of

tasks will still best be performed by humans, especially those jobs requiring industry knowledge or craft skills such as carpentry, electricians, and plumbers.

In the automotive industry, the responsible use of artificial intelligence (AI) is critical to improving safety, efficiency, and the overall experience for drivers and passengers (Kannally, 2023). With the rapid pace of advancement in AI technologies, new automation tools are being devised that can bring significant benefits to the automotive sector (Zhou et al., 2022). Strategies for responsible adoption of AI in this industry include considering the ethical implications and guaranteeing transparency in AI decision-making processes (Hulsen, 2023). In addition, the establishment of sustainable practices, such as the use of recycled and renewable materials, plays a crucial role in reducing the environmental impact of automotive products (Caliskan et al., 2022). Through the responsible and sustainable incorporation of AI, the automotive industry can not only increase operational efficiency but also contribute to environmental protection and societal well-being. Other strategies for the responsible use of artificial intelligence (AI) in the automotive industry include focusing on prioritizing data privacy and security to protect the sensitive information collected by AI systems (Strümke et al., 2021). In addition, facilitating cooperation between academia, industry, and regulators can ease the development of standardized guidelines and best procedures for the ethical use of AI technologies in vehicles (Attard-Frost et al., 2022). Continuous supervision and testing of AI systems to detect and rectify biases and errors is crucial to maintaining the integrity and fairness of AI-powered applications in the automotive sector (Stark et al., 2020). By implementing these strategies in conjunction with existing responsible AI practices, the automotive industry can manage the complexity of AI integration while maintaining ethical standards and safeguarding the well-being of all stakeholders involved.

The **AI Act** was introduced by the European Union (EU) to govern technologies related to artificial intelligence (AI). The purpose of this regulation is to guarantee the ethical standards and dependability of AI systems utilized in a variety of industries, including the automobile industry. Three risk categories are assigned to AI applications by the Act. "First, applications and systems that create an unacceptable risk, such as government-run social scoring of the type used in China, are banned. Second, high-risk applications, such as a CV-scanning tool that ranks job applicants, are subject to specific legal requirements. Lastly, applications not explicitly banned or listed as high-risk are largely left unregulated" (The EU AI Act, n.d.). Artificial intelligence (AI) programs may detect and treat cancer, record and analyze facial data to enforce laws or tailor adverts, and forecast what material will interest you online. Put differently, AI has an impact on many aspects of your life. Similar to the EU's 2018 General Data Protection Regulation (GDPR), the EU AI Act may establish a worldwide norm that determines the degree to which AI improves rather than negatively impacts your life, wherever you may be. International attention is already being drawn to the EU's AI policy. The Brazilian Congress enacted a law that establishes the legal foundation for artificial intelligence towards the end of September 2021. It must yet be approved by the nation's Senate (The EU AI Act, n.d.). Automobile manufacturers may find it difficult to build AI-driven features that interact with consumers as the EU AI Act forbids AI systems from manipulating people or taking advantage

of weaknesses. In general, the automotive industry must thoroughly assess its AI systems to ensure compliance with the EU AI Act, which can be a difficult and resource-intensive process.

2.10 Opportunities

The integration of artificial intelligence (AI) in the automotive industry not only offers numerous opportunities but also holds significant job creation potential, particularly in the development and application of AI technology. The shift to smart manufacturing systems, according to Jerman et al. (2019), calls for new job profiles and capabilities, including roles in programming, robotics, mechatronics, data analysis, Internet of Things, design, and maintenance of smart systems, as well as process analysis and bionics. The successful development and maintenance of AI-driven systems in smart factories will necessitate skilled professionals in these fields to ensure optimal operational efficiency and innovation in the automotive sector. In addition, Valiyan et al. (2022) highlight the importance of sustainable value creation in the automotive industry. This process involves creating positive momentum through creative ideas that balance performance with changing customer needs, improve supplier communication dynamics, and reduce material diversity in production. Such initiatives not only contribute to environmental sustainability but also stimulate demand for professionals specializing in sustainable practices and value creation in the automotive sector. Furthermore, Crossa (2021) underscores how important it is to regionalize production to expand manufacturing and create jobs. This suggests possible employment prospects in the many areas where the production of automobiles is concentrated, resulting in the creation of jobs in supply chain management, manufacturing, logistics, and related sectors. While concerns about potential job displacement due to AI integration exist, there is also recognition of the positive impact of AI job growth on overall well-being (Makridis & Mishra, 2022). The increase in jobs involving AI improves worker well-being and supports economic growth.

One of the significant question marks that have raised interest during the past few years is **sustainability**. When it comes to incorporating artificial intelligence in the automotive industry, it is crucial to address sustainability to lower environmental damage and improve efficiency (Khaligh & Düşmez, 2012). Manufacturers and developers of automobiles need to prioritize certain key strategies to properly address this challenge. To what extent does AI contribute to tackling this sustainability test? Automotive companies should first concentrate on AI-driven innovations that lower CO2 emissions, enhance fuel efficiency, and address issues of electric motors (Wellbrock et al., 2020). This can entail optimizing engine performance, creating smart traffic management systems, and improving aerodynamics. Recycling and reusing resources during the production of cars can significantly decrease the industry's carbon footprint. AI-driven techniques might also be advantageous for the automotive industry in reducing waste and encouraging eco-friendly supply chain management. Lastly, educating consumers about the advantages AI-enhanced electric and hybrid vehicles have for the environment can greatly impact the industry to various sustainable transportation alternatives. By exploiting technological advancements and embracing sustainability, the automotive industry can significantly contribute to lessening environmental impact and creating a more sustainable future (Wellbrock et al., 2020).

The growing emphasis on life cycle sustainability assessment (LCSA) in the automotive sector indicates that the industry's adoption of AI is consistent with sustainability principles (Tarne et al., 2017). Cioca et al. (2019), pointed out that AI technology can be utilized to optimize the design of eco-friendly products and procedures. This demonstrates a holistic approach that takes into consideration the social, economic, and environmental effects of the automotive industry's whole supply chain (Sala et al., 2012).

Reducing the likelihood of **accidents** is one of the main advantages of automated and autonomous vehicles. Over 1.2 million people pass away in traffic accidents each year: Approximately 3500 persons in Germany lose their lives in traffic accidents each year, and over 300,000 suffer serious injuries (Brenner & Herrmann, 2017). It has been evident that Artificial Intelligence technologies in autonomous vehicles, such as high-definition maps (HD-map) and vehicle-to-everything (V2X) communication, significantly improve road safety and lower traffic incidents as highlighted by Chung and Cho (2021). Besides, the application of Deep Learning techniques to detect and identify road surface conditions during nighttime can further advance driving safety by ensuring that the capability of autonomous cars is fully equipped to handle diverse environmental conditions (Zhang et al., 2022; Chen et al., 2021). Recent studies focusing on efficiently improving the safety of autonomous vehicles have also emphasized implementing safety distances into trajectory planning through the modification of occupancy grids for autonomous vehicle navigation (Mouhagir et al., 2016). Moreover, the automotive sector is entering a new wave of energy diversification wherein several vehicle types, including ICEVs, HEVs, PHEVs, REVs, BEVs, and FCVs, will coexist, presenting opportunities for utilizing AI in various powertrain technologies (Zhao et al., 2020).

AI plays a vital role in aiding **data management** through a variety of methods. First, data collection processes can be streamlined by AI-powered algorithms that automatically aggregate and arrange data from a variety of sources such as onboard computers, GPS systems, and car sensors. This automated process of data collection saves time and guarantees a continuous and extended supply of real-time data which is crucial for making decisions. An abundance of data is generated at different stages, from car diagnostics to driving habits, because of the proliferation use of sensors and Internet of Things devices in vehicles (Smith & Johnson, 2020). Thus, AI improves **data quality** by using advanced analytics techniques in the automotive industry like anomaly detection. Data cleansing algorithms locate and fix errors or inconsistencies in the data. AI-driven data management systems can also facilitate data security by integrating robust encryption techniques and detecting irregularities that could impose cyberattacks. All-inclusive, artificial intelligence catalyzes effective and efficient data knowledge management in the automotive industry, enabling businesses to maximize the full potential of their data assets while remarkably reducing future risks (Wang e al., 2021).

2.11 Economic Relevance

Throughout economic history, talented people have driven innovation and economic growth with their extensive abilities. However, in the contemporary era, several factors such as the ongoing and rapid advancement of technology and business models have caused a shift in the markets and have influenced the industries' dynamics (IBM, 2019).

AI has a disruptive power in terms of the economy and is deemed to reshape the business environment (Bammens' LinkedIn, 2023). Businesses seek to maximize their economic value by subtracting Value (V) minus Cost (C). "JLL research states that approximately 80 percent of jobs are exposed to disruption" (FMJ; Carron, 2023).

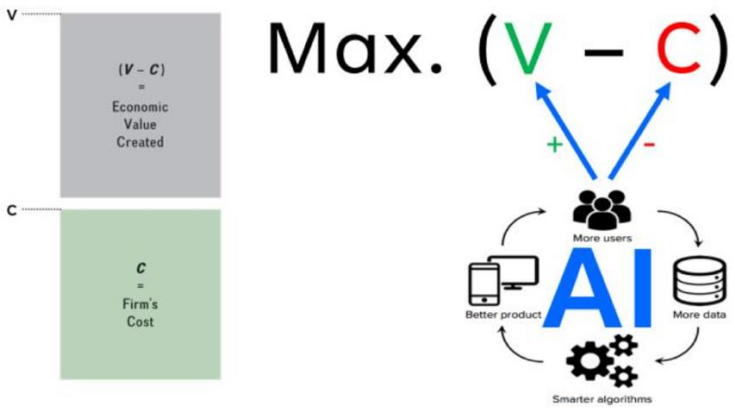

Figure 9: AI4Business (Bammens' LinkedIn, 2023)

The integration of AI in automotive manufacturing is now propelling the economic and technological growth of countries (Reshetnikova et al., 2021; Risman et al., 2021). As previously indicated, certain jobs will be replaced by AI; however, conversely, AI will also create fresh employment opportunities. New tasks will emerge requiring the use of additional abilities. As highlighted by Moniz et al. (2022), the adoption of AI technologies has resulted in modifications to labor relations and productivity causing the automotive sector to reorganize as new job roles emerge. Additionally, the study by Fridman et al. (2019), emphasizes the dynamic and growing nature of R&D (research and development) of advanced vehicle technology, and the evident enhancement of operational efficiency in manufacturing processes (Peres et al., 2020), pointing out the ongoing growth in job opportunities and skill requirements as a result of the integration of automation and AI.

McKinsey & Company's research in 2018 suggests that the adoption of AI could widen gaps between nations, businesses, and labor markets as it has a significant potential to boost economic activities worldwide, with the automotive industry playing a fundamental role in it (McKinsey & Company, 2018).

Moreover, professor Bammens noted in an interview conducted with him about AI's impact on the economy; "Maybe another element is that nowadays AI is very much specific functional domains like operations marketing. I think we will see a development where it will also be used more in let's say, strategic management, or in policymaking". Bammens draws attention to a significant drawback of existing machine learning techniques, highlighting the fact that although these methods are excellent at finding correlations, they frequently fail to establish causality. This restriction makes it difficult to make strategic decisions, especially in management settings where knowing the causes of actions is important. It is hoped that the shift towards causal AI will close this gap by enabling the study of causative linkages instead of only correlations, providing more trustworthy insights for strategic decision-making.

3. Methodological Framework

3.1 Research Context

Exploratory research is a type of research design that is frequently conducted when a researcher seeks to gain or develop a preliminary understanding of a research topic or to explore a new area of inquiry where little is known or understood. It aims to generate insights, ideas, and hypotheses rather than testing specific hypotheses or theories.

Moreover, exploratory research is an essential first step in various fields including social science, that enables researchers to look into new topics or relationships between variables that have not been examined previously (Bhushan et al., 2019; Zhu et al., 2019; Mason et al., 2010). This type of research is known for its flexibility and adaptability, as it lacks specific rules, enabling researchers to explore diverse perspectives and generate new hypotheses (Haile, 2023; Hussain & Cohen, 2017). The primary objective of exploratory research is to identify new tasks or relationships that existing methods may not address (Dietterich, 1990). This can be achieved using a range of methods, including interviews, case studies, and observations. When exploring novel areas, a qualitative approach is often recommended as the most effective method. Qualitative research methods, such as thematic analysis, structured interviews, and semi-structured interviews, enable researchers to gain in-depth insights, understand complex phenomena, and explore underlying meanings and motivations (Lima et al., 2020; Silva et al., 2022; Knihs et al., 2022). Because it enables researchers to produce hypotheses, spot trends, and create theories based on comprehensive, rich data, this method is very useful for exploratory research (Mason et al., 2010; Böhmer, 2001). Furthermore, it offers a more open-ended and iterative investigation of the research problem because it does not necessitate predetermined hypotheses (Faria et al., 2022; Luijken et al., 2022).

3.2 Research Questions

This research aims to acquire a more profound comprehension of the AI-driven approaches in the automotive industry while improving innovation. It will also explore the strategies for implementing AI technologies to attain success. Furthermore, it will tackle key performance indicators (KPIs) used to evaluate the impact of AI-driven innovation on business outcomes. It will analyze concrete cases in Europe within the automotive sector where AI has been deployed. With a focus on exploring the intersection of AI technology and innovation within the automotive sector, this study aims to address a main research question and two key sub-questions.

Main Research Question:

How can automotive companies exploit AI-driven approaches to overcome key challenges and capture opportunities to upgrade innovation?

The main research question examines the potential applications of AI-driven approaches within the automotive industry. Additionally, it explores and identifies the specific challenges faced by the automotive industry in innovation management and the implications of adopting AI while including the opportunities and benefits. It provides valuable recommendations for automotive companies to effectively exploit AI technologies to improve innovation practices.

Sub questions:

1. **How does the quality and availability of data impact the effectiveness of AI-driven innovation?**

   This sub-question seeks to understand the crucial role of data quality and availability in influencing the efficacy of AI-driven innovation. The objective of this question is to provide insights into optimizing data utilization for innovation enhancement by examining the impact of several data parameters on AI applications. It aims to look at various factors such as data accuracy, completeness, and timeliness could impact the outcomes of AI applications, this research question seeks to uncover ways to optimize data management practices.

2. **What are the skills and expertise required to implement AI in the automotive industry for innovation? and how can organizations address the AI-talent gap?**

   The goal of this question is to identify the knowledge and skills necessary to successfully implement AI in automotive innovation. Additionally, it intends to offer practical recommendations for organizations seeking to traverse the complexities of AI-driven innovation in the automotive industry by delving into the skill sets required for AI integration.

Furthermore, the objective of this research question is to investigate strategies and tactics to shorten the AI-talent gap. To bridge the skills gap, this entails exploring innovative recruitment practices, training programs, collaboration models with academic institutions, and utilizing external partnerships.

3.3 Methodology Approach

Given the qualitative nature of this study, semi-structured interviews were employed as the primary method of data collection to explore the complex landscape of AI-based innovation in the automotive industry. The main objective of this research is to clarify how automotive companies may use AI-driven strategies to overcome challenges and grab innovative opportunities. The researcher interviewed experts rooted in diverse areas of the automotive industry to obtain insight into the critical function that data availability and quality play in driving AI successfully. The study also addressed the widespread AI talent gap and examined the necessary knowledge and abilities required for the effective application of AI in the automobile industry. The sample population was carefully selected, consisting of people with a broad spectrum of roles and an extensive amount of experience working for automotive companies. The researcher contacted possible respondents by using personal contacts and professional websites like LinkedIn. A thorough explanation of the goals of the study and the format of the interviews were given to the respondents. A total of seven respondents were contacted, and they all provided priceless insights and experiences that enhanced the dataset and made it easier to comprehend AI-driven innovation in the automotive industry. One of the seven respondents, who holds a professorial position at Hasselt University in Belgium, was specifically interviewed to provide insights on the economic relevance of AI. Some of the findings stemming from this interview were subsequently incorporated into the economic relevance section of the literature review.

Automotive Ecosystem Players	Candidate Position	Candidate Name	ID	Sex	Duration
UiPath, California, USA	Program Director	Chris Lebedeff	C1	M	1 hour 5 mins
Siemens Company, Leuven, Belgium	Director of Digital Industries Software	Steven Dom	C2	M	1 hour 14 mins
Educational Institution, Hasselt University, Belgium	Academic Professor in Strategy and Innovation	Yannick Bammens	C3	M	25 mins
Toyota Motor Europe (via Capgemini)	AI/ML Developer	Hamid Jebli Ouazzani	C4	M	40 mins + Written report & case studies
Ghistelinck & MIG Motors, Ghent, Belgium	Director Used Cars & Vans	Paul Vanneste	C5	M	20 mins
Wisemen	CEO	Steffen Brans	C6	M	45 mins
EEVEE Mobility	COO	Tom Langie	C7	M	45 mins

Table 2: List of Interviews

3.4 Data Collection

The data collection process for this study consisted of conducting online interviews via platforms such as Zoom and Microsoft Teams, harnessing the rapid advances in digital technology for flawless communication. Additionally, one of the respondents supplemented their insights by submitting a written report and case studies in response to the questionnaire besides an interview as well, while another interview was conducted face-to-face with two respondents. The respondents' varied geographic locations, some of whom were outside of Hasselt and even in Belgium, led to this decision. Choosing virtual interviews allowed for greater accessibility without sacrificing the depth of in-person conversation, which was thought to be necessary for a thorough comprehension of the topic. The professionalism of each response guaranteed the authenticity of the results, even in a virtual environment. The results of these interviews will be incorporated into more recent scholarly research to improve the depth of analysis and strengthen the study's interpretive framework.

To gather knowledge and perspectives from experts in the field, this study uses a semi-structured interview format with an open approach. Participants were encouraged to express their views freely, focusing mainly on the pre-established research questions, which were distributed in advance to allow adequate preparation. In particular, two separate questionnaires were used: one adapted to the study of the economic relevance of AI, administered during an interview with a university professor, and another unified questionnaire used for all other participants. The unified interview protocol began with an opening question inviting respondents to introduce themselves and

their roles within the organization. The questionnaire was structured into three parts, each purposefully aligned with the main research question about the exploitation of AI-driven approaches, as well as two subsidiary research questions dealing respectively with data quality and availability, and the skills and expertise required.

3.5 Data Analysis

After seeking their consent, the interviewees agreed to the interviews being recorded, which made transcribing the audio recordings easier for subsequent analysis and interpretation. The researcher acknowledged that to analyze the data objectively, it was crucial to empathically comprehend the views of the respondents. This meant avoiding subjective or emotional interpretations of the data. The use of thematic coding, a technique for categorizing and arranging textual material by spotting recurrent themes or patterns, was made. Through the methodical connecting of text extracts to established codes based on relevant terms and phrases, this approach makes it easier to analyze large amounts of data and offers a comprehensive interpretation.

The coding process enables researchers to organize ideas by linking diverse passages to general concepts, thus easing the identification of patterns and the formulation of meaningful conclusions. In order to find and classify themes and patterns in the content, coding entails the methodical investigation of data. Once discovered, these passages are attributed unique identifiers or names, which serve as reference points for all texts or data of the same idea or concept. This process involves three steps, as shown in the coding tree: Step 1 consists of extracting general information from the texts by reading them; Step 2 entails digging deeper into the material to unravel particular details based on the initial findings; Step 3 focuses on condensing the text through coding, using concise phrases to depict the topics covered. Various codes may be linked to particular data that aligns with the generic themes discovered throughout the analysis process.

STEP 1	STEP 2	STEP 3
Main RQ: Exploiting AI-driven approaches	AI initiatives	Effective AI applications
	Challenges faced by the automotive industry	Cultural differences as an obstacle
		Regulatory complexities
		Who is to blame?
		Collecting qualitative data from real-world experiments
		Road and user safety
		Ethical concerns
	Capturing opportunities and benefits of AI	Creation of new jobs in the future
		Accelerated decision-making and research
		Enhanced safety through simulation
		Personalized maintenance and enhanced user interaction
	Future trends	The future of AI in automotive and its KPIs
RQ1: Quality and availability of data	Management of data quality and availability	Bias in data
		Privacy and security concerns
		Faster analysis of vast amount of data
RQ2: Required skills and expertise	Successfully implement AI in automotive innovation	Training programmes and initiatives
	Strategies and tactics to shorten the AI-talent gap	Attract and retain a diverse inflow of employees
		Role of research and development

Table 3: Coding Tree

4. Findings

Numerous findings were uncovered in this thesis which explores the integration of Artificial Intelligence (AI) in the automotive industry. This research aims to exploit effective AI-driven approaches within the realm of innovation while providing insights into the role of data quality and availability, hence upgrading the automotive processes. The findings of the study illuminate the challenges faced and the opportunities captured by implementing AI technologies. As innovation accelerates within this rapidly evolving landscape, automotive companies must remain ahead of the competition by upskilling their employees and effectively attracting and retaining AI talent.

The study's findings highlight the challenges related to the integration of AI in the automotive industry. However, it also sheds light on the possible opportunities that it could create. Differences in cultures and regulations play a major role in the impact of AI. Deploying AI entails complying with regulations, management of data, and employees' expertise and skills. It is crucial to address the AI talent gap in the automotive industry. The shortage of AI poses a major obstacle for companies seeking to implement AI solutions. Moreover, with the advancement of technology, ethical privacy concerns arise, as well as biases in data might occur suggesting a thorough analysis of data.

The automotive landscape is a diverse culture, and AI adoption introduces its own set of challenges. Amidst these challenges, AI offers a plethora of advantages, including faster decision-making, the creation of new jobs, accelerated research, and several more that serve as a beacon of transformation. AI-powered predictive maintenance, real-time risk assessment, and machine learning offer automakers invaluable tools for analyzing vast amounts of data. As a result, these technologies enable more accurate and knowledgeable decision-making at every stage of the automobile manufacturing process, which eventually improves production efficiency and quality.

Nevertheless, the findings also delineate successful AI-driven approaches while proving effective recommendations for automakers and automotive companies. Strategic initiatives must be implemented for better outcomes. To successfully apply AI advancements in the automobile industry and bring in a new era of efficiency and technological improvement, research and development activities are crucial.

The presentation of the results will be interlinked with the results of the interview sessions in which seven selected respondents participated, with the help of the researchers. In addition, passages from the dialogues relating to the results will be incorporated into this chapter.

4.1 AI Initiatives

The integration in the automobile industry has grown in importance considering that AI-driven approaches have the potential to improve safety, efficiency, and user experience (Kannally, 2023). AI Inference Engines in particular are being used to improve several automotive applications, particularly in the area of autonomous vehicles (Grigorescu et al., 2020). These developments in AI are stimulating innovation in the automotive industry, resulting in the creation of new automation

technologies in addition to enhancing vehicle performance (Zhou et al., 2022). The interviewees also note that AI-driven approaches enhance user interaction through multiple ways which will be discussed further.

Following interview sessions with respondents, it was noticed that almost all automotive companies are currently using AI initiatives within their processes. Overall, AI initiatives are crucial for driving innovation and staying at the forefront of the competition. One of the interviewees, who is a director of the digital industries software at Siemens noted that digitalization is spread in all industries. Siemens' comprehensive approach to digitalization encompasses as well the company's organizational structure with distinct units focusing on several aspects such as automation and simulation

"So it's actually the part of Siemens that is looking into everything that is the digitalization of industries, not just automotive, all industries… you have other parts that look at the factory automation and then the simulating our factories' work. And within so you have digital industries. Then you have within digital industries, you have digital industries, software, and that's a part where that that is looking at all software applications, those are everything that is and also a bit of hardware, but mostly software." (C2)

In the automotive sector, simulation is an essential tool that is used in many different applications, including supply chain management, design, manufacturing, and testing. Through virtual testing and analysis, businesses using simulation systems like Simcenter can improve their processes and end products. One of the interviewees noted that there is *"the Simcenter which is a whole range of business simulation tools that are there"* (C2)

Within the automotive ecosystem, suppliers and clients participate in a dynamic negotiation and collaboration symphony in the orchestration of AI integration. Their interactions work together harmoniously, like a well-tuned instrument, to navigate the challenges of integrating artificial intelligence into automobiles.

"Suppliers AI integration created joint R&D projects for better integration– mostly the software and hardware are designed or developed by close related suppliers creating better reliable resources and better scaling for mass production.
Clients industry: Testing and validation of AI integration in the real world, simulation, test track for benchmarking the robustness and safety of AI product integration." (C4)

While interviewing the respondents, the director of used cars lacked significant knowledge about AI and its applications in business, resulting in a scenario where AI is not utilized in the sales process of cars and vans within the company.

"Well, I have a general idea of AI, and is mostly what we see on a daily basis, going on social media and in the news within the generation, of texts of images, video generation, etc. And mostly

in the creative process. But on a business level, we are not really into AI. As for now, as well, mainly a commercial business selling cars and vans and AI is not yet implemented in our business." (C5)

4.1.1 Effective AI Applications

Several effective AI applications can be implemented within the realm of the automotive industry. The researcher actively searched for expert perspectives during the interviews to delve into the multitude of successful AI applications within the automobile industry.

*"I say the most common thing that people think of when they think of AI, is what we call more the **big data analytics**… when they look at AI, you have a lot of data, and I want to learn something from that data. And that's what we call here we see like, for example, intelligent data, they use automatic extraction, and application of flows and data from previous analysis, or measurements or data coming from the clouds, from sensing from the vehicles, and so on."* (C2)

Big data analytics now has a lot more options thanks to the incorporation of AI into automotive systems, especially in the areas of personalized optimization and predictive modeling. As the interviewee articulates, the automotive sector finds it difficult to process the massive volumes of data gathered from linked cars and is looking for practical insights. **Predictive modeling** is a noteworthy application of AI, whereby algorithms utilize past data to anticipate the performance attributes of upcoming vehicle designs. Even in the lack of comprehensive design models, artificial intelligence (AI) may anticipate things such as energy usage with amazing accuracy by analyzing data from prior cars. This capacity helps engineers to make well-informed decisions early in the development phase and expedites the design process. Moreover, the interviewee highlights as well the crucial role of big data analytics concerning personalized optimization. AI-powered big data analytics allows for customized system optimization for automobiles. Manufacturers can customize vehicle functions for individual customers according to their driving preferences and habits by utilizing data from connected cars. For example, based on an analysis of driving habits and charging behaviors, AI can suggest the best ways to extend the life of batteries. This degree of customization maximizes the vehicle's longevity and efficiency while improving the user experience.

It's also obvious to note that there are other AI applications such as **Natural Language Processing (NLP)**, that have the goal of making computers capable of comprehending, interpreting, and producing human language.

"Instead of looking for help in the files of your software, you can use ChatGPT or something like that. You ask the question in a natural way and it will talk to you in a natural way. Rather than you looking for keywords or you know, whatever software you use, you'll get the help files and you can start searching in the help files." (C2) And then there is as well the Microsoft Copilot, which the director noted having a partnership with.

The intricacy of Natural Language Processing (NLP) becomes evident when one considers the necessity of teaching computers the ability to distinguish between words. Machine learning

techniques are key to solving this problem because they allow computers to interpret and process linguistic patterns more precisely and professionally.

"But it sounds very simple that you have to first teach a computer what is another what is a bolt, and that's where machine learning comes into play." (C2)

Automotive businesses can explore creative solutions and accelerate the designing of new car models by integrating AI tools and using generative AI-enabled design tools (Thoring et al., 2023). These AI-driven design tools help designers solve complex design problems more successfully while also encouraging innovation, which ultimately results in the creation of advanced automotive products (Philipp & Niggemann, 2022). In addition to the aforementioned advancements, AI initiatives within the automotive sector encompass **Innovative Design Support** functionalities. Generative Design Assistance provides suggestions for creative and optimized performance-based designs. Predictive Design Exploration offers the evaluation of all possible design configurations. Self-Learning Design Iterations will dynamically adapt designs based on evolving project requirements.

"There is also what we call innovative design support, where generative design comes into play… And then the generative design, that's a very important one, because that's where you can let the computer come up with ideas that as a human you would not have. So we use it, for example, to create automatically different versions of a vehicle architecture. And an architecture you can the vehicle you have to think in terms of if I asked like, let's say I have a hybrid vehicle, I can have one or two electric motors, I can drive the front wheels, the rear wheels, I can have a smaller a bigger engine, I can have different sizes of battery." (C2)

Moreover, a written report from an AI/ML developer at Toyota Motor Europe with 3 years of experience in AI Development in automotive - in the field of multi-modal perception (vision) and human-behavior prediction with deep learning provided some deep insights in response to the questionnaire. The respondent stated various AI applications that are employed at Toyota.

1. *"**Human modeling**: predict human behavior and preferences during different driving scenarios based on the physiological response of the human (brain EEG-heart PPG-eyes gaze–facial expression).* (C4)
2. ***Driver vehicle performance/safety**: Ergonomics of drivers a Computer Vision approach - body pose estimation.* (C4)

Ergonomics of drivers, a Computer Vision approach - body pose estimation is a technique that makes use of computer vision technology to examine the ergonomics of a driver's position within a vehicle to evaluate and enhance driving performance and safety. Body pose estimation is the process of detecting and tracking a driver's posture and movements while operating a vehicle using computer vision techniques. By using this method, the system may examine several ergonomic variables, including posture, hand placement on the steering wheel, and seating position. Through precise body position estimation, the device can offer valuable insights into possible ergonomic

concerns that may affect comfort, tiredness, and overall safety. With this knowledge, academics and automakers can create and execute interventions that maximize driver ergonomics, improving vehicle performance and safety. To better suit drivers' natural movements and preferences, this may involve changing the layouts of dashboards, steering wheels, and seats, which will ultimately result in a more comfortable and secure driving experience.

3. ***Drag-guided diffusion models for vehicle image generation****: optimization of performance metrics of vehicle shapes."* (C4)

Machine learning plays a central role in the streamlining of manufacturing processes and product design. Machine learning algorithms analyze massive volumes of data to find inefficiencies, improve operations, and enhance product designs by utilizing sophisticated algorithms and predictive analytics. This technology allows us to continuously innovate and refine production processes and vehicle designs, thereby increasing efficiency, quality, and competitiveness in the automotive industry.

"Product design: The proof of concept in AI is that we are using Generative AI to design or optimize vehicle shapes with engineering constraints into Generative AI models." (C4)

One interviewee presented an application (EEVEE mobility) that demonstrates the integration of artificial intelligence (AI) and data analytics to electric vehicle (EV) mobility, providing a complete charging management and optimization solution. The company estimates several elements of EV usage, such as range prediction, charging behavior, and battery deterioration, by utilizing **predictive analytics and data modeling**. The company buys data directly from EV manufacturers to streamline the reimbursement process, avoid costly hardware installations, and guarantee accurate billing based on actual consumption. Reconstructing charging sessions and creating personalized charging profiles with AI-driven algorithms improves reimbursement accuracy and efficiency. Additionally, AI forecasts EV range after prolonged inactivity and forecasts battery degeneration by analyzing charging behavior, allowing for proactive maintenance plans.

"So at the moment, we have, I think 50,000 connected cars in 80 countries, or EVs. And we use, of course, their data to do several things… if you drove for a year, certain kilometers certain charging behavior then your battery will lose capacity. And we tried to predict how much of capacity to lose over next years." (C6)

AI also forecasts the availability of charging stations by analyzing data from connected EVs, which helps with route planning and reduces range anxiety. All things considered, EV performance is optimized, customer satisfaction is raised, and the adoption of sustainable transportation solutions is accelerated by the integration of AI and data analytics.

4.2 Challenges Faced by The Automotive Industry

The interviewees acknowledged during the interview that applying AI technology in the automotive industry presents certain difficulties. They pointed out that although artificial intelligence (AI) has tremendous potential for innovation and growth, there are new challenges that must be properly addressed.

"Well, there are a lot of challenges…I mean, you need to generate new or create new technology. And AI is one part of creating new technology. And a lot of people are hyped up about AI because it helps a lot in certain areas. But it's not the solution to everything, obviously." (C2)

He also added *"The biggest challenge with AI is that you never know what it's going to do. It is unpredictable...so the biggest challenge that we see in using AI is to make AI explainable and predictable."* (C2)

4.2.1 Cultural Differences as an Obstacle

According to one of the respondents, cultural differences can be a major barrier to the automotive industry's adoption of artificial intelligence. The automotive industry is a worldwide industry, therefore incorporating AI technologies in a variety of cultural contexts calls for sensitivity and awareness. Norms, values, and expectations regarding technology adoption, privacy, and trust vary from region to region.

"Different cultures may have different priorities. And so you have to how do you build in the ethics or the values of that culture into your AI model. So for instance, and with possible exceptions, hey, we have a culture that might be more focused on making sure that the pedestrians are safe because the person in the car has all the safety equipment. In other cultures, there might be no priorities on the occupant of the car, but make sure you don't do any damage because it just costs too much." (C1)

4.2.2 Regulatory Complexities

The automotive industry faces a plethora of regulatory complexities when applying AI technologies. These complexities arise from the crossover between traditional automotive regulations and emerging AI applications, creating a challenging regulatory landscape. One of the interviewees shed light on the importance of regulations.

"One is the different regulations between the different countries. And what are those regulations and understanding what is acceptable, for instance, it's one thing to just be able to program to, here's a road, here's a street sign, here's how you should behave." (C1)

The respondent brings attention to the importance of regulations as well as the numerous chances for innovation in the automotive sector. The development of autonomous driving technology

is hampered by regulatory restrictions, especially in Europe, where existing laws compel drivers to actively steer their cars even when they are fully capable of operating autonomously. The implementation of completely autonomous vehicles is hindered by the strict regulatory framework, which emphasizes the need for more lenient laws that can keep up with technology improvements without compromising safety.

"Think regulation is a big one on the policy. For example, in Europe, it's not allowed yet to, not be present or not be actively in control of the vehicle. And even if full self-driving would be available in Europe, then the law at the moment. prescribes that you need the car will say, Oh, watch out, you will have an accident or you have to make a turn or something or a quick stop, then you as a driver have to approve that the car can do." (C7)

The respondent notes that there are plenty of chances for innovation despite legislative obstacles, particularly in the field of software development for car infotainment systems. Electric cars are sold by many OEMs (Original Equipment Manufacturers); nevertheless, software, especially in infotainment systems, is still not always of high quality. OEMs can set themselves apart from the competition by improving user experience and software quality in response to this discrepancy. Furthermore, there is a ton of potential for the creation of cutting-edge third-party services using vehicle data, especially with the impending EU Data Act requiring data sharing from OEMs to third parties. Essentially, the interviewee's observations emphasize how market possibilities, technical advancement, and regulations interact intricately to shape the future of the automobile sector.

To ensure compliance and safety in the development of autonomous vehicles, it becomes even harder to negotiate the various legislation that exists in different nations. Establishing clear guidelines and standards that support safety and innovation globally requires cooperation between industry participants and regulatory agencies, as stakeholders work to overcome these difficulties.

4.2.3 Who is to Blame?

The respondent highlighted an important challenge of AI during the interview, prompting the need for further attention and exploration. When AI algorithms are involved in the context of an autonomous vehicle accident, it can be difficult to determine who is to blame because traditional accountability systems might not work. Because neural networks are translucent, it can be challenging to understand why the AI decided the way it did, even though the automaker may be held legally accountable. This lack of explainability makes it harder to comprehend and handle liability in AI-driven accidents, which emphasizes the necessity of transparent and responsible AI systems in self-driving cars.

"In the autonomous context, think about the situation where an autonomous car has an accident. Who is to blame the car company? Yeah, but the car company will then go on to like, like, why did the car do this? So you're going to blame an AI algorithm for the cause of the accident. But the AI algorithm cannot see why it did that. Yeah. So it becomes a very difficult thing to explain." (C1)

"But I think if an accident happens, then the OEM (Original Equipment Manufacturer)is responsible because nobody's driving. So the driver is not to blame. That's why Tesla probably made their own insurance because otherwise, it would be very difficult to insure it with a third party. So, yeah, then if something happens, Tesla knows it's much safer, it's much less risky to have an accident. So even if they have accidents, yes, they can easily pay it with their own insurance." (C7)

It could be necessary to take a cautious approach when determining who is to blame for autonomous car accidents that involve AI algorithms. Even while the automaker might be held legally accountable, the process is made more difficult by AI decisions' inexplicability. To provide precise criteria and guarantee accountability in such occurrences, regulators, engineers, and legal experts must work together in harmony.

4.2.4 Collecting Qualitative Data From Real-World Experiments

To assess the verified robustness of Sensing-Reasoning Machine Learning (ML) pipelines, this procedure entails carrying out substantial real-world experiments on large-scale datasets (Yang et al., 2020). Because AI is novel to the automotive sector, evaluating occupational health and safety with AI requires an experimental, inductive qualitative approach (Cebulla et al., 2023).

"*Collecting qualitative data from real-world experiments, training -updating and testing the model prediction and being as close to the ground truth as possible."* (C4)

4.2.5 Road and User Safety

There are numerous safety concerns associated with the integration of artificial intelligence (AI) with vehicle technology, including user privacy safety as well as road safety. Because these problems are complex, a thorough analysis is necessary to address the issues brought up by the user. The safety of AI systems in automotive applications is a topic of ongoing research and debate. Machine learning (ML) plays an increasingly significant role in advanced automotive functionality, particularly in driver assistance and autonomous operation, raising concerns about its adequacy from a safety certification perspective (Salay et al., 2018).

"Road, mostly safety, not only safety on the road but also privacy safety for the users. I think that's the main concern." (C5)

There are a variety of safety concerns associated with artificial intelligence (AI) in automotive applications, including issues with unpredictable behavior, cybersecurity integration, and human-machine interactions. To tackle these obstacles, a thorough comprehension of the safety consequences of artificial intelligence (AI) systems in the automobile sector is necessary, in addition to creating strong frameworks for safety assurance and reliability assessments.

4.2.6 Ethical Concerns

The increasing integration of AI into automobile systems raises important ethical concerns. Although these technologies have the potential to improve road safety, efficiency, and convenience, they also raise important ethical questions. There are concerns over the validity of reading emotions only from facial expressions and whether physiological cues are just fingerprints or reflect real emotions.

"Because we work with a lot of humans and physiological data (EEG/PPG/Facial expressions) we do a lot of bias mitigation: Can an expression of a face tell you how a person really feels with a computer vision algorithm? And are the physiological signals our real emotions or just a fingerprint of real human emotions? Therefore, we do bias mitigation by letting the participants in the experiment give their subjective opinion with a score and ensure fairness in decision making by the model." (C4)

Design integrity and benchmarking are aided by preserving information regarding participant demographics and experiment settings.

"Transparency: We always state the gender-age-length-weight of participants we benchmarked the model and conditions of design of experiment testing." (C4)

Creating thorough guidelines and standards is one way to potentially address the ethical concerns surrounding the use of AI in automotive systems. Strict methods for mitigating bias, like using a variety of datasets and involving participants in the assessment procedure, should be included in these guidelines. Furthermore, open communication about the design of the experiment, the characteristics of the participants, and the benchmarking settings can promote responsibility and confidence in AI systems. Through the implementation of these steps, stakeholders can simultaneously advance efficiency, justice, and safety on the road by working to create ethical AI practices in automotive systems.

4.3 Capturing Opportunities and Benefits of AI

As a catalyst for remarkable opportunities and benefits, the integration of AI into automotive systems holds great potential to improve user experience, safety, and efficiency. AI offers a variety of opportunities that cannot be unseen. The potential of artificial intelligence in the automotive industry is immense, ranging from self-driving capabilities that transform the notion of mobility to predictive maintenance algorithms that maximize vehicle efficiency.

"I suppose that AI will allow us to have autonomous cars to have even more entertainment, even more systems in the car that will allow us, to make it part of our ecosystem." (C5)

According to one of the responses, sellers in the automobile industry, especially those who deal in used cars, are aware of the potential advantages of artificial intelligence (AI) in improving

several areas of their business operations. They see AI as a tool to help them become more adept at cost estimation, trend prediction, and trade-in and sales price strategy optimization. AI is also thought to be able to simplify inventory control procedures, enabling more independent and effective stock management.

"On my side of the business being at the selling side, and being in the used car business, it will really help me in estimating, estimating costs of predicting market evolutions, to be able to have to do even to put even better prices on the car, both in trading as in as in selling prices to have a better and and more autonomous stock be stock inventory management." (C5)

Though the response acknowledges the potential benefits, it also raises concerns about sellers' possible lack of expertise or experience in successfully applying AI technology, underscoring the need for training and assistance in this area to fully realize the advantages of AI.

As described by the interviewee, artificial intelligence (AI) has improved autonomous vehicle innovation processes, using Tesla's strategy as an example. Instead of only enhancing current procedures, artificial intelligence (AI) emerges as a key breakthrough propelling the development of driverless cars. This change is exemplified by Tesla's journey, where the software needed to be improved even if the hardware for self-driving capabilities was in their cars since 2019. Tesla's neural network system uses a lot of data gathered from connected cars to make the switch from a multi-sensor model to an AI-powered vision-based model.

"It's more than AI is a part of the innovation too. It's an innovation in itself, enabling more features… And then instead of having to write lines of code, basically it writes itself based on the adjustments that the drivers do, and the input from the cars basically. And then, because all the cars are connected to the internet, any adjustment or update or specific route that is not accurately handled, immediately, the whole fleet knows how to handle it." (C7)

The Dojo supercomputer, a centralized supercomputer, receives this data and uses it to continuously process and improve its artificial intelligence algorithms. In contrast to traditional software development, which involves writing code by hand, Tesla's AI system adapts and changes on the fly in response to user feedback and real-world driving data. Moreover, Tesla's fleet is networked, which facilitates quick updates and modifications, guaranteeing that every car in the fleet gains from each one's experience. Consequently, Tesla has reached important benchmarks that allow its cars to operate entirely autonomously in the US. This marks the beginning of a new age in autonomous driving technology and demonstrates how AI not only improves but also fundamentally transforms the invention process.

4.3.1 Creation of New Jobs in the Future

The industry is changing because of the use of AI in autonomous vehicles and mobility solutions, which may result in new job roles and altered work schedules (Moniz et al., 2022). Regular jobs could be replaced by automation, such as visually examining cars for damage. More complex

jobs that call for subjective assessment, and consideration of long-term effects, however, are unlikely to be entirely automated. Rather, managers and AI systems work together as AI is viewed as a tool to support managerial decision-making processes.

"I think for very simple, routine tasks, AI can fully take that over. So that can be fully automated. Think, again, the automotive sector. So instead of somebody, a person visually checking old cars for dents and scratches, that is something an AI system can easily do. So those jobs might get displaced. Then, if you think about more complex tasks, for example, the manager does. So, manager, it's not like it's not a routine task. You need to be able to balance different perspectives, there will always be kind of subjective judgments, and you have to think about long-term implications. So this is something I don't think AI can automate, but AI can help us with argument augmentation. Then you will have a manager plus AI." (C3)

Considering the information provided above, the interviewee expresses optimism about AI's long-term effects and anticipates the emergence of new industries that will lead to a wide range of employment prospects. They predict that although AI could disrupt certain jobs, it will ultimately help create new jobs and advance the workforce.

"The overall impact in the long run, I think will be positive… So fairly new sectors will be created. And those will create a lot of new jobs, but different types." (C3)

All things considered, artificial intelligence (AI) is having a significant positive economic influence on the automobile industry, providing direct employment opportunities as well as indirect advantages like increased efficiency and safety and the promotion of innovation and entrepreneurship. AI is expected to have significant and far-reaching economic effects as it continues to influence how people move around in the future.

4.3.2 Accelerated Decision-Making and Research

In automotive innovation, automotive companies are spearheading the integration of AI technologies to transform decision-making processes. By drawing on advanced solvers and convergence algorithms, they facilitate accelerated decision-making by enabling faster performance prediction. Through intelligent data reuse, they automate the extraction and application of pertinent information from previous analyses, streamlining workflows and enhancing efficiency. Moreover, real-time smart sensing capabilities ensure continuous integration of simulation and test data, empowering automotive manufacturers to make informed asset operation decisions swiftly and with confidence. In the interview, it was emphasized that AI accelerates the speed of research by rapidly processing large amounts of data, accelerating analysis, and yielding valuable insights, dramatically increasing the speed and effectiveness of the research process.

"With AI, you're able to highlight or speed up research, you're able to speed up how you're approaching things…There's the AI and automotive of self-driving vehicles. And so how does that

work recognising what's going on? When does the car need to pause? When did this car need to actually accelerate even to, you know, to minimize risk or to minimize injury?" (C1)

The respondent further highlighted how the speed of research and analysis. *"You know, 100,000 last accidents in the world, you know, 100,000 accidents in the US, analyzing that data, a human would never necessarily be able to analyze that amount of data."* (C1)

The impracticality of manual analysis is highlighted by the enormous number of data being analyzed, such as the examination of thousands of accidents globally or in particular regions like the US. Automotive firms can now effectively extract useful patterns and insights from this data that would be hard for humans to do without AI-driven solutions. The industry has seen a paradigm change with the introduction of AI technologies into research and decision-making processes in the automotive sector. This has allowed for faster, more informed, and data-driven decision-making, which will ultimately result in safer and more effective cars on the road.

4.3.3 Enhanced Safety Through Simulation

Simulation-based methods offer extremely accurate and realistic environments for training and testing AI algorithms that approximate real-world driving situations while bypassing the constraints and pitfalls of basic sensor-based approaches. Simulations are not only cost-effective as they eliminate the necessity of large-scale physical prototyping and testing, but they also improve overall safety by facilitating the development of AI systems that are equipped to react effectively to dangerous scenarios without jeopardizing human lives. One of the respondents shared insight on the use of a simulation-based approach similar to Snapdragon platforms or Digital Twin technology, highlighting its application in automotive AI. This method circumvents basic sensor approaches and offers a more advanced simulation-driven strategy."

"Simulation-based approach like on snapdragon platforms or digital Twin (avoiding the basic sensor approach)." (C4)

In addition, simulations guarantee scalability to different driving circumstances, enable faster development iterations, and allow data augmentation for improved model generalization and robustness. By using simulation-based methods, the automotive industry can expedite the progress of AI, which results in safer, more efficient, and eco-friendly autonomous vehicles.

"Scaling: big data streams – opportunities cloud-based approaches AWS." (C4)

Scenario-based techniques, in which specific and individual traffic scenarios are virtually evaluated, enable the assessment of safety in automated vehicles through simulation (Riedmaier et al., 2020). With this approach, safety precautions and possible risks may be thoroughly assessed before being implemented into practice.

*"It will create AI faces based on humans just like you have AI generate pictures and you can know, the deep fakes and so on." (*C2)

Nevertheless, the response proposed addressing the problem of evaluating autonomous vehicle (AV) safety for unknown traffic scenarios by using artificial intelligence (AI) and adaptive sampling approaches. This strategy makes use of AI to examine enormous volumes of traffic data, spot trends, and create fresh, crucial scenarios. The technology ensures thorough testing by dynamically selecting and generating a variety of scenarios through adaptive sampling. AI creates realistic scenarios for robustness testing through simulation and optimization, ultimately improving AV safety assurance. This concept emphasizes how crucial AI-driven approaches are to guarantee the dependability and security of autonomous cars in ever-more-complex real-world settings.

"One of the key things when you are creating autonomous vehicles is to understand scenarios that you have. Let's say you have known safe scenarios, which is easy… then you have no unsafe scenarios, which is like a good jumping right in front of your car, you're driving 50 kilometers per hour and the kid jumps. You have to predict what other cars are going to do. And you have to predict the situation." (C2)

It is essential to combine AI-driven techniques with simulation-based technologies to guarantee the safety of autonomous vehicles. The shortcomings of simple sensor-based methods are addressed by simulations, which produce realistic environments for AI algorithms to be trained and tested.

4.3.4 Personalized Maintenance and Enhanced User Interaction

Considering the information that the interviewees shared, one of the significant opportunities that AI offers to the automotive industry is personalized maintenance and enhanced user interaction. Automotive businesses can employ AI technologies to develop customized maintenance plans based on real-time data analysis suited to the unique requirements of each vehicle (Kannally, 2023). With the help of this plan of action, predictive maintenance is possible, increasing vehicle reliability and decreasing downtime by proactively identifying and addressing possible problems. According to one of the respondents, vehicles with artificial intelligence could optimize maintenance schedules depending on driving behavior; for example, it could extend intervals for drivers who drive more leisurely and encourage more frequent repairs for drivers who drive more aggressively. Real-time data transmission from connected cars to dealerships could enable preventive maintenance notifications and improve the whole car-owning experience.

"Maybe you're supposed to get an oil change at a certain interval, well, maybe AI would be able to start taking into account…it can help you determine pay, go check your tires, go check your brakes, go check your vehicle. And also because now the cars or all the cars can be connected via a network, or internet or things, especially fleet vehicles." (C1)

Breakthroughs from companies like Siemens Digital Industries Software are reshaping user interaction and simulation processes for Stellantis. Co-pilots with AI capabilities offer context-aware workflow assistance with their natural language guidance, improving user experience and productivity. Additionally, autonomous simulations save time and resource requirements and

streamline operations by automating setup and analysis processes. Furthermore, the ability to dynamically probe simulation scenarios enables the assessment of vehicle performance across various situations, facilitating comprehensive testing and optimization. These AI-driven enhancements signify a transformative shift in automotive engineering, promising greater innovation, efficiency, and adaptability in vehicle development and testing processes.

"In the development in innovation, when you're looking at software, we're talking about also the use of AI in the enhanced user interaction." (C2)

4.4 Future Trends

The future trends in AI will be seen in various aspects of the sector. Marketing tactics, customer behavior, and the creation of intelligent mechanical materials are all anticipated to be significantly impacted by AI (Davenport et al., 2019; Jiao & Alavi, 2020). AI applications in the automotive and mobility sectors are expected to encompass not just self-driving cars but also new mobility services and in-car experiences (Kannally, 2023). With AI, improved safety features are also developing. As artificial intelligence (AI) evolves, more sophisticated technologies like lane departure alerts, pedestrian identification, and accident avoidance systems are anticipated to become commonplace. This development may result in a notable decline in traffic-related incidents and fatalities. The relationship between AI and robotics is increasingly evident, with AI playing a pivotal role in augmenting the capabilities of robots across various industries, including automotive (Kumar et al., 2021). Kumar and colleagues highlighted that combining robotics and AI has become a powerful tool for task automation in modern industries, indicating a shift towards more efficient and streamlined processes (Kumar et al., 2021).

4.4.1 The Future of AI in Automotive and its KPIs

AI in automotive technology has enormous potential to transform our understanding of transportation and vehicle operation. Artificial intelligence will be incorporated into automobiles to make them safer, more effective, and more intelligent. Artificial Intelligence (AI) has the potential to completely change driving, from advanced predictive maintenance systems to self-driving technology. This will pave the way for a day when cars are responsive, easy to use, and perfectly integrated into our everyday lives.

" Generative AI diffusion models, Reinforcement Learning, Smart AI robotics." (C4)

Respondents highlighted how key performance indicators (KPIs) are used to evaluate the impact of AI on business outcomes through several aspects.

"For R&D trying to aim for patents and collaboration with top universities for publications (KPI=number of publications).
"For mass market production, we try to achieve product integration in every vehicle that comes to market (integrated AI cameras – Infotainment) working together with hardware and software suppliers.

"For business impact, we connect this data to insurance companies that study the insurance claims of the proof of concept." (C4)

In another case, it was underlined by one of the interviewees the significance of consumer value in their methodology, especially when it comes to creating goods and services like electric cars (EVs). They emphasized the wider viewpoint of taking into account not only the worth of their customers but also the value of their client's consumers, demonstrating a customer-centric mentality. The reply proposed that time and effort savings metrics, along with using AI technology to ensure data quality and correctness, should be the main focus of key performance indicators (KPIs).

"It's all about actually customer value, of course, and I think as EV it's about customer value." (C6)

It is anticipated that in the near future, AI will move from managing specific tasks to overseeing more extensive processes, functioning as AI agents with the ability to independently strategize, refine, and enhance outputs. With this development, AI will be able to help with complete workflows instead of just specific jobs.

"Looking a bit more in the future, I would say, like a first big trend is so as I just said nowadays still very much about specific tasks you can do, I think, who will evolve to a situation where AI can take on broader tasks, so you can give it a broad task…And that way you can have AI that helps you with whole workflows instead of very specific tasks." (C3)

4.5 Management of Data Quality and Availability

The successful integration of artificial intelligence (AI) in automotive applications requires efficient management of data availability and quality. Making sure that the huge amounts of data produced by sensors, cameras, and other sources are accurate, dependable, and easily accessible is crucial. Stawiarska et al. (2021), emphasize the requirement of strong data quality management procedures and the importance of implementing quality management standards for ongoing process improvement in the automotive industry. Furthermore, Peres et al. (2020) recommend conducting additional research to optimize data quality aspects to improve Industrial AI applications. These applications can have direct relevance to AI within the automotive industry.

"Data collection quality: We create our own data by testing and experiments or simulation from different sensors and cameras and participants. The quality of the data during data collection is ensured by expensive and reliable hardware. We do proof of concepts and benchmark different sensors and cameras. We ensure data quality by preprocessing pipelines after data collection (sensor contains noise and cameras have light blur or occlusion). The hardest part is manual labeling of the data to use the supervised machine deep learning or computer vision tasks." (C4)

"Data availability: We use cloud-based solutions for big data collection and is easily accessible through the organization." (C4)

4.5.1 Bias in Data

Bias in data is a serious problem with potentially wide-ranging effects in many different fields. Data set descriptions frequently fail to mention potential sources of bias, which can result in skewed findings. As a result, the lack of transparency and potential bias in AI datasets and algorithms has been recognized as a major concern (Daneshjou et al., 2021). In the context of autonomous vehicles, the significance of addressing bias in data used for AI development in automotive applications is highlighted by challenges related to localization, mapping, scene perception, vehicle control, trajectory optimization, and higher-level planning decisions (Fridman et al., 2019). However, one of the interviewees suggests that bias in AI is a solvable problem.

"For example, with bias. You now have legislation, like the AI Act in Europe, that will demand companies that they have good data to train on. So it's not that they can choose not to do it. There will be legislation in place, especially for more high-risk applications that need to have good data. Companies will have to ensure that also, for example, minority groups will be well represented in the data. Right? So that's more on the data side of the bias, you will also see technical solutions for the bias." (C3)

"But I think my point would be that it's a solvable problem. So for example, if you talk about autonomous driving, and you train it in simulation, it's not that difficult for in your simulated setting to add more black people." (C3)

The respondent delineates many tactics utilized by their organization to guarantee the caliber and accessibility of data for artificial intelligence-oriented applications. First, they stress how crucial proactive monitoring is for spotting data irregularities and this will reduce bias in data. The organization can quickly resolve any possible difficulties by identifying any variations from regular patterns by continuously monitoring data points.

"So it's like monitoring a lot if we spot the anomaly. So we're setting up more and more monitoring to see if certain data points fall outside of normal. And then also, because we get the data from the OEM, we provide feedback to them." (C7)

In addition, the company and OEMs have implemented service level agreements (SLAs) that specify expectations for data uptime and the repercussions of not meeting these requirements.

To sum up, data bias is a serious problem that affects many industries, including the development of artificial intelligence for autonomous vehicles. The interviewees do, however, voice optimism that a combination of technical advancements and governmental actions will be able to resolve this issue. Organizations may effectively ensure data quality and reduce bias by

implementing measures such as proactive monitoring, feedback systems with OEMs, and SLA execution. Businesses can improve the fairness and integrity of AI-driven apps by tackling data bias, which will promote trust and spur innovation in the automotive sector.

4.5.2 Privacy and Security Concerns

When it comes to managing data availability and quality for artificial intelligence in automotive applications, privacy and security are major problems. The sheer amount of data being gathered by cars as they become more autonomous and linked creates serious concerns about sensitive personal data breaches, abuse, and illegal access. Nevertheless, various measures can be implemented to address privacy and security concerns. One respondent highlighted Toyota Motor Europe's approach to ensuring these aspects is safeguarded.

"User consent and Transparency: We let the participant sign the GDPR agreement and explain to the participant what data is going to be collected and how it will be used.
Anonymous data: We blur the faces in our paper publication when showing computer vision applications. We only identify participants with male or female, age, weight, and length. Concept or prototype cars are not allowed to be taken pictures or published in papers." (C4)

To address privacy concerns, one participant emphasized new technological options including federated machine learning and data clean rooms. Federated machine learning, for example, makes it possible for organizations to work together by letting them train models locally without exchanging sensitive data. These developments enable safe, data-driven cooperation while providing encouraging answers to privacy concerns.

"…something like data, clean rooms, where companies can collaborate. So they can share data without actually giving access to the other's data... what do I do with federated machine learning, I sent all of these organizations, I sent them my model. And they will train their model on their premise locally, behind closed doors. And they didn't send me the statistical data, like, for example, the weights of a neural network that they trained. And then I would aggregate that. With these types of technical solutions, I'm not seeing any of their data, right? You're just trading it locally. And there's certainly there's physical data. And there were several of these technical solutions that really will help solve privacy." (C3)

4.5.3 Faster Analysis of Vast Amounts of Data

Every respondent agreed that AI will make it possible to analyze large datasets quickly. Their mutual understanding of AI's ability to analyze and comprehend enormous volumes of data at previously unheard-of speeds led to this agreement. AI systems can efficiently sort through large datasets and extract useful insights and patterns by utilizing sophisticated algorithms and machine-learning approaches. This consensus highlights how AI can revolutionize and expedite data analysis procedures in various fields and sectors.

4.6 Successful Implementation of AI in Automotive Innovation

To propel progress in the automobile sector, artificial intelligence (AI) must be successfully incorporated into automotive innovation. Several key factors highlight the importance of incorporating AI in automotive innovation. To stay competitive in the quickly changing automotive industry, top management in automotive companies need to see AI applications as strategic core competencies (Chen et al., 2020). AI implementation requires well-structured business models that are flexible enough to leverage current technology resources (Reim et al., 2020). By integrating AI with creative business models, automakers may generate new revenue streams and value propositions.

4.6.1 Training Programs and Initiatives

Training programs and initiatives for employees in AI are crucial for the automotive industry to guarantee that staff members possess the necessary skills to properly utilize AI technology. Companies can develop in-house training courses on subjects like AI algorithms, data analysis, and machine learning that are customized to meet their unique requirements. Cross-functional training programs facilitate collaboration among different departments, and on-the-job training and mentorship accelerate skill development. Fostering a culture of continuous learning encourages employees to stay updated on the latest advancements, ultimately empowering the workforce to drive innovation and competitiveness in the automotive industry.

"Cross-functional working with specialized research AI teams. On-the-job learning and AI awareness meetings." (C4)

Another respondent emphasizes the significance of AI training initiatives for both internal staff and external customers. They provide training sessions on tool choices, practical applications, and fundamental AI concepts.

"There's a website, which is called there's an AI for that. I mean, there's like, an AI tool for everything you can imagine. So that's where we try to guide companies in how they how they can choose the right tools, how they can adopt AI in a very easy process." (C6)

Moreover, AI facilitates inclusion and accommodates individuals with disabilities in the workforce. Companies could take the initiative and admit people with disabilities to work. AI enables people with disabilities to contribute productively by customizing work settings to their capacities. For example, people with physical limitations can overcome obstacles and complete work more easily by utilizing AI-driven adaptations, such as reordering tasks or offering assistive technology.

"…maybe somebody who has a disability, AI might be able to also adjust how that person could still be active on the factory floor, or active in administration or whatever. Because hey, wait

a second, if you know, this person doesn't have a right arm, but they still know their stuff, they still can be valuable, they can still contribute." (C1)

This highlights the value of taking the initiative to overcome skill gaps by funding programs for ongoing education and training. It could be beneficial to conduct more research on the efficacy of these training initiatives and how they affect worker performance. The values of the organization and society at large are critical to the successful integration of AI to serve people with disabilities. Companies may fully utilize AI to enable people with disabilities to flourish in a variety of jobs within the automotive industry by prioritizing inclusivity and accessibility. In addition to helping people with disabilities, this strategy enriches the workforce and promotes a more varied and equitable working atmosphere.

4.7 Strategies and Tactics to Shorten the AI-Talent Gap

A comprehensive strategy comprising cooperation between the government, academic institutions, and automotive organizations is required to close the AI-talent gap in the industry (Macpherson, 2023). The primary objectives of this collaboration ought to be to enhance and refresh the skills of present staff members, draw in talent, especially for Industry 4.0 advancements, and cultivate a talent management approach (Macpherson, 2023; Sandeepanie et al., 2022). It is apparent that organizational strategies and tactics are impacted by the absence of a clear definition of talent management, underscoring the necessity of a well-defined talent management framework to effectively address the talent gap (n.d., 2018). Lastly, while businesses including the automotive sector need to embrace digital transformation, many are reluctant for a variety of reasons, such as poor communication, a lack of a well-thought-out plan, and a talent shortage (Lubis, 2022).

However, another interview highlighted that talent gaps in AI are not a major problem for their young company. This perspective challenges the common notion of a widespread talent shortage in AI-related fields. This observation may be explained by several things, including the company's location, hiring practices, or standing in the industry. Comprehending these variables may yield significant knowledge for other businesses seeking to address talent shortages in AI.

"I think we don't really have that much problems with the talent gap. Because, again, we're, we're pretty young company. For us, if we search for people, we can, we can find them still very easily… we don't have a very big talent gap… So there are a lot of engineers here. A lot of people who studied something with AI. So that's not really a problem." (C6)

4.7.1 Attract and Retain a Diverse Inflow of Employees

Organizations looking to stay competitive in the quickly changing technology world of today must prioritize attracting and keeping talent for AI roles. Proficiency in artificial intelligence is vital for propelling novelty, creating cutting-edge solutions, and preserving a competitive advantage across diverse sectors. These people contribute specific knowledge and experience that is essential

for properly harnessing AI technologies. Bringing back the human element in company culture is one way to attract and retain employees. To recruit talent, companies could promote initiatives like providing unlimited paid time off (PTO) and encouraging staff to take breaks. Emphasizing the importance of a good work environment implies that most people place a higher value on a great workplace culture than they do on pay. Nevertheless, promoting diversity and inclusion creates chances for professional development, which helps attract and retain talent.

"…But you ask the question of how to pull in more people. And so the company has been very good about like, hey, you need to take a week off here, take a week out there take two weeks off, you know, they bringing back the humanity or bringing back the human element." (C1)

"Diversity and Inclusion: We have more than 60 nationalities working. My colleagues are from all over the world from Italy, Spain, Turkey, Portugal, South America, and Japan. When you look over the border, we can attract more talent and retain them by professional development." (C4)

To remain competitive, it is essential to draw in and keep AI talent. Putting employee well-being first by implementing programs like unrestricted paid time off and cultivating a healthy workplace culture aids in luring top talent. Encouraging diversity and inclusion broadens the talent pool and helps retain talent, which in turn helps organizations use AI wisely while developing a competent workforce.

4.7.2 Role of Research and Development

Research and development (R&D) is a key enabler for the advancement of artificial intelligence (AI) technologies in the automotive industry. With R&D efforts, automotive companies can boost innovation, strengthen safety features, increase efficiency, and expand advanced AI applications for vehicles (Zhou et al., 2022).

"R&D is critical for the advancement of AI. Paper publications, Patent research, and Spin-off projects" (C4)

Starting with small-scale projects to reduce the chance of failure and keep momentum when it comes to AI research and development (R&D) within businesses is crucial. To develop early achievements and inspire excitement for AI initiatives, it is smart to start with realistic goals. The collaborative approach to AI research acknowledges that many organizations may require outside expertise to complement their R&D efforts.

"…what I would recommend for these types of companies is that they would start very small projects. Because something I see often going wrong in practice is that you have a company that says, okay, we have to do something with AI. They invest in AI, but then the project is too ambitious. And then maybe the project fails, and then the whole momentum for AI dies, and the company because they invested a lot and the project failed. So a much better approach would be to start with

small projects. To get things going have some early successes, and then you can get momentum on the R&D sides. But for many companies, will need some type of outside expertise to help them with the R&D." (C3)

5. Discussion

5.1 How can the automotive industry overcome challenges while simultaneously promoting innovation and efficacy through AI technologies?

Based on the findings provided by the multiple respondents in this research, it was previously known that several strategies can be employed to overcome challenges faced by AI in automotive while promoting innovation and efficacy through AI technologies.

First and foremost, it is critical to promote collaborative partnerships among automotive companies, suppliers, and clients. As highlighted in the research, joint R&D projects between suppliers and automotive companies can improve AI technology integration, providing greater reliability resources and mass production scalability. This finding is consistent with the literature suggesting that companies that do not foster the concept of collaborative business encounter significant challenges while attempting to establish collaborative relationships (Binder & Edwards, 2010). It is also confirmed in the findings that clients' involvement in testing and validation of AI integration in real-world scenarios ensures the robustness and safety of AI-driven automotive systems. This aligns with Kannally (2023) highlighting that descriptive models of joint activity offer prerequisites for efficient coordination that can guide the development of cooperative skills of AI technologies in this area. These needs are based on field research and observations of human coordination. To establish interactive processes and enable industry and universities to benefit mutually from government-funded research work, the automotive industry has been forming alliances and networks to facilitate the transfer of R&D capabilities (Zhao et al., 2005).

Secondly, it was mentioned by the respondents that there are various AI applications that the automotive industry can implement such as big data analytics, Natural Language Processing (NLP), and simulation tools which in turn can improve several aspects in this sector including design, manufacturing, and supply chain management. This suggests that by utilizing these AI tools, vehicle development can become more innovative, perform better, and expedite procedures. This finding is consistent with the "Future Maintenance and Service Innovation Using Industrial Big Data Analytics in The United States", (2023) which demonstrates that big data analytics offers significant advantages to the industrial sector. Furthermore, the car industry might greatly benefit from the integration of ergonomics and AI by improving vehicle manufacture and design, as well as improving user experience when driving (Puertas, 2024). It is hence confirmed in the findings that by analyzing the ergonomic aspects of driver positioning within a vehicle, computer vision technology can be utilized to assess and improve driver performance and safety.

It was found in the research that investing in AI research and development is necessary to propel innovation in the automotive sector. Automotive firms may enhance the safety, efficiency, and user experience of their vehicles by investigating AI-driven methods such as machine learning algorithms and AI Inference Engines. Adopting generative AI-enabled design tools can also encourage innovation among designers and speed up the development of new automotive models. According to Saadi and Yang (2023), AI-enabled generative design tools provide new, hybrid

modalities of collaboration between human and AI designers at different stages of the product design process.

Overcoming regulatory complexities is a crucial element that was mentioned in the findings in surmounting obstacles related to AI integration. Improving safety and confidence in AI-driven vehicle systems requires ensuring international regulatory compliance and encouraging transparency in AI algorithms. Nevertheless, Chen (2021) stated that new ethical risks are also brought about by the operational difficulties posed by inconsistent regulatory pressures, competing commercial objectives, problems with data quality, development procedures, systems integration techniques, and deployment scale. Furthermore, the establishment of requirements and standards for successful AI development is undermined by the difficulty of forecasting development decisions' impacts with any degree of reliability (Mittelstadt, 2019). Moreover, creating accountable and transparent AI systems can help with accountability in the event of an accident, particularly with driverless cars. While accuracy is important, other factors that contribute to a service's capacity to earn customers' trust include safety (including fairness and explainability), security, and provenance (Arnold et al., 2019). Transparency in AI is important because it expresses a conceptual metaphor associated with knowledge and could influence norms in regulatory discussions (Larsson & Heintz, 2020).

Lastly, promoting trust and acceptance of AI technology in the automotive sector requires resolving ethical issues including bias reduction and fairness in decision-making. Fairness and bias mitigation in AI-driven automotive systems can be achieved by putting bias mitigation techniques into practice and guaranteeing transparency in data collecting and experimentation.

In conclusion, the automotive industry can overcome obstacles while promoting innovation and efficacy through AI technologies by fostering collaborative partnerships, successfully implementing AI applications, investing in AI research and development, addressing regulatory complexities, and encouraging ethical considerations. These strategies, which are based on the results of the given research, have the potential to advance and improve competitiveness in the automotive sector.

5.2 How do the opportunities offered by AI intersect with the challenges of managing data quality and bias?

There are multiple potentials for the automotive industry to integrate AI, especially in areas like increased user interface and personalized maintenance. These developments mainly rely on the massive volumes of data that are gathered from automobiles, which allow AI systems to create customized maintenance schedules and enhance user experiences. However, there are several challenges to managing data quality and reducing bias that must be overcome for AI to be successfully implemented in these fields.

Maintaining the quality of data gathered from automobiles is crucial to guaranteeing AI systems can use it efficiently for customized maintenance schedules and interactions with users. According to Kannally (2023), not only quality of data is important but real-time data analysis which fits the needs of each vehicle can be based on AI technologies. The overall findings suggest that to get valuable insights and make informed decisions, data must be dependable, accurate, and conveniently available. Robust data quality management practices are needed for this, along with continual process enhancement and adherence to industry-specific quality management standards. To encourage vehicles to collect data, Ren et al. (2018) in an article written by He and colleagues suggested a vehicle recruitment method that would maximize the quality of the data collected (He et al., 2021). This approach highlights how essential it is to provide incentives for cars to submit high-quality data, which will raise the general caliber of the data that is gathered. Another important factor is data availability, which makes cloud-based solutions necessary for effective data collecting and accessible throughout the company. This was confirmed in the findings, suggesting that data quality and availability are needed to leverage the opportunities.

On the other hand, bias in data poses a serious problem. The fairness and accuracy of AI-driven decisions can be severely impacted by data biases, particularly when it comes to human interactions. This aligns with Agarwal (2022) which supports the finding and states that it can be difficult to maintain justice, accountability, transparency, and trust in AI-driven choices when there are biases in the data that AI systems use. This can result in biased outcomes and decision-making. There are several potential sources of bias, such as societal norms, historical trends, and the demography of data sources. To guarantee fair results and prevent the continuation of current inequities, bias in AI datasets and algorithms must be addressed. European laws like the AI Act are starting to address this problem by mandating that businesses guarantee diversity and representation in their training data. Furthermore, new technical approaches to bias mitigation are being developed, providing encouraging directions for raising the fairness of AI systems. Based on the interviews with experts, most of them agreed that the EU AI ACT should be applied and that companies should comply with the regulations.

To overcome these challenges, automotive businesses should give top priority to integrating strong data quality control protocols and bias mitigation strategies into their AI algorithms. To guarantee accuracy and representativeness, this entails making investments in top-notch data-gathering techniques, preprocessing pipelines, and data labeling procedures. Additionally, businesses should use cutting-edge AI strategies, such as simulation-based approaches as mentioned in the AI initiatives in the findings, to support data-gathering activities and improve the variety and depth of training datasets. The automotive industry may leverage artificial intelligence (AI) technologies to transform personalized maintenance and user interaction, while maintaining fairness and openness in decision-making processes, by taking proactive measures to address these challenges.

5.3 How do talent gaps in AI vary across automotive companies, and what strategies can they employ to attract and retain AI professionals, including initiatives to promote diversity and inclusion in workplace culture?

AI talent gaps in the automotive sector show significant variance depending on company age, region, and hiring policies. One of the interviewees observed that younger companies may have an easier time finding AI talent because of their unique appeal and possibly less rigid organizational structures. Conversely, well-established businesses may have difficulties arising from outdated systems or a delayed adoption of new technologies. Companies looking to effectively handle talent shortages must have a thorough understanding of these factors.

Automotive companies can use a variety of techniques to close these skill gaps and draw in and keep AI professionals. One strategy is to prioritize the human element in organizational culture, as stressed by the respondent. Encouraging work environments and offering limitless paid time off are two ways to improve employee retention and satisfaction. Furthermore, the findings also pointed out, that encouraging diversity and inclusion not only creates a more welcoming work environment but also provides chances for professional growth, which in turn draws and keeps top talent from a variety of backgrounds. Establishing in place disability-inclusive recruitment and selection processes can increase the pool of talent and foster an environment that is welcoming to AI professionals, including those who have disabilities (Carrero et al., 2019). Furthermore, by encouraging an inclusive workplace culture, organizations can attract more AI professionals by emphasizing diversity and inclusion in their employer branding (Confetto, 2023). This viewpoint was supported by the findings where the respondent sheds light on the potential of AI to facilitate inclusion and accommodate individuals with disabilities in the workforce.

Additionally, it's critical to invest in initiatives and training programs designed to advance AI skills. The importance of internal training programs, cross-functional cooperation, and on-the-job training in boosting skill development and enabling employees to spearhead innovation is emphasized in research findings. According to Maity (2019), employee advancement for AI in the automotive industry is greatly aided by training programs. The researcher highlights the significance of customizing programs to maximize their efficacy and underlines that employee engagement, involvement, and the amount of training transfer should all be taken into consideration when designing training and development programs (Maity, 2019; Billiot, 2023). Additionally, Kour and Ashraf (2018) emphasize the value of ongoing education for staff members, noting that training is necessary for skill modernization and staff development in any organization (Kour & Ashraf, 2018). Furthermore, as indicated in the research findings, beginning with small-scale AI projects enables businesses to reduce the risk of failure and sustain momentum in AI research and development initiatives, ultimately promoting talent retention and organizational success.

In conclusion, automotive companies can attract and retain AI professionals, fostering innovation and industry competitiveness, by comprehending the subtle aspects of talent gaps in AI

and putting strategic initiatives like promoting diversity and inclusion, emphasizing employee well-being, and investing in skills development into practice.

5.4 In what ways does the collaboration between AI and robotics in the automotive sector, as highlighted by Kumar et al. (2021) contribute to enhancing efficiency and streamlining processes, and what metrics can be used to evaluate the success of such initiatives?

The research findings from numerous respondents indicate that the automotive industry benefits greatly from the collaboration between robotics and artificial intelligence (AI) since it increases productivity and optimizes workflow. This is consistent with Kumar et al. (2021) research that combining robotics and artificial intelligence (AI) has emerged as a potent instrument for task automation in contemporary businesses. This suggests a move towards more streamlined and efficient procedures. Automation of repetitive operations is made possible by the integration of AI technology into robotics systems, which raises productivity and enhances product quality. Automotive manufacturers may achieve precision, accuracy, and adaptability in production operations by utilizing AI-driven robotics. Additionally, by proactively identifying maintenance needs, they can reduce downtime and optimize resource utilization.

Furthermore, according to the respondents, the incorporation of artificial intelligence and robotics in the car sector fosters innovation across multiple domains, such as supply chain management, manufacturing, and design. The implementation of artificial intelligence (AI) technologies, including big data analytics, natural language processing (NLP), and simulation tools, was emphasized by the respondents as a means of enhancing several aspects of the automotive sector. These artificial intelligence (AI) solutions support improved vehicle development, innovation, and efficiency in the industry, supporting research indicating the major benefits of big data analytics and the combination of AI and ergonomics in the automotive sector.

Investing in AI R&D becomes a critical tactic to promote innovation in the automotive industry. To improve vehicle efficiency, safety, and user experience, respondents underlined the significance of investigating AI-driven techniques such as machine learning algorithms and AI-enabled design tools. Addressing regulatory complications is also cited as a crucial component in addressing challenges associated with AI integration in this sector. The effective integration of AI technology in automotive systems requires guaranteeing accountability in the event of an accident, transparency in AI algorithms, and compliance with international regulations.

In summary, AI and robots working together in the automotive industry have the potential to completely transform several areas within the business, including customer service and manufacturing. Automotive firms can increase productivity, creativity, and regulatory compliance by deploying AI-driven robotics, which will ultimately benefit the sector as a whole.

6. Conclusion

The findings of this research suggest that automotive companies can leverage AI-driven approaches to overcome significant challenges and capture opportunities for innovation and advancement in several ways. It examines the effects of AI integration on creativity, efficiency, talent management, and cooperative partnerships in the automotive sector. Relevant findings were drawn from the examination of industry experts' responses and pertinent literature.

The world of automobiles is a mosaic of many cultures, each with its customs, traditions, and expectations. These cultural disparities have an impact on decision-making, communication, and teamwork throughout the sector. It is also quite difficult to navigate a network of regulations, which differ between nations and regions. Automakers have a tightrope to walk when it comes to safety procedures and emissions regulations. The automobile ecosystem also consists of a complicated network of dealers, suppliers, manufacturers, and service providers. Coordinated efforts and strategic alignment are needed to ensure the smooth integration of AI technology throughout this complex network. The promotion of diversity and inclusion and the resolution of regulatory complications were found to be essential tactics for overcoming challenges in the integration of AI. Automotive firms can enhance their trust and confidence in AI-driven systems by guaranteeing regulatory compliance, transparency in AI algorithms, and ethical concerns. Furthermore, promoting diversity and inclusion creates a more innovative and friendly work environment in addition to drawing in top AI talent.

It was determined that partnerships between automakers, suppliers, and clients were essential for overcoming challenges and encouraging innovation using AI technologies. Through collaborative R&D projects, these alliances provide effective coordination and skill development while guaranteeing the reliability and security of AI-driven automotive systems. Additionally, it was noted that improving the automotive industry's design, manufacturing, and supply chain management will require the integration of AI applications including big data analytics, natural language processing, simulation tools, and machine learning. Investing in AI research and development helps automotive companies improve vehicle efficiency, safety, and user experience by stimulating innovation.

Artificial intelligence emerges as a transformative light amidst these challenges, illuminating new pathways and opportunities for advancement. Think about the addition of new jobs: AI-driven breakthroughs require individuals with expertise in robotics, data science, and machine learning. The efficiency of automated jobs increases with the speed of research, freeing up human resources for higher-value projects. AI-powered predictive maintenance and real-time risk assessment are beneficial for safety, which is of utmost importance in the automotive industry. Envision customized maintenance plans based on individual driving styles and car conditions a breakthrough that increases reliability and extends vehicle lifespan. Moreover, the automotive industry acknowledged the partnership between AI and robots as a potent instrument for improving productivity and optimizing procedures. Automotive firms may enhance efficiency, optimize resource utilization, and automate repetitive processes by incorporating AI-driven robotics.

Ultimately, this thesis emphasizes how crucial it is to use cooperative collaborations, strategic efforts, and ethical considerations while implementing AI technologies to spur efficiency and innovation in the automotive sector. Car firms should position themselves for competitiveness and long-term growth in the changing automotive industry by adopting AI integration and resolving related challenges.

6.1 Theoretical Implications

My thesis findings offer several theoretical implications and contribute significantly to the academic discourse on Artificial Intelligence (AI) in the automotive industry. This study explores a range of useful artificial intelligence (AI) applications in the automobile industry, including generative AI-enabled design tools, simulation-based techniques, and natural language processing (NLP). This contributes to the theoretical understanding of how AI can be applied in the automotive sector in a variety of contexts, from design to user interface. Furthermore, the research offers into the specifics and challenges of AI implementation in a regulated and culturally diverse industry by identifying and analyzing obstacles to the integration of AI in the automotive sector, such as regulatory complexities, cultural differences, and ethical considerations. It draws attention to the opportunities and prospects that come with AI adoption in the automotive industry, such as faster decision-making, increased safety through simulation, individualized maintenance, and the creation of new job categories. By demonstrating the potential revolutionary impact of AI on numerous facets of automotive operations and user experience, this study makes a theoretical contribution.

Future research could focus on cross-cultural AI adoption in the automotive industry. The research may explore more thoroughly how cultural disparities influence the uptake and application of AI technology in the automobile sector. As well, it may examine the subtle cultural differences that affect perceptions of artificial intelligence, privacy issues, adherence to laws, and ethical considerations in various nations and areas. By executing qualitative analysis and comparative studies, researchers can determine the cultural elements that influence AI adoption strategies, decision-making procedures, and user preferences in various automotive markets. Therefore, contributing to a more comprehensive understanding of the socio-cultural dynamics.

Another significant research could be on human-AI interaction in autonomous vehicles. Subsequent studies may investigate the dynamics of human-AI interaction in self-driving cars, with an emphasis on user preferences, trust dynamics, and human-AI communication patterns. In a variety of driving situations and cultural contexts, this study could examine how consumers view and engage with AI-driven technologies including voice assistants, gesture recognition, and autonomous driving modes. Through the use of mixed-methods methodologies, which include surveys, interviews, and usability tests, researchers can identify aspects influencing user acceptance, satisfaction, and adoption of autonomous vehicle technologies. Furthermore, experimental research could assess how well various forms of human-AI interaction improve user experience, safety, and confidence in autonomous driving systems. By addressing user needs, preferences, and concerns, this area of research would help develop user-centered design concepts and standards for creating autonomous vehicles that successfully use AI technologies.

6.2 Practical and Managerial Implications

Based on the findings and conclusions of this study, several practical and managerial implications could be taken into consideration. First and foremost, the productivity, creativity, and product development processes of automotive firms can be greatly improved by integrating diverse AI applications, such as NLP, simulation, and generative design tools. By exploiting these technologies, automotive companies can improve workflow efficiency, find more efficient solutions to challenging design issues, and eventually produce cutting-edge automotive goods that satisfy changing consumer demands in this dynamic environment.

Secondly, automotive companies must give top priority to data quality management processes to guarantee the quality, reliability, and accessibility of data for AI applications. Industrial AI applications can be optimized and decision-making processes can be made more effective by putting quality management standards into place and carrying out continuous process improvement. Furthermore, it is critical to address privacy issues and bias related to AI-driven data collecting and analysis. While encouraging fairness and openness in AI systems, techniques like federated machine learning, data clean rooms, and user consent can assist reduce privacy and security threats.

Additionally, for automotive companies to remain competitive in the quickly changing technology landscape, talent acquisition and retention are critical. Innovation and advancement in AI applications for automobiles can be fueled by concentrating on attracting and retaining skilled AI professionals through professional development opportunities, diversity and inclusion programs, and a happy work environment. Besides, research and development (R&D) spending is essential to the advancement of AI technologies in the automobile sector. The future of automotive technology can be shaped by cooperative R&D efforts that begin with small-scale projects and look beyond the company for outside expertise. These activities can spur innovation and advancement in AI applications for vehicles.

6.3 Limitations and Future Research

In the course of this conducted research, several limitations were identified. While all interviewees were experts in their respective fields, one study limitation was the small sample size. The small sample size is mainly due to the novelty of AI in the automotive industry and the confidentiality constraints imposed by companies as well as time limit. This limitation may hamper the generalizability of the study's findings by impeding its capacity to adequately represent the diversity of viewpoints and experiences among the expert community. Another one is that while the native language of one interviewee was English, the majority of respondents' native language was Dutch. Conducting all interviews in English, a second language for most participants might have constrained the depth of explanation and expression.

Future research could look at the ethical considerations involved in implementing AI-based approaches in the automotive industry, focusing on algorithmic biases and the potential societal impact of autonomous vehicles. This study could investigate how algorithmic bias appears in AI

systems used in automotive settings, analyzing the potential consequences for equity, responsibility, and openness. In addition, it could explore the societal implications of autonomous vehicles, including issues related to safety, job displacement, and urban planning. Furthermore, to guarantee responsible and ethical innovation processes, the research may also suggest creating ethical frameworks and guidelines, especially for AI applications in the automobile industry. Interviewing laypeople or members of the public could be one strategy to find out how they feel about companies gathering their data. When creating data-collecting plans and privacy rules, automotive companies can benefit greatly from this method's ability to provide insights into public views, concerns, and attitudes around data-gathering activities.

6.4 Recommendations

To unlock AI's full potential, effective recommendations are essential. Firstly, extensive training programs and activities are required to close the AI talent gap for some automotive companies. Through fostering a pool of highly qualified workers, the sector can continue to lead innovation. Second, a comprehensive strategy is needed to keep these skills. Companies need to promote a collaborative, empathetic, and creative work atmosphere in addition to offering competitive compensation. Reintroducing humans into the tech-driven world guarantees long-term development. Lastly, research and development, or R&D, is essential. Advanced AI research investments combined with flexible implementation drive the next wave of automotive innovation.

Developing cooperative relationships with suppliers, customers, government agencies, and academic institutions should be a top priority for automotive companies. Collaborative research and development initiatives can augment the integration of AI technologies, enhance reliability, and guarantee scalability for large-scale manufacturing. Companies may efficiently handle industry challenges and promote innovation by exploiting collective skills and resources through the promotion of collaboration.

Adopt a variety of AI techniques, including simulation tools, big data analytics, natural language processing (NLP), machine learning, and several more, to enhance supply chain management, design, production, and other areas of the automotive industry. Businesses may improve vehicle development, boost productivity, and accelerate processes by employing these AI tools. Automotive companies may fulfill changing customer wants and remain competitive in a sector that is changing quickly by investing in AI-driven solutions.

Automakers should give the development of human-AI interface systems top priority in addition to the previously listed recommendations, especially in the context of semi-autonomous vehicles. To guarantee user acceptance, safety, and usefulness as the automotive industry moves towards semi-autonomous driving technology, it is critical to concentrate on improving human-AI system interaction.

To establish simple and smooth interactions between humans and AI systems in semi-autonomous vehicles, automotive companies should invest in user-centered design approaches. To

comprehend user preferences, behaviors, and pain points associated with AI-driven features and capabilities, conduct usability testing and user research. Businesses may develop user-friendly interfaces that promote efficient communication and cooperation between people and AI systems by integrating user feedback into the design process.

Moreover, they should provide AI algorithms that can adjust to each user's unique tastes and driving styles in semi-autonomous cars. Personalized interaction mechanisms that cater to individual needs, including voice assistants that adapt and user interfaces that can be customized, can improve user satisfaction and engagement. Automotive businesses may enhance user acceptability and happiness with AI-driven features in semi-autonomous automobiles by providing adaptive interaction.

Closing Quotation

If I had asked people what they wanted,
they would have said faster horses.
— Henry Ford

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Addendum 1: Interview Questionnaire for Economic Relevance of AI

Warm-up questions:

1. Can you introduce yourself and your title/position at the university?
2. Do you have an idea about Artificial Intelligence and AI-driven approaches?

Main Questions:

1. How would you describe the current impact of AI on the global economy, and what are some notable trends or developments in this regard?
2. In what ways do you foresee AI shaping future economic landscapes, particularly in terms of job markets, industry disruptions, and emerging sectors?
3. There is a lot of discussion about AI's potential to both create and eliminate jobs. Could you elaborate on how AI technologies might impact employment patterns across various sectors and skill levels?
4. How can businesses, governments, and individuals best prepare for the economic transformations brought about by AI? Are there specific strategies or policies that you believe are crucial for maximizing the benefits and mitigating the risks?
5. AI often raises ethical and social concerns, including issues surrounding privacy, bias, and inequality. How do these factors intersect with AI's economic impact, and what steps can be taken to ensure that AI-driven economic growth is inclusive and sustainable?

Addendum 2: Interview Questionnaire for AI in Automotive

A- Warm-up questions:

3. Can you introduce yourself and your title/position in the organization?
4. Do you have an idea about Artificial Intelligence and AI-driven approaches?

B- Main Questions:

Main RQ: Exploitation of AI-driven approaches to overcome key challenges and capture opportunities

1. What AI-driven initiatives have your company (or the automotive companies) already implemented in the realm of innovation?
2. Can you give examples of how AI has enhanced the innovation processes concerning autonomous cars?
3. What are the main challenges and opportunities the automotive industry faces while using AI and how did you address them?
4. What are the key performance indicators (KPIs) used to evaluate the impact of AI-driven innovation on business outcomes?

5. What ethical considerations does your company take into account when deploying AI in innovation processes, and can you provide some recommendations for effectively integrating AI technologies for example to enhance the safety of the car?
6. How do suppliers and clients within the automotive ecosystem go or deal with AI integration?

Sub-Q1: Quality and availability of data

1. How does your company or automotive companies, in general, ensure the quality and availability of data for AI-driven innovation efforts?
2. How do you navigate privacy and security concerns related to the use of AI in handling sensitive automotive data?
3. What role does machine learning play in optimizing production processes or product design within your company?

Sub-Q2: Required skills and expertise

1. What is the level of understanding and acceptance of AI technologies among employees in your organization?
2. What training programs or initiatives do you offer (or should automotive companies offer) to upskill employees in AI-related competencies and how do you address the talent gap in AI expertise?
3. How do you attract and retain AI talent in a competitive market?
4. How is research and development (R&D) contributing to the advancement of artificial intelligence in automotive companies?
5. What future trends or developments in AI do you foresee having the greatest impact on innovation in the automotive industry?