

The impact of the fourth industrial revolution on the transitory stage of the automotive industry

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Abstract

The fourth industrial revolution, Industry 4.0, and the Internet of Things (IoT) allow real-time communication and collaboration among machines, operators, customers, suppliers, and manufacturing sectors leading to personalized, cost-efficient, environmentally friendly products. Manufacturing sectors are acting as the backbone for industrial evolutions and the economic growth of countries, and with more than 2000 parts in just one vehicle sourced from thousands of different suppliers worldwide, the automotive industry has become one of the most complex ones, going under ever-present changes since its invention. To maintain their competitiveness in the global market and the era of Industry 4.0, automotive companies need to adopt innovative technologies internally and in cooperation with their suppliers. This chapter will focus on how Industry 4.0 is paving the path towards digitalization for the automotive industry and auto-guided vehicles. Industry 4.0 introduced a new level of organization and digitalization, focusing on controlling and monitoring during the life cycle of products. To guarantee the automotive industry digital transformation, new production and communication systems, industrial policies, and legislation adopted by automotive industries and suppliers, preventing them from falling behind their competitors. Industry 4.0 and its components are leading to innovative technologies such as auto-guided vehicles, multimodality, cars' connectivity, electrification, intelligent automotive manufacturing processes like 3D printing/Additive Manufacturing, and autonomous robots.

Key words: Industry 4.0; Automotive industry, Smart manufacturing, Sustainable manufacturing

Introduction

Industrial developments have been around for quite some time, however as stated by Rifkin, whenever transportation and communication systems are redesigned, and energy consumption is enhanced, the new revolution in the industry would begin [1]. More than 20,000 parts and components in a single vehicle, sourced from different suppliers worldwide, make the automotive industry's role in the economy incompatible with any other manufacturing industry [1, 2]. The importance of this sector is more evident by considering not just production and assembly processes but also sales and after-sales services, marketing, and maintenance of vehicles [3]. By being one of the most supplier-dependent and purchasing-dependent sectors, the automotive industry is one of the most complex manufacturers, which has gone under ever-present changes since its invention in 1886 [2].

Short after the first industrial revolution in the late 18th, which brought steam/water powered processes, inventors started to test automobiles with steam-powered engines. Those engines could power vehicles to push pistons, turning the crankshaft and wheels through produced steam by heating water in boilers. However, so much added weight to the vehicles- that were already dealing with poorly structured roads- by employing steam engines led to the invention of internal combustion engines and the Otto four-stroke cycle which was then applied to gas and petrol engines after the second industrial revolution. After the first industrial revolution and almost a century later, the transition from the first to the second industrial revolution with extensive advances in the industry that contributed to the emergence of new sources of energy (electricity, gas, and oil) took place. Other highlights of the second industrial revolution were the growing demand for steel, chemical synthesis, and communication methods such as the telegraph, wireless radio, and telephone. Mass production based on electric power and automotive conveyors is amongst the significant accomplishments of this industrial revolution. It took another century to witness the third industrial revolution in the second half of the twentieth century with the advent of another energy source called nuclear energy that was previously unusable and microprocessors. The third industrial revolution saw the beginning of electronics, telecommunications, and, of course, computers. Utilizing new technologies, the third industrial revolution opened the door to space exploration, research, computerized systems, and controls in manufacturing processes. Also, in the industrial world, two great inventions of this period, programmable logic controllers PLCs and robots, have helped usher in the age of high-level automation [1, 2].

Today, the term Industry 4.0, also known as the fourth industrial revolution, which was first used by a German professor, Klaus Schwab, in 2011, defines cyber-physical systems that enable the vision of intelligent machines controlling themselves during manufacturing processes through analyzed collected data. This information is gathered and interpreted via the internet, big data analytics, cloud computing, etc., and other types of software and hardware which have been created during the third industrial revolution and have been developing significantly [1, 3, 4].

This revolution is the age of intelligent devices, storage systems, and production equipment that can independently exchange information, perform operations, and control equipment without human intervention. In the corporate world of the 21st century, Industry 4.0 stands for a new era in manufacturing processes base on the interconnection of data flows among different actors (e.g., manufacturers, suppliers, and consumers) and vertical/horizontal intelligent linking of production processes inside organizations from the first stages to finished product [1, 3-5]. Despite the many advantages that Industry 4.0 brings, it also causes some social and environmental concerns that make

sustainable development more crucial than before. Industry 4.0 must fit into ecological and social issues without disregarding the importance of economic growth. As one of the largest industries in the world that is a pioneer in adopting industry 4.0, the question is, "what is the role of sustainable development in integrating the concept of Industry 4.0 into the automotive sector?"[3, 6, 7].

In this chapter, the evolution of cyber-physical systems enabling digitalization in the automotive industry under the umbrella of industry 4.0 is thoroughly discussed. Sustainable development and the challenges in the way of digitalization in the automotive sector, as well as the future of smart automotive industry, are also put in the following sections.

Evolution of embedded systems to cyber-physical systems in the automotive industry through industry 4.0

Due to its flexibility and versatility, an embedded system (ES), a complex set of microprocessor/microcontroller-based hardware and software systems, has been getting control of many industrial functions. This system is exclusively designed for performing dedicated functions either as a part of a whole mechanical/electronic or independent system. The basic structure of such a system includes sensors, actuators, analog-to-digital, and digital-to-analog converters, which were introduced during the third industrial revolution [8].

ES has presented a new configuration of an automatic closed-loop and real-time controller in the automotive industry since its introduction in the 1960s. By turning to be the seamless integral part of vehicles, ESs has mainly enhanced the performance, efficiency, and functionality of automobiles after the advent of semiconductor technology categorized as sensors, memory devices, microcontroller units, and transceivers employed at different levels of applications. Airbags, anti-lock braking systems (ABS), emission control, tire pressure monitor, climate control, navigational systems, satellite radio, etc., are all examples of embedded systems in automobiles to fulfill the demands for safety and comfort, optimized fuel consumption, and pollution reduction. Even though ESs have accelerated the technological transition of the automotive industry in recent years, the rapid continuous development of technology alongside modernization, artificial intelligence, vehicle electrification, and increased awareness toward global warming have driven these systems to evolve to cyber-physical systems (CPS) in industry 4.0. The embedded cognitive system will be at the heart of such transition, and CPSs communication and internal/external direct control of physical or digital processes are enabled by Industry 4.0 using information technology [8, 9].

Although industry 4.0 is based on embedded and cyber-physical systems by which the collected data come to help machines and production sectors control themselves, it also stands for a new level of mechanical intelligent manufacturing processes, including Additive Manufacturing (AM) and Robots.

The roles of each Industry 4.0's key components on the automotive industry's digitalization are explained in the following sections.

Robots

Today's world is shifting to automation, and robots, machines with the capability to handle a complex series of tasks automatically, have found enough significant applications in intelligent manufacturing to impact the value chain, especially in the automotive industry as a pioneer in the industrial usage of robots. These applications vary from welding to painting, assembling, sealing, removing materials,

coating, and transferring parts. Pick-and-place robots, for instance, lead to an increased production rate by picking up and replacing components at speeded rates. Or robots with long arms and higher payload capabilities handle spot welding on heavy body panels. As an industrial sector with the largest number of applied robots, the automotive industry utilizes robots to increase production speed, achieve higher levels of accuracy, reduce labor costs and protect employees from difficult and dangerous tasks [1, 4].

A Tier¹ supplier, Brose Ostrava employs conveyor/pick-and-place robots in material-handling applications to transport the daily received material from more than 200 suppliers and machines loading and unloading in combination with automated warehouses. Handling such repetitive, hard tasks over robots lets operators and engineers focus on other tasks with higher importance and result in higher productivity, similar to what is happening in Continental Tier 1 supplier, which employs robots to operate alongside humans for carrying PCB boards. Today's autonomous robots in the automotive sector could be fed by engineers, operators, and cloud-based systems and be controlled remotely [1].

Additive Manufacturing/3D printing

Constant competitive challenges among Original Equipment Manufacturers (OEMs) and their suppliers to achieve higher performance standards have driven them to employ high-tech manufacturing processes to overcome the problem of fuel efficiency, time consumption, cost, aerodynamics (in vehicles), innovation, safety, security, and connectivity. To fulfill one of the basic demands of customers, customization and fabrication of complex freely-designed objects with advanced and most influential attributes, additive manufacturing (AM) became one of the important parts of Industry 4.0. Significant advances in Additive Manufacturing/3D printing and its subsets, rapid prototyping², and rapid tooling³ have turned this technology into a promising method to transform the potential ways of designing, testing, and manufacturing [4, 10]. AM is building up a 3D-designed part layer by layer through a controlled material deposition. However, in the automotive industry, this technology has paved the paths for mass production of high-performance products, designed scale models for testing procedures, and passing rigorous verification, and finally, lighter and safer products, shorter lead time, and less material used and therefore lower costs [11]. Original Equipment Manufacturers and suppliers in the automotive sector benefit from rapid developments and innovations in AM and advanced materials used in 3D printers. The automotive industry is now adopting the new strategy of AM to go through the challenge of freedom of design for the advent and production of complex but lightweight components.

In the design phase of the production cycle, companies experience some difficulties before deciding on the final design. But one of the most outstanding merits of AM, enabling producing multiple variations of products with fewer additional costs and design restrictions, helps automakers enhancing their products' design by benefiting from physical models and prototypes at higher speeds. Clay models are progressively replaced by CAD-designed files, which are then converted to 3D prototypes.

Failure or malfunction of a product or part may result in catastrophic consequences. Therefore, a new component must be thoroughly evaluated to determine whether it is performing as intended or not before sending it to the market. For these purposes, rapid prototyping is an ideal option in the modern world of industry. By employing AM for rapid prototyping, testing the quality of the desired outcome will be available before the final stage of production through building prototypes. By gaining the advantages

¹ companies that supply parts or systems directly to Original Equipment Manufacturers.

² fast fabrication of a physical part, model or assembly using 3D computer aided design (CAD).

³ when Rapid Prototyping techniques and conventional tooling practices are used together to produce a mold quickly.

of minimizing inventory and avoiding overproduction, more experiments and prototyping can be performed by AM to meet the customer's and suppliers' needs, resulting in better customized and authentic products.

In the automotive industry, tooling¹'s role on the assembly line is prominent to obtain high-quality and customized tools. However, for some automobiles' components, tooling and investment casting are time-consuming and too expensive processes. By using AM in the design phase, automakers can reduce their dependence on tooling and casting. Additionally, improving fuel efficiency can be achieved via AM's ability to use light materials to produce lightweight structures without missing the strength. By exploiting the AM, automakers are now using additive technologies like Selective Laser Sintering (SLS) and Selective Laser Melting (SLM) to print different end-use components, including custom spoilers, windbreakers, bumpers, and other cars' parts. SLM is also employed to fabricate emission systems from heat-resistant Al alloys. In addition, printing pumps and valves are now available via sophisticated AM technology of Electron Beam Melting (EBM) [10].

Internet of Things (IoT)

When it first emerged, the Internet-enabled the connection between people and organizations worldwide. Still, there is now a talk on the Internet of Things, shaping Information and Communication Technologies development (ICTs) using the networked interconnection of everything in everyday life [1, 3]. As an emerging paradigm, IoT makes people's day-to-day life easier and more convenient by providing platforms for devices to communicate their physical context information like location or status to the Internet, other objects, machinery, or even humans [1, 4, 12, 13]. Moreover, beyond the existing barriers between physical and digital worlds, IoT lets physical objects identify their surroundings, interact with humans, and even make decisions and become self-controlled [1, 4, 5]. Since some technologies such as RFID², NFC³ or Sensor and Actuator Networks and even mobile phones cannot be considered as a novelty, rather than being a revolution, IoT is an evolution. However, by being embedded in Industry 4.0, IoT evolves more, experiencing an infrastructural revival in the types and number of devices it employs and how they are connected [1].

The automobile industry is on the brink of a revolution, and as one of the most critical industries, a remarkable transformation that is about to happen in this sector from human-guided to automated guided/self-driven and connected vehicles will have a long-term impact on our daily lives [8]. Of course, automobiles have been linked to smartphones, registered real-time traffic alerts, employed GPS and navigation systems, etc., for quite some time. Still, the vision of autonomous and connected cars is becoming a reality by the Internet of Things. This transformation will shift the automobile industry to the age of services and experiences from products, to software from hardware to information from functionality, and complex and connected ecosystems from industry silos [8, 9].

Connected cars can interact with their surrounding environment, which means they can communicate and transfer data to other vehicles and external devices and infrastructures using sensors and either local wireless networks or the Internet. Extrapolating the IoT concept to the automotive industry, it can be summarized into three connection branches. The first one is the connectivity of one vehicle to one or even more vehicles (Vehicle-to-vehicle (V2V)); the ability to wirelessly exchange information about

¹ Building the different types of components and machinery needed for production, like molds, jigs, and fixtures.

² Radio Frequency Identification (RFID) refers to a wireless system comprised of two components: tags and readers.

³ Near-Field Communication (NFC) is a set of communication protocols for communication between two electronic devices over a distance of 4 cm (1 1/2 in) or less.

the speed and position of surrounding vehicles shows great promise in helping to avoid crashes, ease traffic congestion, and improve the environment. The second is the connection between cars and external infrastructures (vehicle-to-infrastructure (V2I or v2i)), a communication model that allows vehicles to share information with the components that support a country's highway system, such as cameras, traffic lights, parking meters, street lights, etc. And finally, the third is a link between vehicles and external hardware or devices (vehicle-to-devices (V2D)), a particular type of vehicular communication system that consists of the exchange of information between a vehicle and any electronic device that may be connected to the vehicle itself [14].

The complete picture of connected cars and, as a result, autonomous vehicles can be achieved by managing the collected and analyzed data and connecting everything to the Internet. Safety and security systems of cars, telematics, and in-vehicle-infotainment are improving with benefiting from IoT [15]. Automatically transferring real-time data through the Internet, connected cars can send their locations to emergency teams in case of accidents (emergency call). Connected smart cars can employ IoT, integrate GPS with online services, and utilize them to driver preferences, navigating, routing, fuel station availability, traffic alerts, the expiration date of insurance alarm, avoiding a traffic jam, etc. Road conditions, other surrounding vehicles information, in-time-diagnosis of car problems are examples of IoT beneficial aspects in improving the safety of vehicles and roads. Remote control parking, stolen vehicle recovery, online in-vehicle entertainment options, etc., are also the results of embedding IoT into the automotive industry [15].

By sensing and detecting physical objects around a vehicle using built-in smart sensors and processing the received external data via algorithm software, the driving software will define the speed and direction of the car, which is expected to happen in autonomous cars based on the technology of connected cars using IoT.

Figure 1, shows the stages of connected cars' evolution from the mid-1960s to the new mobility era goes beyond 2020 based on industry 4.0.

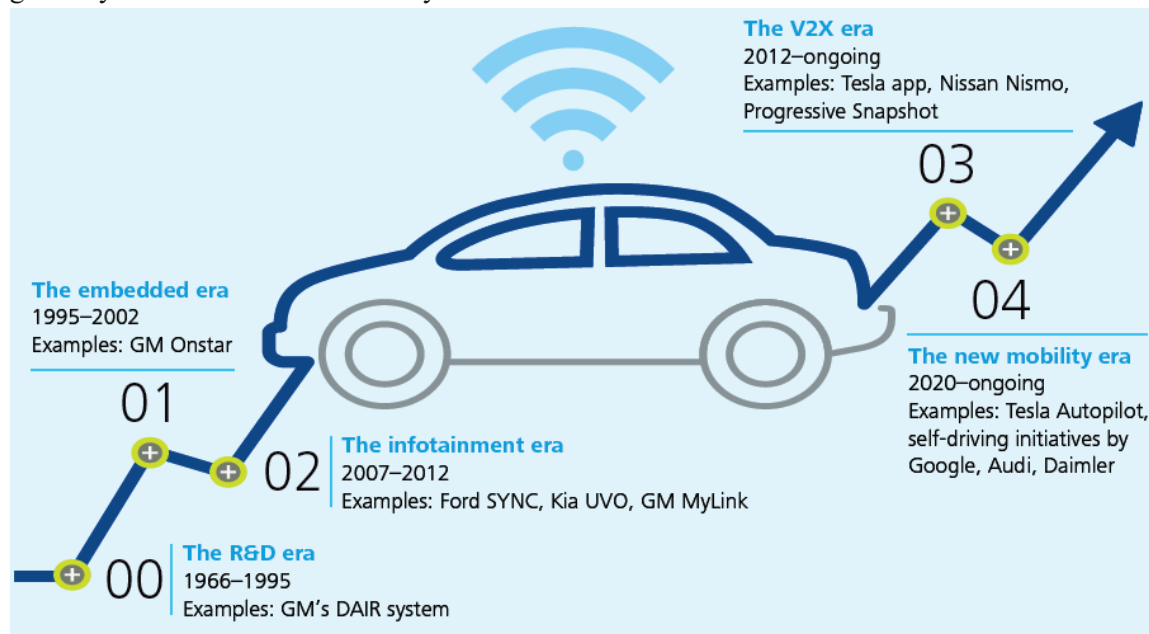


Fig.1. 5 stages of connected vehicles' evolution path [8].

Phase one was the Research and Development (R&D) era, the longest; during nearly 30 years, great innovative ideas were proposed, but lack of technology didn't let them be implemented. Next was the era of an embedded digital communication module (DCM), e.g., mobile phones and sensors used for transferring and communicating data and information wirelessly to an automaker or TSP (telematics

service provider). The infotainment (information and entertainment) era started in 2007 and lasted for five years, introduced applications based on information sharing and entertainment within a car. A shift of power equation in industries, third-party apps, software providers, and app providers are engaged in this stage.

Vehicle-to-vehicle or vehicle-to-infrastructure communication became possible by integrating electronic gadgets, smart devices, and sensors in the era of V2X integration started in 2012. And finally, the new mobility era, the stage of autonomous cars' emergence and evolution, the age of embedded industry 4.0 components in the automotive sector [8]. As an Original Equipment Manufacturer, Volkswagen uses IoT for monitoring returnable packages and load carriers across the supply network. As a result, suppliers can track components from the first point to their destinations through end-to-end visibility[1]. To be more specific, Smart manufacturing refers to data centers that are available to the users through the Internet conveniently [1, 4, 13]. The Automotive sector, with its complex requirements, is completely distinguished from other manufacturers. However, its ongoing revolution around designing, engineering, simulations, data, analytics, and dealers' network require compelling on-site IT infrastructure whose maintenance seems to be a technical challenge. With the help of its super servers, facility of transferring and processing real-time data, cloud computing can help this industry overcome the issue of the flow of information and data. The best example of the automotive industry taking advantage of technology is Google's self-driving car, which changed the impossible to the possible thing [15, 16]. In case of enhancing and leveraging the safety and security of vehicles, cloud computing helps IoT predict mechanical failures and nullifies the downtimes, alerts drivers about disruption in the road condition, etc., based on shared information and resources via V2D, V2I, and even V2V communications [16-18]. The automotive industry can benefit from cloud computing due to its faster, better, and safer data processing and storage. As the leading automotive Tier 1 supplier, Bosch set up its Cloud Backup from Team Knowhow as an easy way of keeping its files and information backed up securely online. Another example is a private cloud of Volkswagen, which provides dedicated applications for its internal operational sectors, clients, suppliers, and sales organizations [1].

Big Data and analytics

Big Data is characterized as high-variety, large-volume, high veracity, and high-velocity datasets which analyzing them using traditional processing procedures is hardly attainable [1, 5].

While volume refers to the quantity of huge and growing data on a daily basis, velocity represents the speed of generating and transferring the data. The term variety refers both to the different sources from which data is gathered and various data types. Finally, veracity means checking the reliability and accuracy of a large amount of data that comes from different sources. 4vs of big data are shown in Figure 2.

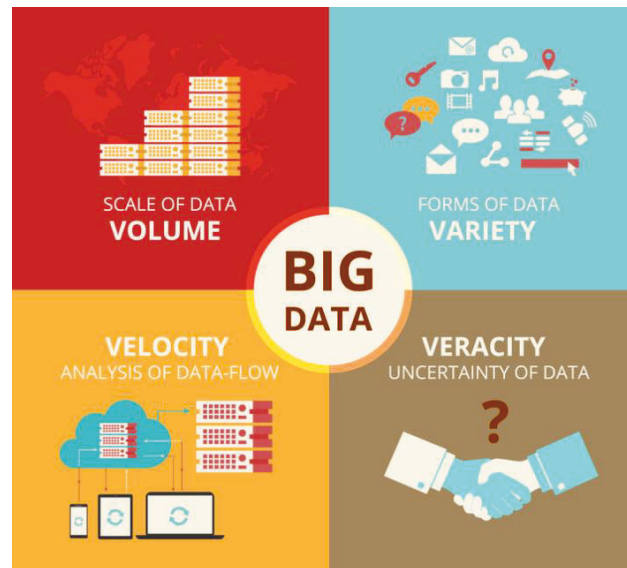


Fig.2. 4vs of big data, (adopted from: <https://www.cbpr.me/big-data-and-public-relations/4vs/>).

Internet is overgrowing these days, which means a larger amount of generated data should be gathered daily. Big data technology can analyze and separate data based on their criticality, which means more critical data from less critical ones. A clear picture of the situation based on interpreted data is transferred by this technology to fulfill business activities.

Big data analytics has become mandatory for all industries and domains because of the rapid development in networking, a higher amount of collected and stored data through IoT and cloud computing. However, the emphasis is on what an organization does with such data rather than the data volume. As an essential analytical basis for insights, big data leads to better decisions and strategic directions in business [3].

Today's high-tech era needs a 24*7 connection between automakers and users, markets, and corporations through access channels like IoT and cloud computing. The received data is enormous, and automakers are keen to employ new dealing methods to collect, analyze, and assist them in acting on such data. Getting a deep insight into the continuously obtained data from external resources via IoT is sometimes banned due to data silos. A certain automaker needs to understand their customers' priorities and needs fully to place them on the agenda and adopt better strategies to configure the optimum incentives and marketing for the targeted group of customers [19]. To protect and keep their connection with their customers, data management/Big data analytics is highly recommended for automotive industry players. They need to keep an eye on their sales, marketing, information services, and the gathered data through apps, social media, V2V, V2D, and V2I connections to target their customers' priorities. Exploiting data from modern connected cars to meet customers' needs and optimize their experience by automakers can be done by employing systems capable of capturing data from customers' experiences through different communication channels and getting a clear view of their preferences, analyzing the stored data, and finally making decisions on what is required to serve their goals effectively [19]. Sources of such big data vary from social networks (Twitter, Facebook, blogs, comments and pictures, Youtube, Instagram, etc.), business and commercial transactions, and IoT (traffic control, weather forecast systems, security cameras, and computers, internet-based systems). When conventional traditional database tools become incompetent in handling a large volume of data with great variety and velocity, big data comes into play. Hidden markets are exposed, customer preferences are found, and cost reduction is seen by an appropriate big data analysis.

Some OEMs are now using big data analytics for optimizing transportation networks such as transportation times, routing, and truckloads, forecasting transportation delays and setting alarms [1].

Blockchain

Recent advances in connected and autonomous vehicles (CAVs) made them attract more attention; however, due to safety, privacy, and security obstacles and concerns, a great uncertainty is around the re-blooming industry of the automotive. The problem is that these vehicles' operation basically depends on the online network and is susceptible to different software and hardware faults and cyberattacks. Different networks model (interconnections among entities and users) such as decentralized¹ and distributed² networks have been proposed as a substitute for centralized³ one, Figure 3. Among them, blockchain has become one of the most promising models [1, 20].

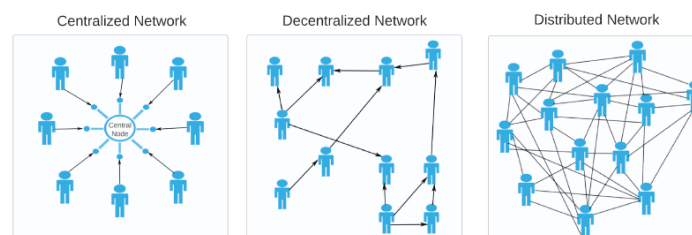


Fig.3. Schematic of three different networks models [21].

A blockchain is defined as a tamper-free/ open distributed ledger capable of storing transactions among different parties exchanged via networks in an efficient verifiable way. With these abilities, this technology can make the vehicle-related experience much better by enabling several applications. However, the automotive industry is among those industries that stand to benefit from the technology of blockchain. Blockchain can lend itself to expanding the functionality of Connected and automated vehicles (CAVs) by improving their security, enhancing users' privacy, and increasing the safety of passengers. Furthermore, the history of records on a vehicle's performance and its parts is vital for a vehicular industry; for example, this recorded data can provide information for insurance and compensation actions in accidents. Another example is odometer fraud detection; blockchain can record mileage information online, making odometer tampering easily recognizable. Daimler (a German multinational automotive corporation) joined to use the Blockchain in Transport Alliance (BiTA) to create blockchain standards in freight transportation. With the help of blockchain, it will be easy to track the automotive components through the supply chain, improve maintenance records, and recall products more precisely [20-22].

BMW is another OEM that employs blockchain to ensure the cobalt used in its battery is clean and is not mined by artisanal miners or even children under the risk of health issues or human rights abuses [1].

Virtual and Augmented reality

¹ A decentralized network has numerous connections between nodes. However, there is still the possibility of connection lost within the network.

² A distributed network has several connection paths among nodes, and the possibility of dis-connectivity has been reduced drastically.

³ A centralized network has one central node, which is several connection paths that have been derived from it.

Virtual Reality (VR)¹ and Augmented Reality (AR)² have entered the world of engineering recently. Due to the pressure of reducing time-to-market, increasing productivity and reliability, and quality of products, the automotive industry has become the leading industrial sector in employing VR/AR in different processes, from designing to manufacturing, testing, and even training [23, 24]. By virtualization, manufacturers can use cyber-physical systems and received information from sensors and other components to create virtual models that represent the physical world. Both VR and AR are widely used in logistics due to the improved efficiency they provide processes with. Logistics play a fundamental role in automotive companies by cooperating with different production processes, ensuring the supply chain of parts, and presenting the realization projects with the help of AR and VR.

Primary applications of AR/VR in the automotive sector are classified as below [23, 24]:

Design: Car designing is an expensive and time-consuming process that needs continuous reviews and modifications before reaching the final design. However, VR/AR can reduce the time and cost by substituting virtual mock-ups for physical ones. Moreover, they bring simplification in case of trial and error by avoiding rebuilding mechanical/physical parts.

Virtual Prototyping (VP): It is a sub-section of the designing process and, with recent advances, can be used to replicate physical models with less time and cost. By developing VR and VP and different software and hardware, models could be modified easily during the first stages of the production.

Manufacturing: Virtual Manufacturing (VM) is a term that describes using VR or computers for improving decision-making abilities, enhancing risks measures, and controlling the manufacturing processes more effectively.

Virtual Assembly (VA): It provides assembling and disassembling the virtual components, for example, how and where to mount parts in a vehicle.

Another usage of VR is a virtual simulation of crash tests and other phenomena such as night driving. By the ability of VR in virtual representations of the conditions of workplaces, evaluation of employees' health, safety, and well-being measures is available now.

Jaguar Land Rover (JLR) is the world's leading automaker implementing VR technologies for various automotive applications, including Cave Automatic Virtual Environment (CAVE). That is a virtual reality space where the automobile's parts act as giant projection surfaces to create a highly immersive virtual environment [24].

Artificial intelligence and deep learning

Artificial intelligence (AI) is a broad field of computer science with multiple approaches. One of the most prominent applications of this technology is automating the driving process. Since automated driving has gained much interest in the last decades, much academic and industrial research has been conducted so far. This field is a relatively new area of industry with some advantages as well as disadvantages. However, the legislature of many countries put some limitations on this technology.

One of the essential demands of this technology is an advanced sensor. Nowadays, three sensors are being utilized in semi-autonomous cars: cameras, RADAR, and LIDARS. For instance, CMOS is a

¹ A system allows users to feel they are in the real world by interacting, moving, and being immersed in a 3D environment.

² A system that uses virtual simulations for representing design workplaces and different processes.

kind of optical sensor (camera) that is widely used to aid in state-of-the-art self-driving cars. Furthermore, many researchers and engineers are trying to design more enhanced sensors. One way to improve the sensors is sensor fusion; the combination of some sensors will help self-driving cars better. Intelligent control systems in Self-Driving cars are launched by artificial intelligence. This science focus on the actual route planning process. That is, how the vehicle will move about its environment and the dynamic obstacles that it encounters. The car must have the ability to lane detection, object detection, and object classification. For this aim, the Neural Networking model, machine learning, and machine vision are performing. Apart from the design of Self-Driving cars, AI plays an essential role in manufacturing process optimization in the automotive industry. Performing Collaborative Robots, Automated Guided Vehicles, Painting Robots, and Automated Welding are examples of using AI technology in the industry, which can help to increase efficiency [25, 26].

Deep learning, also known as the deep neural network, is one of the most prominent branches of artificial intelligence (AI) that mimics how humans obtain certain kinds of knowledge. It is proven that performing deep learning in the automotive industry is very beneficial. For instance, one area that recently saw a considerable improvement in deep learning, is computer vision. Also, deep learning has several well-known applications in image analysis and image classification. Generation appropriate large amount of dataset for training networks as well as new tools and infrastructures for computation are of importance for this method. For the aim of data storage and processing, cloud computing is increasingly becoming a viable platform. Moreover, deep learning benefits online services such as image classifying in Google. Due to the fact that social data is highly unstructured, known as big data, makes deep learning a precious tool for businesses to manipulate data. These companies use deep learning to decide which concepts might be of interest to which customers [26] .

Sustainable development in the automotive industry

With today's globalization and digitalization, countries and, particularly, organizations and manufacturers face sustainability challenges. That means they need to be more socially and environmentally responsible and protective while seeking high economic performance, referring to the term "sustainable development." A straightforward definition of sustainable development is using/reusing/recycling resources to satisfy present needs without negatively impacting the next generations using these resources to meet their own needs. Sustainability guarantees long-term business success and improves living standards by balancing social, ethical, and environmental concerns and economic factors during the production processes [4, 27]. The sustainable development of the automotive industry is defined as human and planet-friendly processes and operations, final products, and services. Some major elements of sustainability in the automotive sector are as follows [7, 27, 29]:

- Sustainable R&D and engineering, which refer to designing products that aim to develop lightweight products with improved aerodynamics while using renewable and recyclable raw materials. Volkswagen is one of the industries employing raw materials, such as cotton, natural fibers, etc., for different components' production. BMW is another example of an automaker that employs sustainable design under economic policies. This company is substituting more plastic parts for metallic parts to decrease the weight and so increase fuel efficiency.
- Product's sustainability, that is moving to electric cars and even biodegradable parts. Electric and automated cars introduced by implementing CPSs of industry 4.0 into the automotive sector contribute to sustainable development by lowering the released amount of greenhouse gases,

decreasing air pollution, and providing new job vacancies, which is leading to positive social impacts.

- Sustainability in the supply chain is adopting eco-friendly operations in different logistics, warehousing, and distribution. For example, Scania is using bio-gas fuelled trucks and building gas filling stations.

Some critical challenges that automotive industries are facing in the way of intelligent transformation are as follows [1, 29]:

- Standardization -which its importance is often disregarded- is considered as a prerequisite for digital transformation in the automotive industry. However, due to the higher speed of technological developments that cause standards to fall behind and the lack of international/global standards in transportation systems, OEMs create their standards and force them on suppliers. Therefore, standardization challenges should be solved by paying more attention to funding standardization bodies and improving international cooperation relationships.
- For different companies to remain competitive in the world of industry 4.0, they have to trust in and accept technologies such as IoT, blockchain, etc., in their companies. This acceptance and trust are nothing without data security. Therefore, ensuring data security is now a significant challenge and becomes more crucial in the future as the volume of the transferred data increases every second.
- Industry 4.0 and digitalization are considerably affecting the lives of employees. Working condition/environment is swiftly changing and becoming more digitalized soon that needs more trained specialists and operators which impose cost and time burden on employers to train them. It also causes reductions in the number of staff, which is not according to the social aspect of sustainability and probably will negatively affect society with an increased number of un-employments.
- While new technologies adoption seems accessible, positive perspectives of employing high-tech devices are negatively affected by imposed huge costs of adopting and maintaining such intelligent machines and internet-based infrastructures, especially for small or medium-sized businesses.
- As one of the industries that are constantly struggling with environmental issues (e.g., CO₂ emission), the automotive industry is now facing the problem of enhancing its sustainable development. They also have to deal with social sustainability due to changing the working environment by employing different smart devices and increased unemployment rates because of robots.

Summary

The revolution of intelligent devices, storage systems, and production equipment, known as Industry 4.0, continuously changes the world and industries. As one of the world's largest companies, the automotive industry is affected by this intelligent transmission from the third to the fourth industrial revolution. This chapter introduces the automotive industry's evolution through history, from the first industrial revolution to the latest one. Different intelligent elements of Industry 4.0, including IoT, big data analytics, cloud computing, blockchain, virtual reality, artificial intelligence, and their influences on the automotive industry, are described in this chapter.

Sustainability in the automotive industry and its concept, which is now an inseparable part of the manufacturing processes, is fully explained in this chapter. It was concluded that although Industry 4.0

brings many advantages to the sustainable development of the automotive industry, it causes some challenges such as social sustainability by utilizing robots which are leading to redundancy. Integrating the automotive industry and intelligent components of the fourth industrial revolution brings some challenges, such as cyber-security, which all are introduced in this chapter. Finally, the future of the automotive industry under the umbrella of Industry 4.0 is developed based on the concept of autonomous and intelligent vehicles. However, we are still far from the idea of smart cities and transportation systems due to the limitations and challenges of digitalization.

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