THE AUTOMOTIVE INDUSTRY'S TRANSITION TO THE CIRCULAR ECONOMY THROUGH DIGITAL TRANSFORMATION

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Abstract - The importance of the double digital and climate transition is imposed by the realities we are going through. At the European level, this double transition is carefully planned and monitored. The automotive industry is part of the category of the main contributors to economic growth, to the increase in the standard of living, but it is also responsible for the generation of a large amount of waste. Car manufacturers invest around a third of EU spending on research and development, specifically to boost vehicle circularity, taking better account of the increasing complexities and specificities of vehicles, including longevity, durability and repairability.
Digitization was quickly introduced by the major car manufacturers, but also by the other actors in the value chain associated with the automotive industry in order to improve their operational efficiency. The article addresses the relevance of a synergy between the Circular Economy - part of ensuring sustainability requirements - and the rapid technological developments manifested in the automotive industry.

Keywords: Digital transformation, Automotive industry, Circular economy, Sustainable Development.

1. Introduction

1.1 Automotive Industry

The automotive industry is a major contributor to the global economy and the largest private investor in research and development in Europe [1]. Some relevant data regarding the automotive sector are as follows [2, 3]: around 13.8 million people work in the EU automotive sector; manufacturing (direct and indirect) accounts for 3.5 million jobs, sales and maintenance for 4.5 million, and transport for 5.1 million; the turnover generated by the automotive industry represents over 7 % of EU GDP; 80% of the growth in the sector is expected to occur outside the EU.

But, beyond the positives, the automotive industry has a complex network responsible for much of the environmental degradation in the value chain [4]. The automotive industry generates approximately five percent of industrial waste worldwide, and with increasing demand for electric vehicles (EVs), the consumption of battery material is increasing significantly [5]. Options for decarbonizing road transport include electrification, for example by using batteries or hydrogen instead of fossil fuels [6, 7].

Through its links with other sectors, the automotive industry has an important multiplier effect in the economy, both for upstream industries such as steel, aluminum, chemicals and textiles, glass, and for downstream industries such as ICT, repair, and mobility services.

Car manufacturers invest around a third of EU spending on research and development [8]. Much of this spending is invested in technologies to boost vehicle circularity, taking better account of the increasing complexities and specificities of vehicles, including longevity, durability and repairability.

In the medium term, improving the circularity of supply chains will further reduce Europe's dependence on raw materials and components from other regions, while increasing sustainability. To reduce bottlenecks and dependencies, the automotive industry needs resilient, circular and sustainable supply chains centered on batteries, semiconductors and green materials. It could also increase the share of local added value in critical EV components and create additional jobs and economic growth. Reusing materials from scrap batteries can save up to 10% of costs and avoid 20% of the CO_2 needed in production [9].

1.2 Twin Transition - Digitization and Climate Action Deeply Linked

Accelerating the green and digital transition is a priority for increasing the resilience of European industry. Both transitions are high on the EU's political agenda, and their interaction will have major consequences for the future.

The European Commission adopted the Communication Strategic Foresight Report 2022: "Twinning the green and digital transitions in the new geopolitical context", which identifies the key areas where political action is needed to strengthen the synergies between the dual transitions and to provide a comprehensive and targeted perspective towards the future on the interaction between the two transitions in the perspective of 2050 [10]. The European Commission has identified in this Report ten key areas in which actions will be necessary, of which, for the automotive sector, the following are of interest:

- **Greener transport -** In this field, it is stated that digitization and artificial intelligence will also stimulate the emergence of more efficient multimodal mobility solutions, such as mobility as a service or transport as a service. The new generation of batteries and digital technologies such as the Internet of Things will enable a major transition to more sustainable mobility for various modes of transport, from passenger transport to heavy vehicle transport and aviation.
- **Key technologies for bridging transitions -** If properly managed, digital technologies can help create a resource-neutral economy and society and save resources in vital economic sectors – which are also responsible for most of the greenhouse gas emissions currently recorded in the EU**.**
- **Stimulating the climate neutrality of the industry - s**mart sensors could increase energy efficiency and rational use of materials in production. Digital twins (virtual representations of objects) could improve system design and enable testing of new products, monitoring and ensuring preventive maintenance, product life cycle assessment, and optimal materials selection.

End-to-end transparency on ESG (Environment, Social, Governance) criteria such as digital traceability is an important way to make critical supply chains more sustainable. As sustainability standards in key industries begin to develop – consider the launch of the Battery Passport, which contains ESG data for batteries – the European automotive industry should remain at the forefront of ESG performance to gain and maintain competitive advantage in the future [11].

The green transition and the digital transition have specific dynamics, but their ability to reinforce each other is great. A better understanding of these interactions in the automotive industry is essential to maximize synergies.

To face the challenges generated by the double transition, green and digital, car companies have developed visions and strategic plans that are generally based on the following key objectives [12]: technologies that do not produce waste; reducing emissions throughout the life cycle; reduction of fuel consumption and alternative sources of propulsion; replacement of non-recyclable materials; reducing energy and water consumption in the production process. To maintain competitive advantage, EU efforts should focus on concluding and enforcing preferential trade and investment agreements that will facilitate access for European companies to third markets and continue to benefit from economies of scale [13].

In this context, of the double transition, green and digital, that the automotive industry is currently going through, circularity is the key to addressing environmental challenges by maximizing value retention throughout the life cycle of products and materials. To implement a circular value chain, industry stakeholders should commit to the use of recycled content and material efficiency and establish reverse end-of-life operations.

2. Digital Disruption in the Automotive Industry and Circular Economy

Oliver Wyman and the German Automobile Association have identified seven fundamental trends influencing the automotive industry until 2030, enabled and accelerated by digitization, AI and machine learning [14].

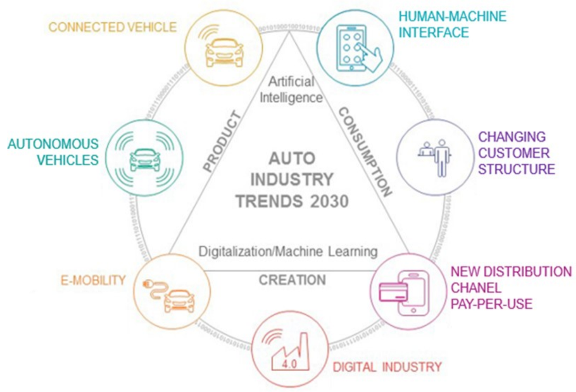

Figure 1: The Mighty Seven: Seven fundamental trends drive
Source: Oliver Wyman analysis [https://www.oliverwyman.com/our-expertise/insights/2018/jun/fast-2030.html]

In 2024, the automotive industry is increasingly integrating cutting-edge technologies into its operations. Key automotive industry trends include a significant rise in electric vehicle production, a growing market for pre-owned vehicles, and an uptick in digital car sales. Alongside established technologies like AI and big data analytics, the industry is also embracing the Internet of Things (IoT) and blockchain for diverse applications. This technological evolution is reshaping the automotive landscape, driving innovation and efficiency.

The major Automotive Industry Trends estimated for 2024 are: Autonomous Vehicles (AVs), Vehicle

Connectivity, Electrification, Shared Mobility, Artificial Intelligence, Big Data & Analytics, Human-Machine Interfaces, 3D Printing, Internet of Things [15].

Technologies such as artificial intelligence (AI) and state-of-the-art advanced driver assistance systems (ADAS), along with growing V2X infrastructure, are bringing the industry closer to self-driving functionality. As the automotive industry develops vehicles with increased levels of **autonomous driving**, the following challenges also arise:

- The increase in the number of sensors and increased connectivity, face the challenge of transporting and processing a huge amount of data in the vehicle.

-In-vehicle network complexity, power consumption, and weight must be reduced by moving from a domain-oriented network architecture to a zonal architecture.

- radar technology is constantly evolving, with increased bandwidth and resolution, as well as more complex modulation and signal processing.

- Test technology is evolving in parallel to enable the entire automotive radar ecosystem, from chipset vendors and module suppliers to OEMs and service organizations, to verify the performance of radar sensors and the ADAS functions they enable.

Connected vehicles technology brings some challenges and opens up new possibilities, applications and services. These innovative applications and services range from the switch to keyless vehicles to digital parking maps to intelligent traffic management and green environments. This comes from the abundance of in-vehicle sensing and improvements in on-board computing, networking and communication, which paves the way for innovative applications that guarantee a safer, more convenient and greener driving experience [16].

Compared to other consumer goods, technologies embedded in vehicles take relatively long to penetrate markets due to high costs, durability and strict regulation. This also applies to connected and autonomous vehicle technologies. Current barriers can be divided into technical, legal and public acceptance barriers. In the context of Europe, two important barriers are identified, namely the availability of infrastructure for testing and launching vehicles and user acceptance [17].

2.2. Digital Transformation in the Automotive Industry

Digital transformation has received widespread academic attention and has become an important background for studying strategic organizational change [16, 18, 19, 20].

Digital technologies are dramatically reshaping the industry, and companies are undertaking large-scale change efforts to capture the benefits of these trends or keep up with competitors. Any transformation is a challenge, but digital transformation goes far beyond that, requiring both business and organizational change. It requires a different mindset and should be reflected in rethinking the company's global software architecture.

Digital transformation refers to automotive companies integrating modern technologies into vehicles and business operations. The goal is to improve efficiency, meet consumer expectations and position for the future. This can involve using connected systems and data to increase the quality of production. Vehicle designs may also include new materials and methods. In sales, dealers can use displays and interactive tools to satisfy tech-savvy buyers. The focus is on providing a personalized, simplified experience. Within vehicles, connectivity platforms and advanced driver assistance systems aim to enhance comfort, safety and mobility. This extends technical innovation through the customer journey.

Digital transformation is a means for automotive OEMs and tier suppliers to modernize their processes to increase operational efficiency, create sustainable products and deliver new experiences that consumers expect. Digital transformation is a driving force in today's competitive market and a key enabler for innovation.

With the increased use of modeling and simulation, data science, analytics and other technologies in product design, companies are now connecting these technologies with product lifecycle management and virtualization to create partial or full digital twins of products. In turn, this can lead to further digitization of the production chain.

A digital thread creates a closed loop between the digital and physical worlds to optimize products, people, processes and places. With the technologies available, a holistic digital thread spans the entire product life cycle that occurs within a company and extends to suppliers, customers, and products and people in the field.

Digital transformation is achieved through enterprise technological innovation, based on open sharing and efficient use of data resources to rebuild business processes and business models to improve the user experience.

Digital Twin can help improve information management in the circular economy [20]. The Digital Twin is a virtual collection of information about a particular product and its entire life cycle – from the design phase to end-of-life management, for example in terms of recycling. It allows viewing the design parameters and status data of a real product based on its data model.

In case of changes in the state of the real product, its virtual image can be automatically updated by near-real-time transmission and evaluation of sensor data. The digital twin thus allows direct and intensive monitoring of its real counterpart.

Information can be exchanged between different processes and actors and throughout the entire life cycle. Processes and product status become more transparent and traceable [21].

2.3. Use of AI and Machine Learning Technology in the Automotive Industry

The use of AI and machine learning technology in the automotive industry has been highlighted by Fyusion, a visual intelligence company that uses AI and machine learning technology to create 360° imaging and comprehensive reporting solutions. Fyusion's patented AI algorithms enable lightweight 3D imaging, deep visual understanding, automatic damage analysis and vehicle health reporting. Fyusion technology was first introduced through consumer social media applications, attracting more than 100 million users [22].

The Inspect3D SDK enables AI-based automotive damage detection in an easy way for end users. Inspect3D's capabilities are integrated with existing workflows, but can identify for example more scratches, more of what's really in the image - more of what the human eye alone can't.

Next, the main stages are highlighted, namely capturing the image of interest, analyzing it and providing a report.

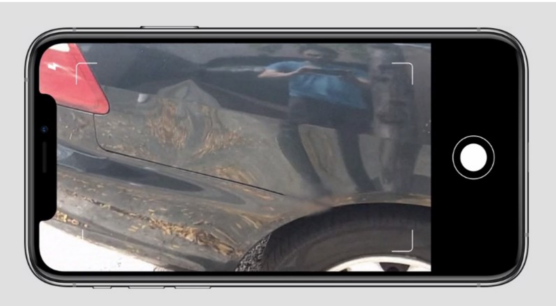

Figure 2: Capture damage in 3D with Inspect3D, Fyusion's patented 360° imaging technology
Source: https://fyusion.com/inspect3d/

Analyze step: AI consistenly identifies damage and severity.

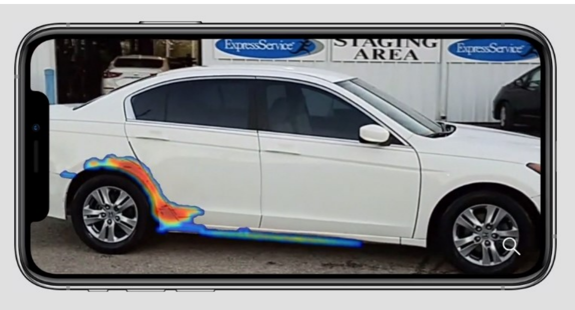

Figure 3: Analyze: AI consistently identifies damage and severity
Source: https://fyusion.com/inspect3d/

Simple visual reports are highlighted in Figure 4, bellow.

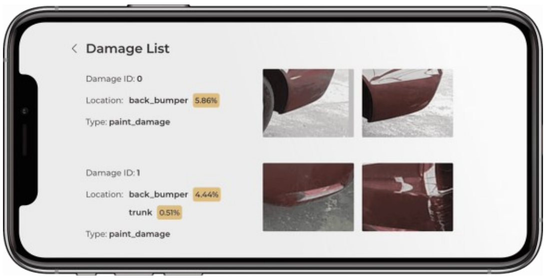

Figure 4: Simple visual reports
Source: https://fyusion.com/inspect3d/

Inspect3D SDK from Fyusion can be fully integrated into web-based solutions, embedded into the majority of mobile applications, or established as a stand-alone product, giving the flexibility to build an offering that makes the most sense for the business.

2.4. The Relevance of a Synergy between the Circular Economy and Technology

Digital technologies are transforming the automotive industry and impacting traditional business models, determining the emergence of new business opportunities related to Industry 4.0, and companies must adapt to these challenges [23, 24]. Digitization also makes networking, collaboration and co-creation (by sharing expertise between organizations and combining skills) easier and more effective with stakeholders, including customers [25].

The impact of digital transformation on the automotive industry spans different actors, from car manufacturers, service providers, public transport providers and consumers to governments [26, 27]. Optimizing energy consumption in road vehicles will be important to increase their range [28]. Fast mobile internet and universal connectivity combined with improved traffic management systems will be key to optimizing traffic flow. Mobility-as-a-Service (MaaS) is a solution where a digital platform provides integrated travel options using a variety of means in real-time. Users could make decisions based on accurate, real-time information about travel time, cost and environmental footprint. MaaS should enable users to get the best value proposition and pay for the entire journey through a single payment system.

According to the Ellen MacArthur Foundation, implementing circular business practices could save 45% of carbon emissions and 90% of wasted materials. Moreover, by implementing a data-driven "R strategy" (reuse, remanufacturing, recycling), a circular economy not only helps businesses achieve their sustainability goals, but also generates new business opportunities for industry [29].

3. Digital Transformation and Circular Economy in the Automotive Industry – Examples from the Big Producers

3.2. BMW Group

The BMW Group constantly follows the principles of the circular economy: RE:THINK, RE:DUCE, RE:USE and RE:CYCLE [30]. The BMW Group has set a target to reduce life-cycle carbon emissions per vehicle by 40% by 2030 compared to 2019, which includes an 80% carbon reduction at production level [31]. The BMW Group is strongly involved in the development of a circular economy and efficient resource management. With RE:BMW CIRCULAR LAB, a platform launched in 2021, the BMW Group is sharing insight into the company's contribution to holistic product development, careful use of resources and the transformation to a circular economy [32]. The BMW Group uses virtualization, artificial intelligence and data science to connect all relevant aspects of automobile production.

The BMW Group presented in 2022 the BMW iFACTORY, its revolutionary strategy for the production of cars of the future, implemented in all BMW Group factories worldwide. Digitization opens up new dimensions for the BMW iFACTORY. Therefore, the concept of sustainability is also reflected in Plant Lydia, BMW's Shenyang production base [33]. BMW Brilliance Automotive Werk Lydia can be considered a Metaverse factory. Integrating the virtual world with the real world shortened planning time, enabled cross-regional and cross-time zone collaboration, and effectively overcame the adverse effects of epidemics, which alone shortened the plant's construction time by six months. [34].

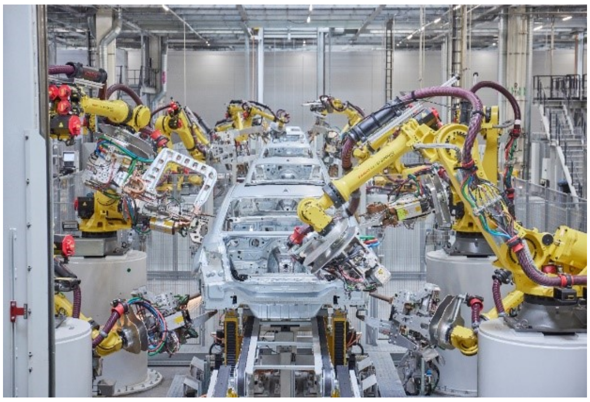

Figure 5: BMW Brilliance Automotive Werk Lydia in Shenyang, China: Bodyshop (06/2022)
Source: https://www.press.bmwgroup.com/

Plant Lydia is based on data: cloud-based digital platforms and the Industrial Internet of Things connect every product, process and person through transparent, always available and integrated data. This extensive use of data science improves quality control, increases efficiency and enables predictive maintenance. The widespread use of artificial intelligence, data analytics and algorithms has changed decision-making from "experience-driven" to "data-centric".

About 100 AI applications are currently in use at BMW's Shenyang production base. While Plant Lydia follows the BMW iFACTORY strategy of "LEAN. GREEN. and DIGITAL", it is precisely in the field of digital that the new factory is truly pioneering. With Epic Games' powerful Unreal Engine 3D creation platform as its backbone, Plant Lydia was the first BMW Group plant to be fully planned and simulated in a virtual environment from the start, with the entire production process designed virtually.

3.3. "Factory of the Future" - 5G-Enabled EV Manufacturing from FORD and Vodafone

Ford Motor Company is committed to leading the automotive industry towards a more sustainable future and using 5G to set the stage for its digital transformation. The company wanted to connect and improve its manufacturing techniques to move away from internal combustion engine technology and adopt plug-in and fully electric vehicles. Based on the success of a pilot line with 5G, Ford decided to collaborate again with its long-term partner Vodafone [35].

Towards digital transformation and sustainability, the company aims to create the "Factory of the Future", enabled by the high-bandwidth, ultra-low latency 5G Mobile Private Network (MPN). Supported by The Welding Institute, the UK Government and other partners, the project is powered by Vodafone's 5G combined with Edge Computing and AI. Connectivity solutions are helping Ford improve its manufacturing techniques to move away from internal combustion engine technology and towards plug-in and fully electric vehicles.

Vodafone 5G is completely transforming production at Ford's E:PrimE (Electrified Powertrain in Manufacturing Engineering) facility in Dunton, Essex [36]. The high-speed, low-latency 5G Mobile Private Network (MPN) enables ultra-secure data capture, real-time independent control, complete data sovereignty, remote analysis and support. 5G technology is able to provide real-time management of the data generated by the electric battery welding process. Vodafone's 5G MPN also brings greater flexibility to operations so Ford can more easily reconfigure production lines. The MPN team implemented real-time machine process analysis and control using 5G to continuously optimize vehicle manufacturing processes and improve production efficiency [37].

Analyzing real-time data from 5G-compatible sensors installed at its Dunton plant in the UK, automaker Ford Motor Co. it can monitor the production process and make rapid adjustments automatically in response to changes in the environment, input materials and other factors [38].

3.4. Re-Industry and Industrial Metaverse at Renault Group

In December 2023 – Renault Group announced the launch of Re-Industry, a plan for the profound transformation of its industrial system, with objectives of reducing industrial costs per vehicle by 2027: by 30% for thermal vehicles and 50% for electric vehicles [39].

Renault Group relies in particular on Industrial Metaverse, an accelerator of competitiveness, to reinvent automobile production. In 2022 – Groupe Renault has accelerated its digitization with the first industrial Metaverse, whereby 100% of production lines are connected (8,500 pieces of equipment), 90% of supply flows are constantly monitored and 100% of Supply Chain data is hosted in Renault Group Metaverse, a true replica of the physical world controlled in real time.

To collect data from all its industrial sites, Groupe Renault has developed a unique data capture and standardization solution, a mass data collection platform to power Metaverse industrial and thus provide the levers for process performance real-time production. This solution is now marketed in partnership with ATOS to other industrial players under the name of the ID@Scale project [40]. Groupe Renault then fashioned its physical assets into digital twins. Every factory has its replica in the virtual world. Like factories, the Supply Chain has its own digitized universe. It is an integral part of the industrial metaverse and is also controlled in real time by a control tower.

Integration into an extended ecosystem is facilitated by the use of digital twins, it is enriched with supplier data, sales forecasts, quality information, but also exogenous information such as weather or road traffic, etc., as well as Artificial Intelligence allowing the development of predictive scenarios.

The acceleration of this digital transformation is possible through the convergence of advanced technologies (Cloud, real-time, 3D, Big data). Groupe Renault has developed a unique platform for the convergence of technologies needed to run digital twins and their ecosystems in a resilient way.

The supervision offered by Metaverse through better visibility of the work environment allows the acquisition of agility and autonomy in decision-making. AI algorithms facilitate employees' ability to anticipate, as do flow optimization and management functions for supply chain experts.

8000 robots work in Renault factories, performing the most difficult and repetitive tasks: handling heavy parts or picking parts. Thus, operators are able to focus on higher value-added tasks such as engine or vehicle assembly quality.

With VR, Group Renault trains its operators, anticipates maintenance problems and performs production line simulations. For example, it studies how best to integrate a new part on the line and optimize the configuration, perform tests and adjustments without interrupting the production flow.

Groupe Renault presented its industrial Metaverse at the Technological Industry Days, with several case studies [41]:

- The Industrial Data Management Platform 4.0 (IDM4.0), developed by Renault Group, collects all Renault Group industrial data. Stored in the cloud (Google Cloud platform), this data feeds the industrial metaverse and allows correction or improvement of the production process in real time. Since 2019, 300 alerts have been detected and 300 production shutdowns avoided.
- The extended Supply Chain Control Tower is the point of convergence of the Supply Chain professions in a dedicated space: the Control Room. This global surveillance tool, which concentrates information flows, alerts in real time on risks or anomalies in all transport operations and, thanks to Artificial Intelligence, proposes optimized crisis management scenarios.
- The decarbonisation of industry is a lever for energy independence, so the Renault Group is committed to: being Net Zero Carbon by 2025 for the ElectriCity division and the Cléon plant, by 2030 for its European production sites and by 2050 for all industrial units in worldwide. Real-time monitoring of the carbon footprint of equipment and transport capacity will be an important lever for achieving the trajectory and a renewable energy mix of 50% in France by 2026 and 100% by 2030.

At the heart of Renault's Industrial Metaverse, virtual reality and artificial intelligence enable the simulation and optimization of production processes in real-time. These technologies provide unprecedented insight into operations, enabling virtual testing, adjustments, and ultimately predictive maintenance. Integrating blockchain into Industrial Metaverse ensures data security, traceability, and integrity. For Renault, this means more transparent supply chains, better inventory management, and improved quality assurance.

Industrial Metaverse enables Renault to completely rethink its production processes. Thanks to real-time simulation and analysis, the company can test new methods, anticipate potential problems and optimize production. This approach reduces times and costs while improving the overall quality of the vehicles. The carbon footprint is also significantly reduced (by 50%). The transformation process is already underway: today, 100% of production lines are connected. Supply chain and product development are being transformed by Metaverse. With more accurate data and better visibility of the entire process, Renault can make faster and more informed decisions. This agility translates into an increased ability to respond quickly to market demands and to innovate in vehicle design.

Renault Group has been engaged in Industry 4.0 since 2016. Digital technology has already led to savings of €780 million. By 2025, it will enable savings of €320 million, to which will be added €260 million in inventory savings, a 60% reduction in vehicle delivery time and a 50% reduction in carbon footprint of vehicle production, as well as a significant reduction in innovation cycles and a contribution to the 60% reduction in warranty costs targeted by Renault Grup [42].

3.5. Industry 4.0 at ŠKODA AUTO

Škoda Auto makes extensive use of industry 4.0 leading technologies at its plant in Vrchlabí, Czech Republic. Since June 2018, at its component factory in Vrchlabí, Czech Republic, Škoda Auto has been using a fully autonomous transport robot supplied by the Japanese company Omron [43].

This robot can recognize obstacles along its journey through the factory and incorporate other information from its surroundings when planning its route. If necessary, it changes its course to always reach its destination as quickly as possible. It thus contributes to the further improvement of workplace safety and the efficiency of factory transport processes. To learn the route, the vehicle only needs to be guided between stations once using a tablet or joystick and thus recognizes the environment, as well as changes in its surroundings, and adapts its route if necessary.

State-of-the-art technology allows the robot to navigate its environment; using sensors and laser scanners, it recognizes stationary vehicles and obstacles as well as people crossing its path. The control system calculates the approach speed and detects whether a collision is imminent. In this case, the robot stops itself or goes around the obstacle. Unlike other systems used by Škoda Auto, it immediately adjusts its route based on information from its surroundings, without having to stop in the process. If the fully autonomous robot detects that it will regularly encounter obstacles at a certain point along its journey, it permanently changes its route.

The robot makes 120 trips per day and covers a total distance of 35 km on its route between the mechanical measuring center and the machining machines. In a single trip, the transport robot can carry a load of up to 130 kg and chooses the correct routes completely autonomously. Unlike traditional automatic conveyor systems, it does not require web guidance in the form of induction loops, magnetic strips or reflectors. If necessary, the electrically powered system can travel to all destinations in the Vrchlabí plant, which covers 16,000 m^2.

Figure 6: ŠKODA AUTO uses LD mobile robot at Vrchlabí plant
Source*: Omron Europe*
https://industrial.omron.eu/en/solutions/blog/skoda-auto-mobile-robot

These autonomous transport robots are used, for example, to transport parts between processing machines and the measuring center as well as for automatic part ordering and delivery to CNC machining lines. The autonomous robot contributes to the continuous improvement of work safety in Vrchlabí and helps to minimize work risks. It recognizes people crossing its path, as well as other vehicles and stationary obstacles.

In production, Škoda Auto uses cooperative robots in the production of direct-shift transmissions at the Vrchlabí plant and supports employees with one of the most sensitive tasks in transmission production - the insertion of the gear actuator piston.

In July 2020, to successfully install and integrate a new robot workstation at the Škoda Auto component factory in Vrchlabí, the Czech car manufacturer used a digital twin. It consists of a 3D model of the workstation. In addition to the robot's arms and the logic behind the sensors, this also reproduces the safety devices. This allows all mechanical and kinematic processes to be realistically simulated.

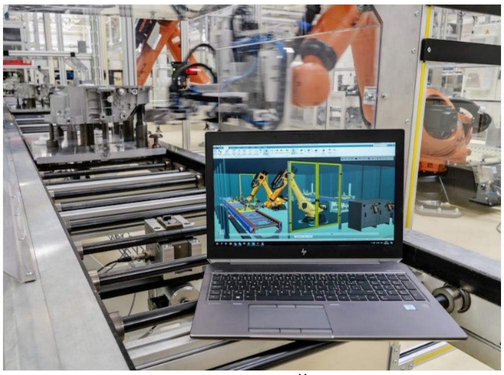

Figure 7: Digital twin used at ŠKODA AUTO Vrchlabí plant
Source: https://www.skoda-media.de/press/detail/3466/

Virtual simulation of all work steps and processes using a digital twin made it possible to configure and integrate a robot workstation during continuous operation. The software ensures communication between all hardware components as well as software-based control processes on the production line. By running all processes and scenarios in advance using digital simulation, Škoda Auto was able to shorten the duration of the operational implementation of the project by approximately three weeks, and approximately 40 square meters of production space was saved by optimizing the space for the new workstation. Robot control programs were also developed using the digital twin, even before the robots and the necessary associated peripheral systems were in the factory.

3.6. Hyundai and Kia Debut Virtual Reality (VR) Design Evaluation System

Kia Motors Corporation and Hyundai Motor Company in December 2019 launched a new car design evaluation system using Virtual Reality (VR) at the group's global design center. The new system, introduced at the R&D Center in Namyang, South Korea, demonstrates the increased focus on improving the automotive development process by implementing VR technology [44, 45].

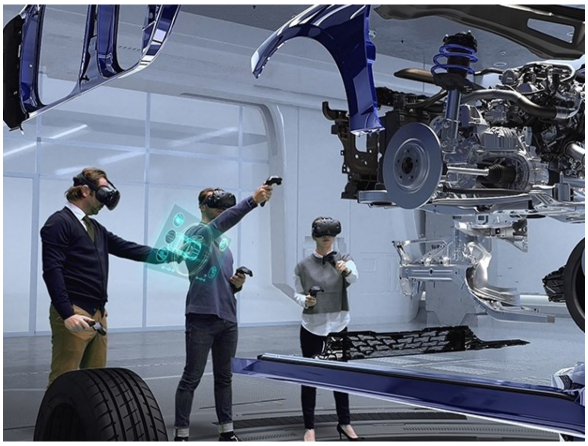

Figure 8: Hyundai and Kia Debut Virtual Reality (VR) Design Evaluation System

Source: https://press.kia.com/eu/en/home/media-resouces/press-releases/2019/Hyundai-and-Kia-Debut-VirtualReality-Design-Evaluation-System.html

Hyundai and Kia's new VR design evaluation system enables simultaneous participation in design development processes. The VR headset allows brand vehicle designers and engineers to virtually enter development simulations, with 36 motion tracking sensors that detect and track the locations and movement of all users, allowing each to participate accurately in real time. The new VR design review system can now support up to 20 simultaneous users, enabling greater collaboration between teams.

As a result, the new state-of-the-art facility allows designers at each brand to more efficiently review a multitude of design concepts earlier in the development process and in ways that were previously physically impossible. The system simulates interior and exterior design elements, lighting, colors and materials, and even the virtual environments themselves. New VR systems improve design quality and efficiency. Additional technologies and capabilities better position Hyundai and Kia to meet future mobility demands.

The technology leverages multiple development applications, enabling teams of designers and engineers to conduct vehicle design quality assessments and development verification processes. Three-dimensional computer-aided design (CAD) data collected from each stage of the vehicle development process is used to assess the quality of each design in virtual environments. The VR design quality check system is capable of 100% accurate equivalents; previous digital assessments were limited to two-dimensional analyzes and did not allow for detailed performance assessments.

The virtual development process is a necessary step to quickly respond and react nimbly to customer needs and paradigm shifts in the automotive industry at Hyundai Motor. In addition to reducing development costs, these new virtual technologies are expected to increase profitability and trigger a cycle of continued growth in R&D investment for Hyundai and Kia.

Hyundai first used this system during the design evaluation stages of the HDC-6 NEPTUNE Concept Class 8 heavy-duty truck, revealed at the 2019 North American Commercial Vehicle Show.

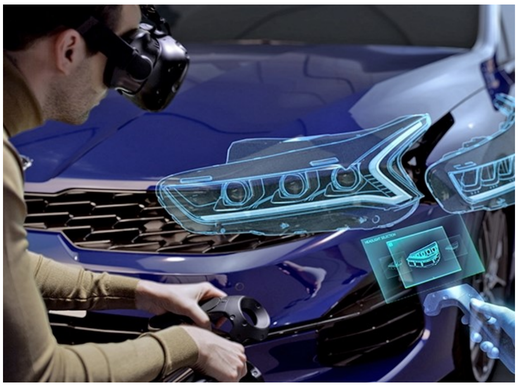

Figure 9: Hyundai and Kia: VR design quality verification

Source: https://press.kia.com/eu/en/home/media-resouces/press-releases/2019/Hyundai-and-Kia-Debut-VirtualReality-Design-Evaluation-System.html

VR design quality check processes also show tremendous potential for the development of safety technologies, as participants can virtually test vehicles in a variety of simulated environments and situations, such as highways, urban roads, hills, tunnels and conditions low lighting.

VR allows Hyundai and Kia vehicle development teams to simulate the operations of individual vehicle components such as doors, trunk lids, hoods and windshield wipers. In addition, the system allows teams to more effectively test the ergonomics and aerodynamics of the vehicle.

Hyundai and Kia also plan to further introduce VR technologies into production and assembly lines to create more ergonomic, efficient and safer work environments. Hyundai and Kia will also introduce virtual development processes in product planning and manufacturing so that it will be possible to create a research and development cycle for low-cost, high-efficiency vehicles.

Initially, virtual models will be formulated using data from an architecture-based research and development system, analyzing market demand. The model is then verified virtually, enabling the creation of harmonized and accurate performance targets based on customer requirements. Where previous quality control processes started with the manufacture of a test vehicle, this process can now be carried out virtually, at the pre-production stage.

Quality verification using virtual models and techniques in the early stages of design will ultimately improve quality control of real-world vehicles.

Other applications for virtual digital verification envisage the employment of VR in the development of future mobility solutions, such as high-level autonomous driving. These virtual verification processes accelerate development and implementation stages, and enable the company to react promptly to changing mobility.

Kia also plans to expand facility design evaluation capabilities for development use on future models. Plans to establish remote VR design assessment capabilities will enable real-time virtual collaboration between each brand's design centers in Europe, America, China, and India, along with an enhanced virtual development process through the implementation of Augmented Reality among other technologies. By fully implementing virtual development processes at all stages of R&D and pre-production, Hyundai and Kia anticipate a 20 percent reduction in vehicle development time and a 15 percent reduction in annual development costs [45].

4. Conclusions

The automotive industry is an important contributor to the global economy, the largest private investor in research and development in Europe, but it is also responsible for the environmental degradation in the value chain. The automotive industry is being reshaped by the integration of electric vehicles, the emergence of autonomous, connected vehicles, personalization, all aligned with meeting sustainability requirements.

Faced with enormous pressure to remain competitive, manufacturers are turning to technology to digitize and automate operations.

The examples from the major manufacturers in the automotive industry demonstrate their concern to include digitization for the development of new generations of vehicles, increasing productivity, reducing costs and of course achieving sustainability and energy efficiency:

With RE:BMW CIRCULAR LAB, a platform launched in 2021, the **BMW Group** is sharing insight into the company's contribution to holistic product development, careful use of resources and the transformation to a circular economy. The BMW Group uses virtualization, artificial intelligence and data science to connect all relevant aspects of automobile production. The BMW Group presented in 2022 the BMW iFACTORY, its revolutionary strategy for the production of cars of the future, implemented in all BMW Group factories worldwide. Digitization opens up new dimensions for the BMW iFACTORY. Therefore, the concept of sustainability is also reflected in Plant Lydia, BMW's Shenyang production base.

FORD, towards digital transformation and sustainability, aims to create the "Factory of the Future", enabled by the high-bandwidth, ultra-low latency 5G Mobile Private Network (MPN). Supported by The Welding Institute, the UK Government, and other partners, the project is powered by Vodafone's 5G combined with Edge Computing and AI. Connectivity solutions are helping Ford improve its manufacturing techniques to move away from internal combustion engine technology and towards plug-in and fully electric vehicles.

Renault Group launched the Re-Industry, a plan for the profound transformation of its industrial system, with objectives of reducing industrial costs per vehicle by 2027: 30% for thermal vehicles and 50% for electric vehicles. In 2022 – Groupe Renault accelerated its digitization with the first industrial Metaverse, whereby 100% of production lines are connected (8,500 pieces of equipment), 90% of supply flows are constantly monitored and 100% of Supply Chain data is hosted in Renault Group Metaverse, a true replica of the physical world controlled in real-time.

Škoda Auto makes extensive use of industry 4.0 leading technologies at its plant in Vrchlabí, Czech Republic. Since June 2018, at its component factory in Vrchlabí, Czech Republic, Škoda Auto has been using a fully autonomous transport robot supplied by the Japanese company Omron. In production, Škoda Auto uses cooperative robots in the production of direct-shift transmissions at the Vrchlabí plant and supports employees with one of the most sensitive tasks in transmission production - the insertion of the gear actuator piston. In July 2020, to successfully install and integrate a new robot workstation at the Škoda Auto component factory in Vrchlabí, the Czech car manufacturer used a digital twin.

Kia Motors Corporation and Hyundai Motor Company in December 2019 launched a new car design evaluation system using Virtual Reality (VR) at the group's global design center. The new system, introduced at the R&D Center in Namyang, South Korea, demonstrates the increased focus on improving the automotive development process by implementing VR technology.

Digital transformation is achieved through enterprise technological innovation, based on open sharing and efficient use of data resources to rebuild business processes and business models to improve the user experience.

The examples presented in this article highlight the challenges that the automotive industry is going through, in the double green and digital transition. The examples presented in this article highlight the challenges that the automotive industry is going through, in the double green and digital transition.

Digitization plays a central role in and for the successful implementation of the circular economy in the automotive industry, it forms the basis for the successful execution of industrial processes, for the economic and sustainable management of dynamic product and material flows.

Digitization, through advanced technologies such as blockchains, artificial intelligence, the Internet of Things, big data, robotics, and others, contributes substantially to closing the loop and accelerating the transition from the current linear system to a circular system in the automotive industry.

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