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Chapter 1: The evolution of automotive manufacturing and global distribution networks in the era of smart industry

1.1. Introduction

The automobile industry is a classical industry that is both capital- and technology-intensive. Since the dawn of the automobile industry, mass production has served as the competitive weapon to maximize profits through scale economies. With transnational expansion in the 1960s to 1970s, automobile manufacturers started to coordinate global production bases across nations with diverse resource endowments, wage levels, and structural economic conditions, while suppliers were subjected to the structure and patterns of global automotive networks. However, the technological and organizational evolution of global automotive networks has drawn less attention. In the era of smart factories, automobiles have also become high-tech products equipped with multiple sensors and a host of sophisticated software. Manufacturing vehicles at the power of clicks and remotely updating the software without leaving the garage represent two aspects of the automotive industry's digitization.

Due to the rise of advanced information technology, global value chains have been rearranging to build just-in-time, flexible production systems in line with the shift from product mass consumption to diversified production, and the organization of automobile manufacturers has divided the operations into multiple modules outsourced to suppliers. In the Internet of Things era, the automotive industry has entered another level of digitization besides global reconfigurations of value-adding activities and an organizational restructuring of supply networks.

Many automotive firms have been actively engaged in the smart construction of factories in the so-called Industry 4.0 era (BlazingCDN, 2024; IdeaUsher, 2024; Intelegain Technologies, 2024). The smart factory initiatives have focused on extending production and product networks along with the value chain in terms of new business models enabled by digital platforms and are also important for a spatial restructuring of production networks or changes in the geographical organization of the factories across nations. While the Industry 4.0 initiatives have highlighted a digital transformation of production processes, the “smart factory” envisions a new paradigm of manufacturing to reshape the factory itself as a production and service network, as well as an ecosystem to aggregate and utilize value-adding activities.

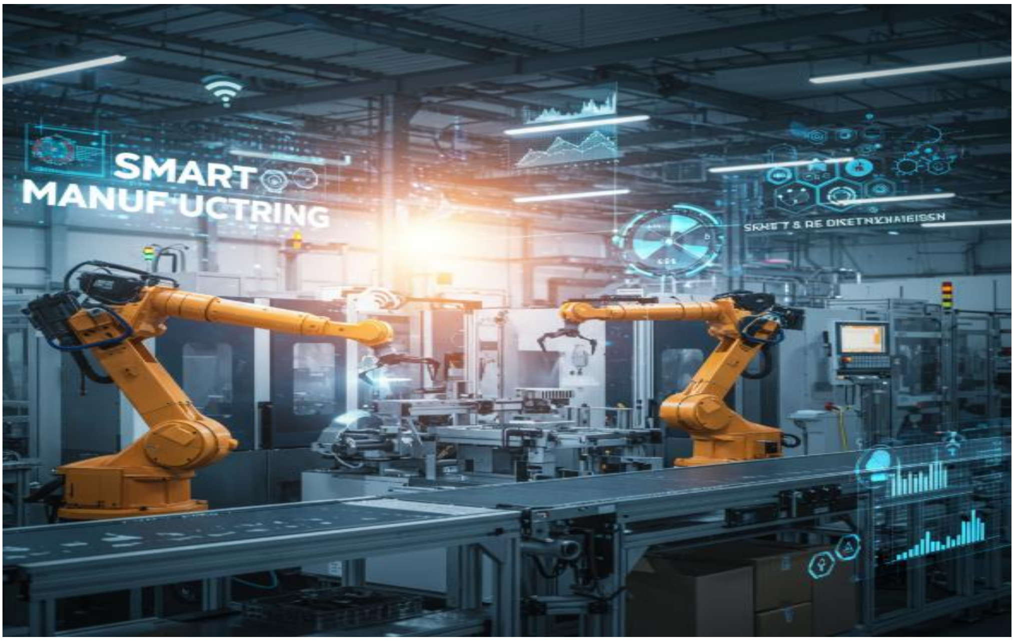

Fig 1.1: Smart Manufacturing

1.1.1. Background and Significance

The U.S. automotive industry has undergone radical transformations in the last few decades, leading to developments in automotive manufacturing, global distribution networks, and the evolution of Smart Industry. In particular, research on the automotive industry has dramatically grown since the publication of the benchmark book over two decades ago. Covered topics include the value chain structure and transformation, rivalries within and outside the industry, suppliers and the diffusion of technological innovations, spatial industrial dynamics, and consumer behavior. Over this period, the global automotive industry has faced, and continues to face, unprecedented challenges, ranging from rapid globalization to disruptive technologies and environmental crises.

Automotive manufacturers are currently at a crossroads. Not directed towards the ``next big wave” of innovation, many prominent manufacturers aim to revolutionize the automobiles they make, above all, by going beyond conventional approaches to increasing product performance, reliability and safety. Instead, they are scrambling to determine how to best manifest growing concerns about reduced energy consumption, atmospheric pollutants and greenhouse gas emissions. Based on the assumption that business as usual would lead to disaster, manufacturers' initial, if sometimes passive, approach has been to reach for "greener" or substitute technologies. However, an unintended consequence of these efforts has been the emergence of new competitors from outside the industry, who are challenging not only manufacturers' ecological relevance, viability and market share, but also their long-preferred approach, development paths, business model and supplier-customer relationships.

Competition is thus being redefined along new dimensions unable to be penetrated by conventional automotive manufacturers. Manufacturers' core components, which are the focus of their current efforts, have been "decomposed," replicated or substituted by consumer electronics. OEMs' roles within the distribution chains remain under siege as well. Some focus on the hearty, but frail, conventional car sharing market, while others are exploring partnerships in a neighborhood or regional area of Connected Automated Vehicle, Applied Wireless or the Internet of Vehicles. For those unable to uncover or maintain a suitable approach, particularly smaller manufacturers, it is feared their relevance is at stake. In sum, while safer, cleaner and less congested cars or road-based transportation is being sought after, the automotive industry, more violently than in the past, is subject to continuous upheaval.

1.2. Historical Overview of Automotive Manufacturing

It has been more than a decade since the production and logistics of automotive OEMs and suppliers began to steadily internationalize. In 2012, the top 15 automotive OEMs controlled around 75% of the assembled vehicles produced worldwide. More than 60% of the automotive components consumed in these vehicles were manufactured outside the territories where these vehicles were assembled. Whereas Ford assembled vehicles in one location and typically sourced all parts and components in the same region, today, most automotive production sites assembled vehicles from the components sourced globally. The modern automotive production network involves hundreds of manufacturing and assembly sites and dozens of firms. The automotive assembly plants' territorial offerings now encompass areas with widely varying economic, social, political, and cultural contexts. In this context, scholars, journalists, and practitioners have speculated on significant potential implications of the new 'global' production and logistics for automotive supply networks, such as an extraordinary threat to their survival. Research on automotive GPNs (Global Production Networks) and their implications for suppliers, OEMs, and the wider economy was initiated. Much has been learned about the historical evolution and the form of these networks. However, it remains equivocal how they continuously change and their implications for OEMs, suppliers, and the wider economy today. The article will use a 'network' approach to analyze supplies' how automotive production and logistics networks have changed in the last decade's global production and logistics. Extensive use is made of company reports, news reports, and trade press to compile lists of automotive supply networks. These lists are painstakingly cleaned and linked using a combination of sophisticated computer programs. Creating an exhaustive, comprehensive supply network that maps how supply networks in the automotive industry have changed over the last decade is then a question. Such research is crucial for both academia and industry, as it sheds light on automotive supply networks' drivers and implications.The core factor, the view of the product, the role of cooling in both material interaction and manufacturing performance, development of better thermal, piezoelectric, and strong piezoelectric composites, expanding substitutes, e.g. oil-hole tapes and gas-tate way design, applications for new energy vehicles, new energy automotive technology roadmap, innovative LMPV process, liquid injection techniques as molding processes and electromatic molding technologies as mold refurbishment process. The study is an on-going project that seeks to integrate during design new state-of-the-art technologies with the design of automotive manufacturing processes that utilizes the integrated resources of knowledge acquisition systems and multi-fidelity simulations.

1.2.1. The Birth of the Automotive Industry

Ford Motor Company created the automobile production line that revolutionized the relationship between mechanization, organization and productivity in American industry. The Ford Model T was a simple, sturdy, reliable, low-priced automobile. In 1914 Ford produced an unprecedented 248,070 automobiles. Other manufacturers soon adopted the car line with greater or lesser skill; output soared to over 1,400,000 by 1920. By the 1920s it was common for firms in various industries and regions to organize production on automobile production models. In addition to assembly line production the interrelated innovations of mechanization, mass production and standardization became increasingly important forms of organization in American industries. Meat packing plants and shipbuilding firms produced on a large-scale basis either by mechanizing production or organizing it by capital-intensive, variable production techniques. The contraceptive pill was standardized chemically and mass produced in large-sized lots. Machine tool builders designed simple, flexible, universal lathes, milling and drilling machinery, and incorporated them into machine shops. Ford automobiles, produced in the inexpensive, ubiquitous black Model T series configuration, were favored by many Americans; suburban commuters purchased Model Ts “sight unseen” by the thousands, traveling the earliest American roads daily. However the Model T era could not last; by the 1920s high-priced luxury cars drove the Model T from the market and Ford's manufacturing system became antiquated. Automakers were over optimistic about consumer demand for Ford's smaller, mid-priced Model A and poured in lavish, nonproductive investment to retool the factories that could not recapture the efficiencies of the Model T era. What happened to Ford was tragic not only for the employees and investors, but also for the city of Detroit, where general manufacturing prospered along with special equipment machine tool builders automated Ford's enormous shop floors by hundreds of millions. Although Ford management allocated capital in anticipation of automakers long-term needs, it was too little, too late. In 1843 Detroit began producing automobiles by steam power, but this was soon transformed into a flourishing automated industry and distribution networks which extended worldwide supporting the mass production of automobiles.

1.2.2. Key Innovations in Manufacturing Processes

Manufacturing innovation includes new processes and new technology applications, but the important aspect is their novelty and advantage (Kenility, 2024; Khambholja, 2024). The automotive industry is highly competitive, with focus on quality, price, design and flexible production to meet customers' requirements. Innovations of processes undertaken included laser welding technologies; waterways assisted injection systems; full water system cooling; 4, 6 & 8-cylinders engine production; antibacterial & bio-sourced surface coating in macrocamping; 5 panel injection system accelerator for headlining deco extrusion; environmentally friendly paint finishing Hall; high frequency induction heating for bumper thermosetting paint; thin tank monochrome coating and catadioptric mirrors pathway diffuser control knives. The technologies innovated cover material management; inter-linking of supply auto-stretch and APS; production resource inter-animation; JIT partnership logistics; initial detecting meeting-the-product data; efficiency of frequency generator and RFID Parker sorter check. The automotive industry is a highly competitive environment that forces companies to drive efficiency into all facets of operations, thereby creating a more flexible, productive and efficient transformation process. With more systems than ever in cars, comes extensive wiring and a complex supply chain. The industry is at a pivotal point to identify smart opportunities throughout the automotive manufacturing process, from the factory to the global supply chain, right through to the servicing and repair of cars across every continent.

1.3. The Impact of Technology on Automotive Manufacturing

The automotive manufacturing industry generates an annual global revenue of US$2 trillion, which is projected to decline in the coming years. The industry continuously evolves with product innovations in hardware and software layer, like the introduction of electric and hybrid vehicles in the powertrain segment. Global mega trends and their impacts on the automotive manufacturing industry can be listed as digitalization, reshoring, electrification, globalization, safety and pollution regulations, urbanization, increasing leverages, automobility as a service, skilled labor shortages, technological-innovation-leadership shift, new entrants, and changing customer expectations. In addition to these trends, a set of enabling technologies would promote automotive manufacturing towards the SMART & innovative industry. These are also known as Industry 4.0 technologies: IoT, IoE, AI, big data analytics, Cloud computing, Cyber-security, advanced software algorithms, simulation, virtual-simulation, and Augmented Reality (AR).

Fig 1.2: Automotive Industry

With the new product architecture, new systems in automotive manufacturing are necessary to be developed. A digital product definition framework, consisting of a 3D model with bill-of-materials (BoM's) and requirements, is a necessity for the new industry. To exchange data between design and manufacturing systems, a standardized description language for the 3D model is required. A semi-automatic approach for converting proprietary 3D model formats into a standardized description is presented.

Methods for transferring single 3D models, introducing a reference mesh and constraints, are applied. A methodology was also developed to transfer an assembly of parts. The clustered assembly is defined in the cloud. Access to this part-to-assembly definition is part of the cloud democratization concept. A production company is free to choose a 3D format and a power-source. The path towards production companies realizing the planned business model is presented. The outlined concepts were applied in a successful prototype working on several production facilities.

To avoid congestion in urban environments, cars become increasingly automated. The advantages of increased safety come at the cost of ethical decisions during low-probability high-consequence events when an accident cannot be avoided anymore. Probably, no perfect solutions for these cathartic events in automated driving will be found, but the questions need to be discussed to increase acceptance for highly automated driving solutions.

1.3.1. Automation and Robotics

Robots have been virtually present in industrial production since the 1950s as a concept of the mass recognition of the potential of automation. After a slow introduction, robots have found their way into many factories – especially in the automotive sector, where welding and painting jobs have been partly or even fully automated. The typical large industrial robots used for automation in manufacturing are quite immobile. They are used to perform a single, fixed job at a fixed location. Industrial production has in general lagged behind the other sectors in the introduction of IT and communication technology and has intensively used mechanical and electrical technologies. By the 1990s, manufacturing companies slowly started to equip their organizations with PLCs, which still had a very poor performance and were often integrated as autonomous islands in the production facilities. Robotic technology conceptually leads to fundamentally new designs and algorithms for the machines, refining either the mechanical, control, or software components of it. It is possible to develop mobile robots, robotic pickers that can assemble a taillight in a second in presence of at least half a dozen competing choices, or vision-based monitoring systems able to poll a complex, poorly structured environment to check where the missing bolts or nuts are.

While the hardware and software technological break-throughs necessary to grow out of the inflexible environment are on the edge of being discovered and using them in a working application, the thoughts about reading and designing factories in the light of increased flexibility have gone far ahead. Although currently, robots are basically used only for repetitive tasks for which they were explicitly programmed previously, the concept of new (robotic) machines designed according to their new degrees of freedom could lead to a new world of manufacturing. New manufacturing machines might be built that are able to autonomously reconfigure themselves, reschedule their job and communication processes on-the-fly, and interact in a physical way with the human workers.

1.3.2. The Role of Artificial Intelligence

In the new era of Smart Industry, an intelligence-driven supply chain and manufacturing networks are crucial to enhance the integration and informationization of the supply chain and manufacturing systems. Artificial Intelligence (AI), as the core engine to drive the development of smart manufacturing, is of great significance in effectively allocating the production resources for automated factories and directly influencing the passengers experience and company operating efficiency for automotive manufacturers. The development of AI technologies, including smart and connected devices, big data, natural language processing, and deep learning, has promoted the transformation of traditional manufacturing industries to smart manufacturing networks by enabling the perception, cognition and decision-making capabilities. However, with the rapid emergence of these new technologies, the integration and applications of multiple AI technologies in automotive manufacturing networks are still in their infancy. In addition, as the decision-making complexity and scale increase, AI-led strategic optimization should be conducted through a multi-agent system instead of a central optimization approach. Currently, although an increasing number of technological studies on AI in manufacturing and production networks are carried out, only limited applications have been reported in automotive manufacturing networks, especially applications of decision-making aspects. The AI technologies on demand partitioning and scheduling, factory routing, and ordering strategies have been studied. However, there are few studies regarding the integration of multiple AI technologies in adaptive resource allocation. Demand and production inventory were predicted through machine learning, which is the only manufacturing aspect involved in AI applications. No overall architecture for integration of multiple AI technologies and specific investigations are focused on distribution networks as a manufacturing perspective. The auto generated rules, as a new kind of knowledge that is transferred from data to AI models, are introduced into the multi-agent systems for achieving better interpretability and performance.

1.4. Global Distribution Networks in the Automotive Sector

The global distribution networks of the automotive sector have evolved remarkably since 2000. This change followed three phases. The first was a continued globalization of manufacturing until 2005. This led to a geographically diversified supplier base and the saturation of North America and Europe as investment centers of the automotive sector. The second phase was an abrupt drop in investment and trade, which led to a fragmented production network, while emerging countries became the main destinations for gross exports outside the European Union. The third phase began in 2010. As passenger cars accounted for an increasing share of road traffic, only a few countries remained with net imports. Based on a trade-flow analysis, this section argues that, since the mid-2010s, the automotive sector has been losing its weight relative to core industries in major regions. While this has led to a decrease in intra-regional dependence in North America and Europe, it has accelerated in Emerging Asia and, more interestingly, in East Central Europe (ECE). The globalization of the automotive trade networks continues with ECE as a target for recipient parts and low-cost assembly platforms. The expansion of the global distribution networks of the automotive sector will be examined through a sequential trade-flow analysis of the net exports of motor vehicles, parts, and accessories and other vehicles. The geographical scope is limited to the OECD member states, which include 80% of the world's total FDI stocks and over three quarters of cross-border M&As. These states are divided into major regions: North America, Europe, Emerging Asia, Japan, and ECE. Euro/Africa is not included due partly to their limited number of players.

The thesis assesses the whole spectrum of supply chains, from raw materials to dealerships, but focuses on the automotive assembly manufacturers. The article presents a case study of the Honda Accord supply chain, in which each step in the supply side business processes is covered to illustrate how the structures and retrospectively operational characteristics of every individual supply chain respond to strategic vision and execution.

1.4.1. The Evolution of Supply Chain Management

Historically, supply chains in the automotive industry have undergone three phases over the last century. The era of craftsmanship production began in the late 19th century. Production required highly skilled workers and coordination across the supply chain was poor. Shortly afterwards, in the early 20th century, the concept of mass-production was developed, aiming for shorter vehicle manufacturing times. The production concept was based on an assembly line where nearly every process time was fixed and in-cycle exchanges of semi-finished products were introduced. The concept was quickly taken over by other manufacturers. In the 1970s, the introduction of digital technology enabled manufacturing resources in cells. Since the 1980s, focus on total quality management led to manufacturing systems that were both high quality and flexible. New approaches in product design, logistics, maintenance and workforce training also emerged. To maintain high profit margins and to forward technical and procedural competencies, manufacturers have begun to purchase products and worldwide production services. In the mid-1990s, this focus shifted from the supplier-tier level to the whole supply chain. This has led to global supply networks. The auto industry supply chains are the longest in the world. It takes at least a year for an auto-motel carrier that has been ordered from a Japanese parts supplier to be manufactured, shipped to the United States, and available for retail. These networks are still evolving and rapidly becoming more global.

The thesis identifies and describes the most important trends, strategies and factors that are shaping the structure and operational characteristics of every auto industry supply chain. It is not exhaustive and states tendencies rather than certainties. All manufacturers face the same trends as well and have adopted similar strategies, but there are still considerable variations in how they protect themselves against evolution, the scenarios they address, and their overall orientation.

1.4.2. Logistics and Transportation Innovations

Over the past five decades, the competitiveness of automotive manufacturers has increasingly depended on the distribution of their plants and suppliers, and the logistics systems and networks linking them. The revolutions in transportation technologies have greatly reduced transport costs. To be competitive, also in the future, automotive manufacturers need to adapt to the resulting logistics systems and networks on a global basis, responding to ever-closer competition and customer demand for ever-shorter door-to-door delivery times. Such adaptation necessitates an element of radical redesign and wholesale implementation of new logistics technologies, methods, and transport modes on a worldwide basis. For the automotive industry worldwide, the decisions of what, where, and how to transport have consequences for the future due to which vehicles or components are produced. For the vehicle or component manufacturers, decisions translate to how they will distribute their products to their customers and stockholders. Consequently, competitive advantage will come from an understanding of these decisions and their implications .

Increased focus on logistics and transportation is not limited to the automotive industry. Globally, manufacturing, cargo, and service providers are shifting from traditional to 4.0 model-based business designs. Coined in 2014, the logistics 4.0 concept incorporates the same smart, interactive, service-oriented features that govern the smart industry movements. Logistics 4.0 broadly encompasses a digitized, fully integrated supply chain. Logistics controls are switched from monitoring-based to smart sensors, databases, and advanced analytical processing at each link in the supply chain for early identification of events requiring actions. Like smart industry, the concept of logistics 4.0 is expanding, as evident in reverse logistics 4.0 and its integration into the overall scope of an organization’s operations. Digital twin technology is already being applied in logistics applications. New features, such as distributed ledger technology, are emerging that could also fit into conventional logistics configurations within a 4.0 paradigm.

1.5. Smart Industry and Its Influence on Automotive Manufacturing

Smart Industry 4.0 technologies, such as the Internet of Things (IoT), Big Data, Artificial Intelligence (AI), and Cloud computing, are revolutionizing industrial processes and manufacturing. Their deployment in the automotive industry leads to a transformation of products, processes, and markets. The disruptive trends include advances in vehicle connectivity, automated driving, electrification, shared mobility, and new competition from information technology companies and start-ups, creating a competitive environment far more intense than before. Exerting pressure on incumbents is the focus of the “new players,” as they can offer radically novel and superior solutions to traditional products. To prevent being left behind, experimental efforts in new areas of business, technologies, and policies are being made by traditional automobile manufacturers to explore alternative trajectories toward a sustainable market position and competitiveness.

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Fig : Automotive Management

The automotive industry is also facing a major challenge where notable programs and technologies change in terms of sustainable mobility. This challenge requires a multi-disciplinary focus that can systematically analyze the interdependencies of innovative technologies with various levels of complexity for automotive products and processes, as well as sustained profits and overall market growth for a healthy economy. To promote sustainable mobility, research is needed on issues of product evolution, integration of production technology, and innovative management. The discussion about the sustainable development of the automotive industry as a whole remains scattered and rather shallow. In view of the many serious shifts, predicting likely scenarios of the automotive industry over 25 years would be most meaningful. A comprehensive assessment framework to evaluate the feasibility and desirability of these shifts is presented, as well as the exploration of business models, production resources, labor needs, ownership and competitiveness.

1.5.1. The Internet of Things (IoT) in Manufacturing

The Internet of Things (IoT) plays an important role in manufacturing as it enables interconnection of physical objects (machines, vehicles) and virtual objects (software, application protocols). The globalization process imposes increasingly high requirements on products and services provided by manufacturing companies. The set of products and services required by modern customers must meet their expectations and reliability, accessibility, usability, speed, and freedom. In turn, the perception of the value of the product or service by the customer depends on the properties of the manufactured product or service, as well as on simultaneously performed actions, including the logistics process, sales and delivery of the product or service, and after-sales service . New digital technologies, the Internet in doing business, and big data in combination with advanced analytical methods contribute to generating such value. Smart enterprises are manufacturing companies that have completed digital transformation processes. Modern global industries are connected systems, where all means of production (including machines, tools, semi-finished products, finished products, maintenance and service instruments, personnel, and modes of transport) are combined in such a way as to ensure the coherent implementation of a single technological business process at the procurement, supply of raw materials, manufacturing of products, the service and sales of products, logistics, finance, and accounting. Each industrial IoT system has to deal with large amounts of information. To purposefully process all this data effectively and efficiently, systems for collecting, storing, and processing both structured and unstructured data have to be implemented.

The presence of the Internet, mobile technologies, cloud computing, big data, and a common Internet protocol stack enable the transformation of manufacturing from isolated, mechanized systems into complex systems of systems, where the connectivity of real objects is complemented with information, communication, and cognitive capabilities. Such heterogeneous systems consist of independent and distributed individual entities that can be either a physical object (the things) or a virtual object (software, IDs, application protocols) connected to the Internet. In an industrial context, IoT systems often encompass smart things, devices and physical objects embedded with sensors and actuators that can interact in a cloud-based environment to control and monitor the performance of machines, processes or entire plants. The Fourth Industrial Revolution is characterized by the shift from traditional automation and information technology (IT) architectures in manufacturing towards IoT-based solutions. These solutions enhance the monitoring of the physical processes, improve business processes, and support the whole supply chain giving smarter access to all data generated during production.

1.5.2. Data Analytics and Decision Making

The competitive advantages associated with the Fourth Industrial Revolution, or Industry 4.0, require value creation to be based on advanced data-driven decisions in all manufacturing domains. Enabling technologies leverage the latest developments in areas such as IoT, AI, machine learning, big data analytics, and data-driven technologies connected to the Smart Industry. In addition to new technologies, a multi-discipline domain competence across engineering, manufacturing, and production is necessary to convert massive amounts of generated data from pre-existing automated systems to value-generating decision processes.

With this pipeline across a multi-disciplinary domain, manufacturing organizations can augment the intelligence and sophistication of production systems, addressing three major challenges concerning data volume, variety, and velocity. These challenges must be overcome at its nodes across a scalable distributed architecture with processing units that operate on the received data, in real-time, at the edge. With several case studies, it has been shown that data-driven decision-making significantly increases productivity, efficiency, and quality in industrial production systems depending on large-scale and real-time processing of heterogeneous industrial data at a distributed edge, cloud, and on-prem.fs. In the i4.0 (of Industry) treatment of manufacturing, this is pursued by adopting a human-centric approach with advanced automation and at the same time increasing the speed and volume of data. New batch processes such as additive manufacturing lead to extensive 5G networks or edge-cloud configurations to be engineered and constructed. The increasing automation with the trend of Industrial AI also leads to the bottlenecks of integration and interoperability.

Data analytics provides value creation capabilities companioned with its associated data infrastructure. However, traditional approaches relying on pre-processing data presentation metrics for visualization and reflection depend too much on the where-withal of operating engineers. Rather incapable of monitoring diverse phenomena across unlimited objects and time spans let alone applying semi-automatic or automatic data-driven decision-making directly.

1.6. Sustainability in Automotive Manufacturing

The automotive industry's approach towards sustainability can be encapsulated within two broader internal initiatives: establishing 'lean' production and consumption systems, coupled with green, ecological concepts, schemes, industrial process and production technologies. Currently, concepts arising from this sustainability initiative canvass both consumer and production parameters from the viewpoint of external efforts towards sustainability of the entire production and consumption chain. This embodies the principles of life cycle analysis (LCA), carbon footprints (CF), etc. Alongside, there are internal guidelines governing policy objectives and components. Most evolutionary literature of the lean approach in the automotive industry is directed towards initial conditions of being 'lean'. There's been relatively little reference to the conceptualisation and feasibility of sustaining automotive lean systems in a continued mode. Each of the steps in this initial, more or less coherent, consideration set is viewed as internal to today's production commodity. In this sense, these correspond to the types of issues already raised by the earlier evolutionary literature. As well, in contrasting this with earlier evolutionary discussions, it could be remarked that from today's perspective the automotive industry did get through this initial period of 'lean' successfully, creating new companies and terminating the less effective ones.

There is an expectation that the automotive industry should possess the capability of 'sustaining' this choice of approach, particularly as global players where business and management systems are essentially the same. Here the emphasis has shifted towards: the possibility and desirability of viewing such choice as a premise towards sustainability. The consideration set raised as internal choice parameters focused towards those aspects particulate to the automotive sector. Mindful of the extent of this notion of 'sustaining it', through its most relevant product generations and relative competencia this consideration set would exhaustively cover supply chain, production, and product/process outcome effect. On the other hand, along with since there have arisen notions condensing with the 'green' approach towards manufacturing, these two approaches currently form, along with demand external effects, a triple service structure. The present literature describes and conveys these articles as 'lean and green'. There's an implied expectation business systems of this kind would, no matter the complexities involved, enable a manufacturing system wide establishment of the principles involved.

1.6.1. Eco-friendly Manufacturing Practices

In the inherent pursuit of sustainable operations, manufacturing sectors continually strive to improve performance by reducing wastes on one hand, while improving eco-friendliness of their operations on the other hand. Hence, this concept is basically narrowed down to two perspectives, that is, sustainable lean manufacturing practices and practices pertaining specifically to eco-friendly manufacturing. For example, in this new millennium, as the automotive assembly industry gears up towards this ecologized and lean production system, it must not take for granted the clear potential of eco-friendly policies. The gradual shift to lower carbon power supplies with carbon capture and storage research and development are anticipated, and clear regulatory pressures are likely. A creative approach to re-use and recycling at the end-of-life stage of vehicles, manufacturers and recyclers-problems can be swiftly anticipated and explored.

In consonance with the five pillars of lean manufacturing such as automation, continuous waste removal, work cell line flow, responsive scheduling and standardization, these eco-friendly policies therefore are tentatively proposed as potentially viable policies for both environmentally sustainable and economically sound production systems. In an automotive manufacturing plant, resource consumption in its entire production process is unavoidably entangled with direct waste generation of pollutants and indirect waste production of greenhouse gas emitting ingredients. Therefore, this green policy in either aspect of the production stage would yield two-fold benefits of both improving eco-friendliness and reducing wastes, i.e., cost savings. In the past decades, many automakers have applied this eco-friendly policy, including re-manufacturing, energy conservation and recycling in both operational fixtures and processes.

The manufacturing industry employs various measures to improve products, processes and production practices while minimising environmental pollution, wastes and natural resource consumption. Inconsistencies and divisions on green practices and performance measures across the global automotive supply chain create dilemmas for redress and improvements.

1.6.2. Circular Economy in the Automotive Sector

In line with the EU's Green Deal, the automotive sector is aiming for a climate-neutral economy by 2050. In this regard, future-proofed mobility is based on zero-emission vehicles, ideally running on a carbon-neutral battery. The debate about the environmental situation is often reduced to a discussion of battery technology. The great passion for battery-powered e-mobility is understandable. However, there are also hopes for fuel cells powered by hydrogen and for a biofuel-based traffic system. The latter is often considered as a good or very good possibility. But it's important not to overlook the fact that the respective availability and feasibility of the energy carriers, which is determined by infrastructural and other investments, are entirely different. And not to forget: In any case, the total CO2 footprint of the production and recycling processes of future mobility options has to be adapted to the respective future mobility scenario, be that battery electric, fuel cell electric, or biofuel based systems.

In the future, there are excellent chances for a circular economy with a global battery supply chain. The solution is a 'circular economy' of zero-waste processes. The objective is a sustainable closed-loop solution for resources, processes, and products in the electric vehicle and battery supply value chain with safety and social performance. In this regard, two key challenges basically define the future of automotive value chains: (1) The transition from combustion engine based to electric vehicle-based mobility systems in private and commercial transportation. And (2) the transition from a linear take-make-dispose economy to a circular economy with a shrinking value in use period and high recycling rates. These challenges aim to increase the sustainability of supply chains, thus reducing the supply risk of resources and the overall carbon footprint of the product and process.

Economic and social transformations are elemental, in particular, a successful energy transition toward carbon-neutral mobility systems and a circular economy. These transformations will demand large-scale statewide investments, human and technological capacities, and new international partnerships. But the existing and nascent partnerships with the automotive on-board computer would take over significant decision-making for general transport or manufacture processes in the era of Industry 4.0.

1.7. Conclusion

The automotive industry can be characterized as a factory and market. The automotive industry is a factory because producers design, produce and distribute automobiles from all its parts, which are themselves manufactured by suppliers in the Global Production Network (GPN) formed by the automotive industry. Trade patterns are the links and flows of parts and automobiles in this GPN, which are influenced by various factors. The automotive industry is a market because the trading of automobiles also goes beyond production activities or the GPN, to include other sellers and buyers, concluding contracts and legal agreements in addition to the trading activities explicitly. Consumers sometimes trade used automobiles to dealers, dealers act as sellers and buyers on the market of new automobiles. This market also has its power structure. Automakers, such as Volkswagen AG Group, Daimler AG and BMW AG, with high turnover have strong bargaining power against their suppliers. This structural power is the market manifest of manufacturing activities of the automotive industry, which is characterized as a factory and market. Globalization and recession have changed trade patterns of the automotive industry. Trade patterns of the automotive industry are still shaped by state policies, such as tariffs, taxes, regulations, and have become an important target of anti-global warming and trade protection pressures. These are production reasons behind trade patterns. Protectionist measures taken by many nations or economies on motor vehicles and auto parts, affecting the quota and tax rates of motor vehicle exports, have more extensive, more direct and more dramatic impacts on trade patterns of some developing countries' automobile manufacturing industries, than the general impacts on their new passenger car production capacities. Recessionary pressures, structural shifts, and cost competitiveness challenges faced by Japan- and US-based automakers have changed several aspects of trade patterns in this Southeast Asia-Mainland China auto GPN, such as economic geography, industrial composition, parts variety, trade intensities and direction. But these changes are manifested as adjustments in trade value and export tendency instead of in trade volume and trade pattern structure.

1.7.1. Future Trends

For the development of future strategies for the global automotive industry, a scenario technique was applied to describe the future evolution of the value chain Today's global automotive industry is challenged by the rapidly changing environment it is embedded in. On the one hand, a potential change in industry structure may take place triggered by regulatory pressure. On the other hand, mega-trends are altering customer demand and urgency for product and technology variety. Companies respond to the difficult challenges faced today by implementing numerous strategic decisions; however their commitment to the strategies chosen often fails. Hence, a second broad area of inquiry, i.e. which future situations are preferable from a technical, economic and social point of view, has been investigated. It has been suggested a range of decisions, each describing how value chains would evolve today's automotive industry and how those decisions would affect the overall future meaning.

The automotive value chain itself is primarily explained by a two-dimensional model with the sorted dimensions of the focus on product / component variety and proprietary product technology. Focus on proprietary application technology signifies a pronounced value chain originating from Fordism, while focus on component variety indicates a product driven value chain structure. The classification enables a better understanding of how current and future value chains are embedded in its environment and what conditions would need to be satisfied in order to allow for a fundamental overhaul of the automotive value chain as it is commonly understood today. It has further been argued that the model can be expanded or aggregated to allow for whatever scale of analysis is desired.

To support innovation processes across globally dispersed sites, a robust global infrastructure is required that will be able to provide the necessary tools and resources for global collaboration and innovation. Different driver groups and scenarios determine vast ranges in the future development of the ICT landscape within the automotive industries. Irrespective of future details or solutions, the development of global resources and tools necessitates the coordination of decisions at the highest level. The automotive industry trend toward globalized engineering, manufacturing and assembly has taken a significant step since the end of the last decade. In light of this development, maximizing the global usage of resources has become another major area of focus for industries in the era of growing competition.

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