THE IMPACT OF COVID-19 REGULATIONS ON SUPPLY CHAINS IN THE AUTOMOTIVE INDUSTRY

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ABSTRACT

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The emergence of the coronavirus has changed many aspects in our lives. Some of them will probably remain. After two years, the pandemic is still not over. The governments have introduced strict regulations, especially in the beginning, in 2020 in order to stop the spread of the virus. Many regulations are affecting the international supply chains, especially the automotive supply chains, as they have many aspects of fragility, more than many other industries. In this paper the automotive supply chains and impacts of the international COVID-19 policies on them are analyzed. Afterwards advice is given on how supply chain managers can prepare better for such uncertainties in the future by literature review. The result is that supply chain managers should now rethink their supply chain structures. In the last years the automotive supply chains became more and more international, as trade barriers fell and transport costs sank. Now there is a turning point. Besides the pandemic regulations there are more influencing factors for this development, trade barriers are being rebuilt and transport costs are rising due to increasing carbon emission prices. The answer should be localization of supply chains to the markets, multiple sourcing for more (strategic) components and the introduction or increase of buffer stocks, to prevent possible supply chain disruptions. This is of course no overall advice to every company in the automotive industry, but the companies should rethink their strategies and revise their supply chain structures in the current situation.

Keywords: COVID-19 Regulations, Supply Chain, Automotive Industry

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Nikolaus Moos

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1. Introduction

The automotive industry has its origin in the USA in the 19th century (Larson, 2008), afterwards also the U.K., Germany, France, Italy and later Japan became big players (Michigan, 1996). Today the biggest players in the automotive industry are China, Japan, Germany, India, South Korea and the USA. Aspiring countries are furthermore Mexico, Spain, Brazil and Thailand (OICA, 2022). Supply chain activities involve the extraction of raw materials, the manufacturing of components, the assembling of products, warehousing and transportation (Kenton et al., 2021). Thereby the focus lies on the process flow, involved by the information flow. To classify the upstream of suppliers, the direct suppliers are called 1st tier suppliers and then dependent on the upstream grade, 2nd-, 3rd-, etc. -tier suppliers (Rogers, 2022). The coronavirus (Sars-Cov-2) was firstly discovered in China at the end of december 2019. The virus was estimated to be very deadly, with a high infection rate. So the answers by the Chinese government were very strict. But unfortunately the international outspread couldn't be prevented. So more and more countries followed by introducing measures like China. Some countries implemented stricter measures, others less strict measures. This is applicable until today with the fact that most countries adjust their measures by changing infection rates (Ritchie et al., 2022).

The automotive supply chains are today very complex, that is due to several trends we had in the past years. Following they are summarized: globalization of the supply chains which led to more international interdependencies, transfer of the production mainly final assembly closer to the markets, which led to emerging production countries like China and Thailand, a growing up of car models on the markets and an increase of the number of components and part numbers built in the cars (Aichner, 2013; Pavlínek et al., 2015; Essentra Components, 2022; Swan, 2001). The automotive industry has been hit since the outbreak of the pandemics as one of the hardest. The worldwide car production went down from 91,786,861 in 2019 to 77,621,582 in 2020, which is a decline of 16% and 2021 there was only a slight recovery to 80,154,988 (OICA, 2022). Additional to the decrease of production, customers have to wait longer now for car orders than before the outbreak, While the average waiting time for a new car order was between 6 and 8 weeks before the COVID-19 crisis, afterwards by the end of 2021 customers waited up to 6 months for their new car orders (Evans, 2021). At the same time production and logistics costs have increased (Tan, 2021; Pertschy, 2022).

The aim of the paper is to describe how the different COVID-19 regulations have influenced the automotive supply chains, which regulations had the biggest impacts and how supply chain managers can prepare and react better for such situations in the future. The main focus lies on how the current situation should be a turning point for companies' supply chain strategies. The research includes the automotive industry in some of the biggest production countries, which partly are highly affected by pandemic regulations. As there are many more countries in the world with automotive industries, general advice for all countries and companies cannot be

given. Also not all effects of all COVID-19 regulations can be regarded, so the research focuses on the most important influencing factors.

2. Research Methodology

This paper tries to give answers on the question, how companies should prepare better for the occurrence of COVID-19 regulations or similar risks for supply chains. The paper is primarily a documentary research paper. The sources of information are mainly literature research, but also communication with experts and my own experience by working during the COVID-19 crisis as supply chain specialist at GKN, an international 1st tier automotive supplier. Literature research includes only high quality references, like professional journals, professional books and primary sources from the official internet pages of internationally recognized organizations and governments. Sources of organizations include international associations and official business reports of big automotive manufacturers. Also an important source are researches of the big business management consultancies like Roland Berger and Mc Kinsey. Most information is at least double researched to gain a high confidence of the findings.

In the literature review part the topics automotive supply chain aspects, COVID-19 regulations and their impacts on the international supply chains are reviewed in detail. This is done by showing the structures and regulations in 4 of the biggest car producing countries: China, Japan, Germany and Thailand. China has been chosen, as it is the biggest producer with also very strict COVID-19 regulations, but with a low overall decrease in production. Japan, as it is the 2nd biggest producer measured by passenger cars and with much less COVID-19 regulations. Germany, as it was the number 4 biggest producer before the COVID-19 crisis, but with a very high decrease in production then in 2020 and 2021. And Thailand, as it was an emerging producer with a high decrease of production in 2020, but with a good recovery in 2021 (OICA, 2022; Ritchie et al, 2022).

In the results and discussion part, several studies about how supply chain managers should react now on the COVID-19 crisis are being discussed. In the conclusion and recommendation part the author is giving his own conclusion on the research question and an outlook for possible future research, so the research is inductive.

3. Literature Review

3.1. Supply Chain Aspects

As described in the introduction, today, especially the automotive supply chains are very complex. This can be determined based on the following facts. While in 1970, there were 140 different new car models in the market (USA), the number increased continuously to 240 car models in 1998 and 684 car models in 2012 (Aichner, 2013). The specialization of the companies progressed more and more. So we have more and more participants and players, 1st-, 2nd-, 3rd-, etc. -tier suppliers today in the industry. Figure 1 shows the structure as

exemplary. Due to the increasing specialization, the share of value creation of the suppliers in the automotive industry has increased to up to 75 % now (Pavlínek et al., 2015). Furthermore, the supply chains are very international today, as trade restrictions have been reduced in the past (Pavlínek et al., 2015), and also most manufacturers and many suppliers are very huge and internationally represented by manufacturing sites today. And until today, the typical supply chain strategies are highly based on the "lean production"-principle. That means for the supply chains low inventories and just in time (JIT) or just in sequence (JIS) deliveries, to save process and inventory costs (Baker, 2019).

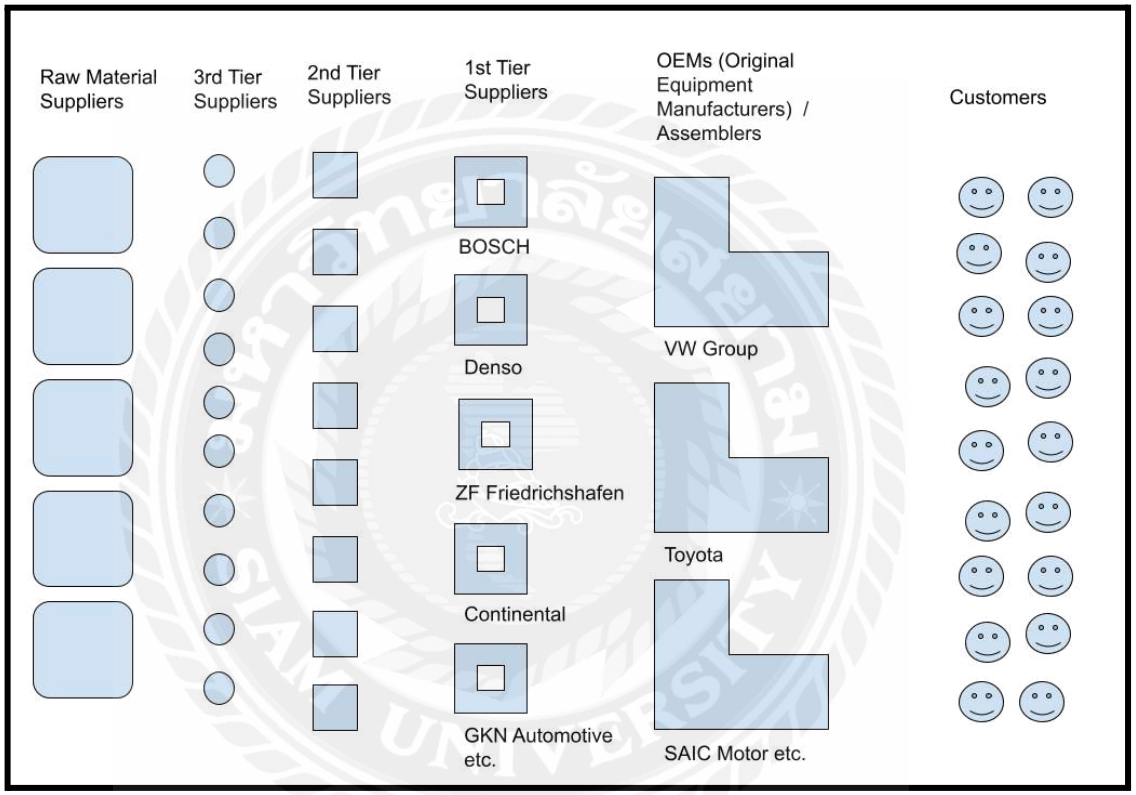

Figure 1: The Automotive Supply Chain Structure exemplary

In table 1, the development of the annual automotive production worldwide and in the four considered countries China, Japan, Germany and Thailand is shown. Except in China, the decrease in production since the pandemics was massive. It is also seen that there already has been a decline before, but not to that extent. While the automotive industry in Thailand recovered well in 2021 in Japan and especially in Germany, production further decreased.

Year / Country	2018	2019	2020	2021
China	27 809 (-4%)	25 721 (-8%)	25 225 (-2%)	26 082 (+3%)
Japan	9 729 (+-0%)	9 684 (-1%)	8 068 (-17%)	7 847 (-3%)
Germany	5 120 (-9%)	4 661 (-9%)	3 742 (-24%)	3 096 (-12%)
Thailand	2 168 (+9%)	2 014 (-7%)	1 427 (-29%)	1 686 (+18%)
Worldwide	95 635 (-1%)	91 787 (-5%)	77 622 (-16%)	80 155 (+3%)

Table 1: The automotive production in the selected countries and worldwide including commercial vehicles in thousand units rounded (source: OICA, 2022).

Since the outbreak of the pandemics, the costs for production, warehousing and transport are highly increasing. In figure 2, the index of container freight is illustrated. The increase between March 2020 and February 2022 equals 700 %. In the warehouses bullwhip effects can be seen (Honda, 2021). That is caused by uncertainties of deliveries, so the actors in the supply chains have to build up higher inventories to prevent further supply chain disruptions. Figure 3 shows the international ocean schedule reliability, which dramatically declined in 2020 and is still at this low level of 30 % in January 2022. This low reliability is responsible not only for higher warehousing costs, also for higher production costs, as production plans have to be changed frequently and cannot be set up in the longer term. Furthermore employee costs increased due to additional safety at work requirements and absenteeism.

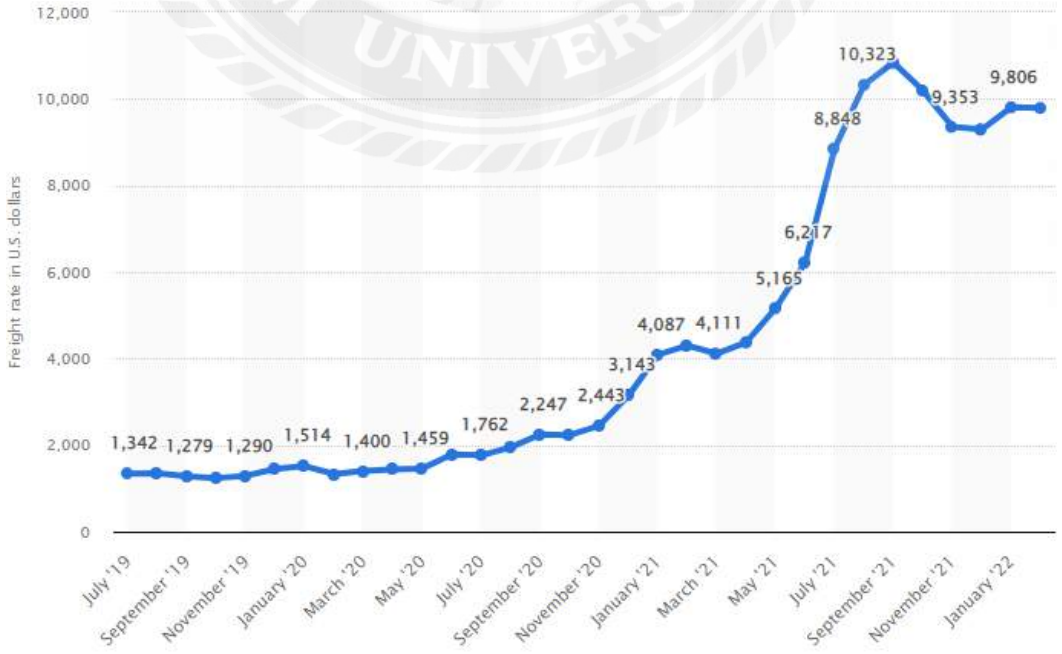

Figure 2: Global container freight rate index from July 2019 to February 2022, Source: Statista (Placek, 2022)

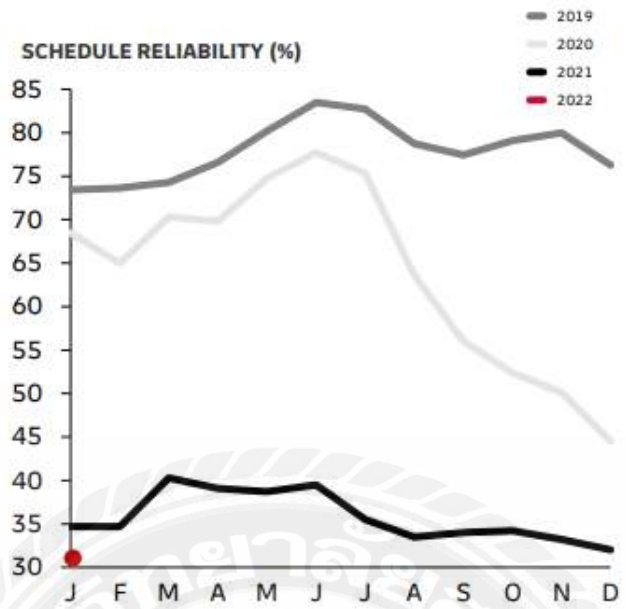

Figure 3: Ocean Schedule Reliability (Source: DHL, 2022)

3.2. The Automotive Industry and Supply Chains in China

The Chinese automotive industry is characterized by big state-owned manufacturers, foreign companies are only allowed to produce in joint ventures with local manufacturers (until January 2022). Chinese brands have a share rate of about 40 % of the sold cars (Noël, 2020). Imported cars play with 5% of the total number of sales, a relatively minor role, so the foreign brands are mainly produced in China (ITA, 2022). SAIC Motor, Chang'an, Geely and Dongfeng are the biggest four dominating manufacturers, they are producing ca. 60 % of the whole volume (China Daily, 2021), they are producing both within joint ventures with foreign manufacturers and independently. A very new trend now is that the Chinese manufacturers are starting to export more and more cars, for 2021 the number exceeded the mark of 2 million units, ca. 8 % of the produced units (Global Times, 2022).

The supply chains are still in a developing phase. As the industry had substantial growth rates in the past years (until 2017) with a high focus on the primary producers (OEMs), the supplying industry was left behind. In many areas, the manufacturers are dependent on foreign suppliers and many parts are not locally sourced (Pawlicki et al., 2017). But in 2020, the central government gave this matter a higher priority in its statement (Galea-Pace, 2020). So today the supply chains are improving, very well developed and relatively independent. That can be seen in the low production decline in 2020 and 2021.

3.3. COVID-19 Regulations in China and Impact on the Automotive Supply Chains

China was for a long time the first country with strict COVID-19 regulations, as the virus had its origin there. So the way China responded to the outbreak became the benchmark for many countries. Also the Chinese regulations were for a long time, from the beginning until today in comparison to those in other countries, one of the strictest (Hale et al., 2021). Also China is until today one of the left countries still pursuing the so-called "Zero-COVID"- strategy. This strategy has the consequence of hard restrictions on free movement, freedom of travel and partly temporary company closures.

At the beginning of the pandemic, in February 2020, this strategy of China affected the international supply chains very hard, particularly the automotive supply chains, as the outbreak was in the Hubei province with many international automotive key suppliers (Zhan et al., 2021). As the strategy has not changed yet until today, we still see big effects on the international supply chains. These effects are caused by local lockdowns after local COVID-19 outbreaks and strict test and quarantine rules at the international harbor docks. The international container crisis is supposed to be triggered by these lockdowns and quarantine rules, as they led to long jams at the harbors (Duhalde et al., 2022). Despite the huge impact of the Chinese policy on the international automotive supply chains, the production rate inside China barely decreased, the impacts hit mainly other countries.

3.4. The Automotive Industry and Supply Chains in Japan

The Japanese automotive industry is highly dominated by Toyota with ca. 40 % production share rate of the total country production. Additionally there are seven smaller producers named Daihatsu, Suzuki, Mazda, Honda, Nissan, Subaru and Mitsubishi. Also a characteristic of the Japanese automotive industry is that it is highly export-oriented, almost 50 % of the produced cars were exported in 2021 (Marklines, 2022). Imports, with ca. 6 % of the registered cars play a smaller role.

In the past, the supply chains were locally structured, but the globalization trend from the 2000ies led to more and more international connections and dependencies. The automotive supplier industry is highly developed and it is different to the industries of other countries partly in direct ownership by the manufacturers (Neely, 2017). The automotive industry is located throughout the country with a high focus on the southern Chubu region, close to Tokyo (Jama, 2021). A special characteristic of the Japanese manufacturers is that two-thirds of their production volumes are produced overseas (Marklines, 2020). And also the Japanese automotive industry is well known for its supply chain approach, called lean production which is now applied worldwide. This approach aims to keep inventories and buffers as low as possible, thus saving process and storage costs (Baker, 2019).

3.5. COVID-19 Regulations in Japan and Impact on the Automotive Supply Chains

Japan had since the beginning of the pandemic in international comparison relatively few COVID-19 regulations, especially for an industrial country. Only in some ways they became stricter over time, so there is still a strikt travel ban from many countries (Hale et al, 2021). As the measures are relatively little, the impact of these regulations is low. But as the Japanese supply chains are very dependent on imported raw materials from East-Asian countries (with strict COVID-19 regulations) and on the availability of containers and international trade, the Japanese automotive industry has also been hit hard by the pandemic (JETRO, 2020). The reduction of the annual car production in Japan was 17 % in 2020 and then more 3 % in 2021 (OICA, 2022).

3.6. The Automotive Industry and Supply Chains in Germany

The German automotive industry is highly dominated by the Volkswagen (VW) Group, which owns several brands like VW, Audi, Seat, Skoda and Porsche. 44 % of the domestic car production are VW brands (Volkswagen AG, 2021; OICA, 2022). Furthermore there are Mercedes Benz and BMW with respectively ca. 20%, Ford with ca. 11 % and Opel with ca. 5 % share rate of the domestic production of cars[1]. Like the Japanese automotive industry the German is also highly export oriented, also ca. 50% of the produced cars were exported in 2020 (VDA, 2021; OICA, 2022).

The supply chains are very complex. Traditionally there is a high number of medium sized companies. But there are also big 1st tier suppliers like BOSCH, Continental and ZF Friedrichshafen (Gelowicz, 2020). In the supply chains there are many inter europe connections. The German automotive supply chains are considered highly specialized by international benchmarks. OEMs have outsourced many competencies to specialized companies (Federal Ministry for Economic Affairs, 2022).

Even more than the Japanese car producers, the Germans produce overseas, the best example is the VW group with worldwide 9 Mio. produced cars in 2020, while the domestic car production was just 1.6 Mio (Volkswagen AG, 2021). VW group factories can be seen worldwide in many countries on all continents. Most German brand cars were sold in China in 2020 (Kerler, 2021).

3.7. COVID-19 Regulations in Germany and Impact on the Automotive Supply Chains

The COVID-19 politics in Germany is characterized by alternating relaxed and strict measures. In the beginning the government reacted relatively late, but then with very strict measures. After the infection rate went down the regulations had been relaxed and then after the infection rate increased again, the regulations became stricter again (Hale et al., 2021). Especially the first lockdown from March to May 2020 influenced the supply

[1] These share rates are calculated from the announced numbers of the manufacturers published on the official annual reports divided by the total country production number according to OICA (OICA, 2021).

chains hard. On the borders to the neighboring countries long truck lines occured, as the European countries closed them (Ankel, 2020). In March and April 2020 many car producers then shut down their factories. The following reasons led to these shutdowns: supply chain disruptions caused by the China shutdowns and border closures, more difficult production conditions as employees fear COVID-19, simplified legal situation for state wage reimbursement and a general excess production with surplus stocks since 2019. (Koellner, 2020; Federal Ministry of Finance, 2021; Perspektive Online, 2020). In total the German car production rate decreased since 2020 more than in most other countries, while the decrease in 2021 was mainly caused by the semiconductor shortage (Pertschy, 2022).

3.8. The Automotive Industry and Supply Chains in Thailand

The Thai automotive industry had in the past for a long time low economic significance. But since the millennium, after the "Asian Crisis" it has had a similar development like the Chinese, however with less growth in the 2010s years and less domestic shareholding (Warr, 2018). So until today the country got in the top ten automotive producing countries worldwide. The industry is highly dominated by both Japanese production companies and pick-up production (Rastogi, 2018). Contrary to the Chinese automotive industry, the Thai is very export oriented with an over 50% export rate in 2021 (Marklines, 2022a). Also very specific for the Thai automotive industry is its geographical concentration in the central area of Thailand between Bangkok and Rayong (Rastogi, 2018).

The supply chains are still in a developing phase. As the industry had big growth rates in the years from 2000 to 2013, driven by the big Japanese OEMs (Rastogi, 2018; Athukorala et al., 2009), the supplying industry was left behind. Big automotive suppliers built up productions in the automotive industry areas in Thailand, however the share rate of foreign produced automotive parts is still very high with 65 % in 2018, most parts imports come from Japan (OECD, 2021).[2]

3.9. COVID-19 Regulations in Thailand and Impact on the Automotive Supply Chains

Thai governmental responses to COVID-19 can be seen as a mixing strategy compared to the responses to the previously described countries. The introduction of measures was relatively late. The authorities began mainly with strict travel bans and other measures, which later became relaxed. As infection numbers rose then in 2021, there was a period of strict regulations. Until 2022 these measures have been relaxed again (Hale, 2021). So the Thai automotive industry got one of the hardest hits in 2020, mainly due to the strict travel regulations and demand decrease. Nevertheless, it experienced a good recovery in 2021 (Marklines, 2022a).

[2] Calculated from the OECD ICIO (Inter-Country Input-Output) table 2018 (OECD, 2021).

4. Results and Discussion

In summarizing, we can say that COVID-19 regulations had enormous effects on the automotive supply chains and production rates. On the one hand, due to the strong international interdependencies but also due to the lean-production principle, which led to low inventories, so production stops occurred earlier. The high international interdependencies we have due to relatively low logistics costs and fewer trade barriers in the past. However, besides the COVID-19 regulations, there are also other influencing factors on the supply chains and production rates that influence logistics costs and international trade today. These factors include mainly the semiconductor crisis, a general increase in trade restrictions, and the increase in carbon emission prices (Rueger et al., 2021). Troubles, like the semiconductor crisis, are actually not new. In the past, there were international supply chain disruptions due to the earthquake in Japan in 2011 for example (Wheatley et al., 2011) and also the accident in the Suez canal in 2021 had substantial effects on the international supply chains until now (Duhalde et al., 2022). All these factors would have fewer impact on the supply chains, if they would be less internationally interconnected. So all these factors should perhaps trigger a general rethink in supply chain management. Recently published articles of the big management consultancies are coming to this conclusion (Rueger et al., 2021; Hensley et al., 2022). However, they are not completely coherent in their findings. So the research "Rethinking Global Automotive Production Networks" written by Michael W. Rüger, Rolf Janssen, and Wilfried Aulbur in 2021 claimed a "glocalization" of the international automotive supply chains. This means that the long transport of components and parts should get less to avoid the high transport costs, counter uncertainties in the supply chains and tariffs. Local sourcing should get more and more critical. The research of SNECI from 2021 comes to the same conclusion.

Other researchers, like from McKinsey (Hensley et al., 2022) and Ideagen (Vjestica, 2021) are seeing the answer more in increasing the supply chain transparency. That would forecast difficulties earlier, so that the OEMs have more time for reaction. However, a better securing of the supply chains by increasing or introducing buffer stocks is controversial in the research, as it impacts supply chain efficiency.

Furthermore, the following countermeasures to the current crisis are discussed in the literature. Short- and mid-term measures can be introduced fast, but they may be very costly in the longer term. Short and mid-term measures would be an increase in the safety stocks and increase transparency in the supply chain. A good practice for achieving higher transparency in the supply chain is the extension of EDIs (Electronic Data Interchanges) between companies. While the willingness before pandemics was lower, it is rising now as companies see the consequences of the crisis (Hensley et al., 2022). In the way of EDIs, not only the stocks and demand forecasts of the first tier supplier and the next customer should be shared, the information should be shared with more supply chain players. The introduction of a higher supply chain transparency is relatively easy as many companies are already using industry standard ERP-systems (ERP = enterprise resource planning) or

standard EDIs are already existing, which only have to be implemented by the IT-departments. With increased transparency along the supply chain, possible bottlenecks can be detected early, so the companies have more time for reaction. The increase of the (safety) stocks can be very costly in the long term, as it increases capital commitment, handling costs (process costs), and warehousing costs.

The long term measures need more time and resources. The most important is a stronger preference for local respectively national sourcing, especially for strategic parts. As described above, the international interdependencies of the automotive supply chains are strong. One reason for this organization is the wide range of car models and variants today (Rueger et al., 2021). So to keep efficiency high by localizing the supply chains, the manufacturers could reduce the number of car models and variants offered (or produced) in the regions. This is an essential requirement to operate cost-efficiently and with a local supply chain. As a result of a wide variety of produced cars in a "small" factory, production scale effects would get lost. On the other hand, this decision could also lead to a decrease in market coverage. So, in the end, it is also dependent on the business concept.

The second long-term measure could be an introduction or update of the sustainable risk management plans. This may result in more multiple sourcing of parts and/or the introduction or increase of buffer stocks. Both measures could reduce the risks of production disruptions.

5. Conclusion and Recommendation

Since the outbreak of COVID-19, there has been a high increase in transportation costs and strict traveling rules, which led to terrible delivery performances (DHL, 2022). As also other research stated, the rise in transportation costs will probably remain after pandemics, due to the increasing carbon emission prices. And additionally, trading barriers are continuously rising, now also seen after the recent outbreak of the Ukrainian-Russian war with its substantial consequences for international trade.

There are many indicators, which should cause companies in the automotive industry to now consider rethinking their supply chain structures. One effect, which is now affecting the European automotive industry hardest, is the semiconductor crisis. This crisis led to a further high decline in automotive production in Germany in 2021, while many other countries' productions started to recover already. The semiconductor crisis hit Europe hardest, as there is no production of it. So the localization and deglobalization of the supply chains are essential now.

Also, there is still after two years in general no end of the COVID-19 crisis visible. Who knows, which variants will come next and how political deciders will react to them? Trading barriers are rising, and transport costs are increasing, especially now after the outbreak of the Ukrainian war.

Furthermore, we have a big change now towards electric vehicles (=EVs), new mobility trends towards smaller personal carriers like e-bicycles, autonomous driving, and the use of shared services (driven by digital features). The biggest impact on the automotive supply chains is the transition towards EVs. And the other trends will also affect, the demand for cars in the developed countries will probably further decrease in the long term. These trends enforce a fundamental restructuring of the supply chains. Companies should use this restructuring by localizing the supply chains and rethinking their supply chain risk management.

This is also maybe the positive aspect of the COVID-19 crisis, that urgent changes now are easier to implement and that automatization may be pushed forward in certain areas.

As stated in the introduction, there has been already in the past a trend to shift productions toward the demand markets. So companies have partly already transferred productions to other countries than the traditional producing countries. Examples are seen in China, Thailand, and Brazil. But despite these shifts, the international automotive supply chain dependencies have still risen. So more effort is required.

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