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SUPPLY CHAIN RESILIENCE IN THE EUROPEAN AUTOMOTIVE INDUSTRY

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Abstract:
The transformation of supply chains is an important factor for European Automotive OEMs to compete internationally. But it turns out that these are not as resilient as required. A resilient supply chain requires appropriate risk management measures that minimize internal and external influences. However, in some areas of value creation and supply chains, weaknesses are evident that are determined by a high dependence on international supplier markets. This approach to research in this area investigates whether Automotive OEM internal departments perceive certain risks differently. This was done by means of a survey of European OEMs to reveal different perceptions on important aspects of risk-based factors. Internal resilience would be necessary as a first step towards strengthening the supply chains in order to subsequently position themselves against stronger emerging competition from the Asian and US economies. This requires a strong European centering of supplier and partner networks, for example in the area of physical goods such as semiconductors and batteries. In order to support these necessary developments, networks are being established and promoted by the EU. GAIA-X and especially Catena-X are bases for the Automotive industry to adapt and optimize resilience and compliance regulations to governmental and intranational guidelines. As result of this research, it remains to be said that the realignment of supply chains must succeed in improving cooperation and delivery conditions across the entire OEM spectrum while at the same time reducing costs. In this way, the European Automotive market can be positioned as a resilient, strong market player for the future. The basic prerequisite for this is a uniform and coordinated view of risk-based factors in the individual companies and departments.

Key words: *automotive oem, supply chain management, risk management; electric automobility, supply chain resilience, supply chain law*

INTRODUCTION

Relevance

Global supply chains during and after the COVID-19 pandemic have shown that they are not as resilient as they have been over the past 20 years.

> *"The use of regional differences in production costs enables cost advantages in international competition but can also be the cause of disruptions in the supply chain. This became visible during the Corona crisis and the associated shutdown and lockdown measures, as well as most recently through the Ukraine war" [1].*

The term resilience is used by various scientific disciplines but differs in cause-effect parameters and applications. The term is often used in medicine and psychology as well as in climate research. But economics is also increasingly including it in research [2].

[3] define economic resilience as follow:

> *"Economic resilience is the ability of an economy to take preparatory measures to deal with crises, mitigate the immediate consequences of crises and adapt to changing conditions. The degree of resilience is determined by the extent to which the actions and interactions of politics, business and society can ensure the performance of the economy as assessed by the social objective function even after a crisis" [3].*

Difficulties in risk-based factors were already apparent before, which also affected the Automotive industry before the pandemic in the transition to electric cars, especially in the area of raw materials for battery production and electrical components [4]. However, the years 2020 to the present in particular have made this vulnerability even more apparent. The causes here lie primarily in the temporary global disruptions and problems caused by the pandemic and increasing geopolitical disruptions between the USA and Europe with China over Taiwan and in the war in Ukraine with Russia. In addition, there is the urgency in the field of action of climate protection and new political legislation in the EU, which have an impact on the aforementioned situations and are determinative for almost all industries (cf. e.g. [5]). [6] demand in addition to the required personal contribution from OEM and their suppliers also that the governments increasingly

create resilience in the framework conditions for the industry. The necessary fields of action can be found in the Figure 1.

Fig. 1 Fields of action in the automotive industry and politics for more resilience in supply chains
Source: [6].

The integration of GAIA-X will be deepened in the discussion of the paper.
The Automotive sector is of particular importance here for economies that have a high share of companies and employees in total economic output. The most important factor for all OEMs in Europe is the transformation of production processes to efficient production for Battery Electric Vehicles (BEV) within the framework of the climate policy goals of the EU and the national governments.

LITERATURE REVIEW

This transition still presents the Automotive industry with numerous challenges today in order to build up their supply chains in a stable manner and to keep them at a competitive level. Long transport routes, great dependencies on certain supplier nations and current compliance with legal requirements for supply chain conditions are sometimes diametrically opposed to this. In particular, compliance with existing and forthcoming regulations on the climate neutrality of supply chains, as well as the observance of working and production methods at suppliers, which must be determined according to humanity criteria, should be mentioned here (cf. e.g. [7, 8]).
Consequently, the need for supply chain risk management must be assessed even more comprehensively in order to position the European Automotive sector resiliently and competitively against Asian and US suppliers. That the situation for the European Automotive market looks serious is shown by estimates from the consultancy AlixPartners, which reported in July 2023 that Chinese car manufacturers exceed the exports of all other nations. In doing so, they are serving the international markets in addition to the prospering domestic market, pushing national suppliers further back. As a result, China is also influencing the raw material prices of manufacturing, which are rising due to high demand. In the electric car sector, battery prices are kept at a level that does not allow the demand for e-cars, implied by high costs, to increase markedly [9]. The situation for Europe is further aggravated by the fact that China is increasingly securing control over Latin American and African deposits, in addition to its own raw material deposits, by investing billions in the producing countries and dominating the purchase by Chinese companies. In the process, environmentally friendly standards and humanitarian working conditions are not consistently taken into account as they apply to European companies, which drives the incentive in these countries for entrepreneurial cooperation with China (cf. e.g. [10, 11, 12]).
As a solution, the German Federal Government, in cooperation with the EU Commission, has developed a strategy for the economy that should help to make the European market more resilient and thus also more independent of other competitive markets (cf. e.g. [13, 14, 15, 16, 17, 18]). The thesis here is that despite all the difficulties of cooperation between the OEMs, cooperation can have a positive effect on the resilience of the supply chain as well as the value chain (cf. e.g. [19, 20, 21]). As the European OEMs work with very similar strategies, consequently the same problem areas arise for all of them. Increasingly, these are supranational risks that must be addressed by all companies. Based on this, one can speak of a prisoner's dilemma in this constellation, which was developed from game theory (cf. e.g. [27, 28, 29]). One approach, which had not been completed by the time the research report was written, is the GAIA-X network structure, which, as an open information platform, allows registered members to make enquiries to other providers as well as to provide information regarding their own production ideas or innovations (cf. e.g. [33, 34, 35, 36, 37, 38, 39]). The content provided is the sole responsibility of the providers and can be viewed and used by other members of the network (cf. e.g. [40, 41, 42]. The basics of the architecture and use are offered in the course of the research report. The statistical analysis is carried out from the overall results. The listed thematic complexes are merged as data sets with reduced dimensions (cf. e.g. [44, 45, 46, 47, 48, 49, 50, 51, 52]).
Driven by the participating OEMs and important partners, an independent network was developed specifically for the Automotive industry, which builds on the GAIA-X architecture. Services explicitly for the Automotive sector are subsumed here under the name Catena-X, which can also be used to strengthen the market of EU OEMs vis-à-vis American and Asian suppliers (cf. e.g. [53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63]).

GOALS AND OBJECTIVES

An analysis of European OEMs in the context of supply chain resilience and end-to-end risk management has not yet taken place sufficiently internally at the Automotive manufacturers. Surveys in the sector, e.g. by Ernest &Young, Deloitte or other national organizations, have so far mainly focused on national markets, are future-oriented without a deeper reflection of previous emergent situations and/or provide statistical data in the supra- and international area. This has created a gap in the research, which takes a deeper analytical look at what has happened in the last three years. This gap, which has not been sufficiently covered, is to be addressed in a separate approach with this research approach based on test persons from European OEMs, which produce different car brands in a higher number of units in the Automotive sector. Such OEMs are particularly dependent on the physical goods of batteries, electrical parts and components, and

semiconductor systems in the electric car sector and require supply chain safeguards to avoid production failures or delays. They are considered risk-based factors for the performance and competitiveness of the European Automotive market.

The main objective of this research is to identify risk-based factors in the currently implemented supply chains and to analyze whether they are sufficiently considered in the risk management of European car manufacturers. European car manufacturers are aware of the multiple challenges posed by the transformation of supply chains for sensitive physical goods. However, many disruptive effects have occurred during the transformation phase since 2020. This leads to the core question:

How are political/legal influences and requirements from the experience of the pandemic and the geopolitical changes of recent years perceived by OEMs in dealing with risk-based factors?

To this end, it is necessary to identify the existing systems and perceptions of the OEM in order to be able to describe the conditions and factors of change. As a result of these perceptions, the second important question arises:

Have the OEMs in Europe adequately adjusted their internal processes to the situational innovations and mitigated risk-based factors?

It is assumed in the research approach that interests of departments in companies are aligned differently. This depends on the degree to which they are affected and the requirements for direct response to certain events. Such differences in the perception of parameters selected here in the area of political influence and pandemic consequences can have a negative impact on the resilience of value creation and supply chains, although they require internal holism. It is assumed that the current consideration of all new risk factors is not yet uniformly established at all OEMs. In addition, the results of the survey assume that the management systems can still be further developed to a relevant level in risk assessment. It is therefore important for the area of recommendations to underpin the question of a new robust and resilient system for value creation in supply chains with concrete derivations. The fact that only parts of the value chain are considered also leads to limitations in the scope of the empirical research in this study. As only physical goods are addressed, which have their own supply chains with weaknesses in resilience and robustness, subjects from the ‘purchasing’, central coordination of company logistics’ and ‘sales’ cohorts are surveyed, as they have the closest contact with these goods in their work processes. Based on this, possible solutions are subsequently presented that take holism at the OEMs into account and have an effect on the resilience of the European Automotive market.

In the following, the research approach is presented in order to approach the topics described above and to explain the risk-based factors.

RISK-BASED FACTORS IN THE AREA OF SUPPLY RISK MANAGEMENT IN THE AUTOMOTIVE SECTOR

Raw materials are one of the determining factors for BEV production worldwide and they show that high dependencies have emerged in the European industry, which as risk-based factors affect all manufacturers in Europe and therefore make a pan-European strategy necessary.

In a comprehensive analysis of the relevant raw materials for battery production, (cf. e.g. [11]) found that Europe is not independently positioned in terms of mining strategies for raw materials and is therefore highly dependent on producing countries and processing industries, especially in China.

> *"None of the raw materials required for battery cell manufacturing are currently mined in significant quantities in Europe. Europe is therefore highly dependent on the import of mineral raw materials. The global dynamics in the development of cell manufacturing capacities will lead to new or worsening dependencies and shortages, especially regarding the supply of materials. In addition, Europe lacks sufficient capacities for further processing" (cf. e.g. [11]).*

If one looks at the individual raw materials separately, problem areas arise with the nations that are decisive in extraction or further processing.

Lithium is led in production by Australia, followed by China, Brazil and Chile. This does not yet appear to be a problem, but it is becoming a European problem, as > 50% of the further processing is done in China. The concentration of further processing of magnesium is even stronger, with China taking over 90% of the world market. For cobalt the share is 65% and for graphite, which is needed for electrode production, China's share of production is >65% and further processing is almost 100% in the country (cf. e.g. [11]).

Russia's share of the world's nickel and cobalt production is not that high, so the current conflict has not yet had an impact on the procurement of raw materials for Europe. However, the dependence on energy is much higher here (cf. e.g. [12]).

To get out of this dilemma, new strategies are being sought to reduce dependencies and provide European industry with more autonomy and greater resilience in the necessary supply chains. The call for 'more government' is becoming louder as the linkage between supply chains and geopolitical decisions has become more pronounced since 2022.

[13] highlights the ambivalence of industry and politics that has increasingly crystallized in the years since 2020 [13] emphasizes:

> *"The risk of disruption to supply relationships is now forcing companies, to a much greater extent than in the past, not only to "price in" political factors, but also to react to policy stipulations. However, the realistic timeframes for transforming supply chains, especially when they are very complex and long, are hardly compatible with the short response times expected by policymakers."*

Here, he emphasizes the strong influence of supranational policy decisions that are binding on all EU industries. The responsibility to 'clean' supply chains as a top priority sets in motion a renewed examination and transformation of supply chains for the industry, which further increases the pressure. In this context, policy makers are called upon to create framework conditions for secure supply chains. These would be mediating functions with important partner countries. At the same time, people are still resisting the strict guidelines of politics, which restrict the selection of suppliers and at the same time break up existing supply chains w2ith some countries. This would theoretically also be the case with China, as its working conditions and environmental policy do not meet the requirements [13]. On the one hand, with the legislative initiative the politicians want to achieve that the industry connects more closely with suppliers that geopolitically correspond to the conditions in the EU and also to the ethical and moral demands. In 2022, the European Commission presented the Corporate Sustainability Due Diligence Directive initiative and formulated the requirements for human rights, sustainability and fair trade [14]. On 1 June 2023, the developed directive was adopted by the European Parliament [15]. Nationally, Great Britain, France, the Netherlands and Germany have positioned themselves here with draft laws (cf. e.g. [16]). With Great Britain, France and Germany, these are also the three largest Automotive industries in Europe that see themselves committed to a new structure. However, (cf. e.g. [16]) state that just 10% of the affected companies have analyzed their supply chains for the new requirement and are thus able to respond appropriately to the law.

The tendencies of the close links between politics and supply chains are also clearly highlighted by the expert circle on the transformation of the Automotive industry in the field of semiconductor technology. This circle concludes in 2023 that the accumulation of producers in the Asian regions is becoming an increasingly risky factor for European OEMs. Taiwan as a leading semiconductor producer is in the geopolitical interest of China's power expansion policy. At present, it is impossible to predict how political autonomy will develop. In the event of political intervention, Chinese-European relations would also be even more strained [17]. In addition, the effects of the pandemic are still being felt today, with production declining in 2020/21, as did demand. From the middle of 2021, the Corona situation eased again and a strong increase in demand set in. The producers were not able to cover this bullwhip effect and the effects can be felt in the markets in the delivery times [18].

This results in clearly defined risk-bearing factors that must be taken into account by the OEMs and included in the internal strategy and risk assessment. Politics plays a decisive role here, both internally and externally, as a decision-maker outside the company.

The question that has not been clearly answered so far is the alignment of OEMs in their internal and external processes to support the management of the risk-based factors. Since all OEMs have a similarly weak starting position in the risk-based factors and the requirements are similarly distributed, the Automotive industry in Europe finds itself in a prisoner's dilemma, as demonstrated by game theory. It is therefore necessary to weigh up between the position of each OEM continuing to act as an individual player in the market or the option of cooperation between the European Automotive industry. The thesis here is that despite all the difficulties of cooperation between the OEMs, cooperation can have a positive effect on the resilience of the supply chain as well as the value chain (cf. e.g. [19, 20, 21]). However, this also requires similar perceptions in the individual departments of the OEMs, which allow for a uniform corporate strategy.

METHODOLOGY

When considering risk-related factors that threaten European car manufacturers, it can be assumed that all participants in the industry are subject to approximately the same requirements and stresses. [22] find that three behavioral parameters of the OEMs are responsible for disrupting the resilience of the supply chains and their own value creation.

- High degree of outsourcing of production to subcontractors:
  - Advantage: cost-reducing
  - Disadvantage: Intransparency of supply chains; information asymmetries cause delayed reactions in the event of supply bottlenecks or failures
- Individual procurement with one supplier:
  - Advantage: Easy communication and high-quality performance
  - Disadvantage: Supplier power is high; flexibility in case of problems is low; failures can only be compensated with high effort
- Just-In-Time:
  - Advantage: low storage costs; customer wishes can be fulfilled individually
  - Disadvantage: All information of the supply chain must be available; high vulnerability in case of delivery problems and failures

In the empirical elaboration of the topic, it was found that the perception of individuals, groups or departments varies and differs from that of others, so that the internal perception of closed systems, such as companies, of risk-based factors varies. Our own research therefore focused on the necessary identification of this department-led data in order to generate a data basis for further research in this specific subject area. In doing so, the departments in companies are primarily focused on their own problem areas and are guided by the achievement of their own figures as a degree of fulfilment. A company-wide view of the risk-based factors is thus largely absent [23].

The environment in which the European OEMs find themselves and in which they are tackling the transformation to electric automobility is characterized by a high degree of dynamism that offers several possible future scenarios. This spectrum of potentially possible scenarios is broad and can only be captured within certain limits. Game theory is tailored precisely to this analytical situation and

offers possible solutions within this recognized continuum [24].

European OEMs find themselves in this situation, as not all aspects of the environmental situation [25] can be captured due to the current need to adapt. In addition to the possibility of individual strategy formation for each individual company, game theory offers the possibility of cooperation, collaboration and strategic binding of several companies and entire industries [26].

As the European OEMs work with very similar strategies, consequently the same problem areas arise for all of them. Increasingly, these are supranational risks that must be addressed by all companies. Based on this, one can speak of a prisoner's dilemma in this constellation, which was developed from game theory in the 1960s (cf. e.g. [27, 28, 29]).

In the Prisoner's Dilemma, the basic assumption is that all participants in a situation have the same incomplete information base. This applies internally as well as externally in the companies. Therefore, the market participants cannot coordinate because their own interests override the common interests [24]. Thus, they are unable to develop a successful strategy that leads them out of the situation. Since there are also no possibilities to obtain further sufficient information from outside and at the same time no new connections can be gained from their own information, the theory of the prisoner's dilemma relies on cooperation as an efficient set of instruments to improve the information situation and thus make progress. However, this can only work in cooperative structures according to the principle of give and take, because if one cooperation partner perceives imbalances, the cooperation as a whole fails (cf. e.g. [26].

The advantage of applying game theory in the form of the prisoner's dilemma lies in the fundamental understanding of the competitive mechanism for all market participants in the OEM sector. If one looks at the OEMs in isolation in the industry and removes the pure electrical suppliers and the absolute specialists with small series and custom-made products, the result is an oligopolistic market that cannot be described as dynamic, since the market participants do not renew themselves frequently, but serve the market over the long term. And it is precisely for these markets that game theory and the special prisoner's dilemma are a good application to capture and adapt the existing competitive mechanisms [24].

The new market situation and the abandonment of the OEM's traditional core competencies should be understood as the basis for redefining corporate strategies and requires a new holistic view of internal and external processes, supply chains and value creation [30]. The alternatives are fixed in the form of the BEV strategy for the OEMs, but the adjustments are sluggish because international suppliers determine the new market. An example of this is the long adherence of European car manufacturers to fossil fuel drive technology [31]. This has been optimized for years and supplemented with hybrid systems. In 2035, the legally prescribed 'end' for production will come, and new strategies are urgently needed to make the phase-out easier.

Against this background, the empirical research was developed according to these points.

Quantitative research was favored for the empirical investigation of the core elements of research on the topic due to the limited data available from direct surveys of OEMs. Only limited parameters were available for the use and design of the consideration of risk-based factors for the conversion of electric vehicle production in the form that no comparable approach with a departmental differentiation could be found. Existing research exists, but it has generally been determined for OEMs, so that a generalized approach was pursued. Only by determining valid data bases on a quantitative basis at a differentiating departmental level was the potential created to identify gaps and problem areas for the topic, which could then be analyzed in greater depth using qualitative methods.

As this field of research is new in its approach and comparative studies are only available in partial areas or in generalized form, the descriptive analysis of the sample was elaborated first. This was taken into account in the form that the superordinate cohort of OEMs is defined and can be narrowed down. This makes it possible to determine clearly defined boundaries of the participants who are surveyed as a cohort. As the OEMs in Europe do not differ in their basic corporate structures, the individual cohorts could also be clearly defined and verified for the survey.

The descriptive analysis enables direct comparisons of the individual departments to be made, both graphically and in terms of interpretation, based on the data obtained. However, it must be emphasized that the hypothesis analysis can only be carried out with the help of meaningful statistics. In order to be able to proceed appropriately with this hypothesis analysis, suitable inferential statistical methods are therefore applied following the descriptive presentation.

In order to provide an up-to-date overview of the current deployment and implementation of measures in relation to the risk-based factors along the supply chain examined here, a specially created survey was conducted among the largest OEMs in Europe. The study was conducted from June to October 2022.

The OEMs selected as test persons for this purpose were as follows:

Germany: AUDI, BMW, Ford Europe, Mercedes-Benz, Opel, Porsche, Volkswagen

France: Bugatti, Citroën, Dacia, DS Automobiles, Ligier, Peugeot, Renault

Great Britain: Aston Martin, Bentley, Jaguar Land Rover, Lotus Cars, McLaren, MINI, Morgan Motor Company, Rolls-Royce

Italy: Abarth, Alfa-Romeo, Ferrari, Fiat, Lamborghini, Lancia, Maserati

Sweden: Volvo

Spain: Seat

Czech Republic: Škoda Auto

This research approach was delineated and focuses on the following points:

1. Environmental impacts for the Automotive industry, expressed in policy frameworks and legislation,
2. Behavioral changes in relation to emergent situations due to the new supply chain legislation at EU level,
3. The influence of the COVID-19 pandemic on the conversion of the supply chain for electric cars and
4. The assessment of risk management in the current supply chain.

For European manufacturers, this implies distancing themselves from existing dependencies and building their own European solutions. In doing so, the new risks must be assessed. At the same time, the higher compliance requirements of the legislator must be taken into account. The OEMs' freedom of action is severely restricted here and the transformation of the supply chains can at best be achieved in the medium term, as there are no infrastructures that enable compensation. Against these basic conditions, which can currently be identified, it is necessary to determine how far the OEMs have progressed in order to react appropriately to these requirements and to what extent they perceive the risk-based factors internally in the departments in order to be able to transfer them into a holistic structure [23]. For this purpose, a separate empirical approach was built up, focusing on three departments of the OEM that recognize these effects most strongly in their own work. Purchasing, as supply management, internal logistics, as distribution management of production relevant parts, and sales, as sales management, were selected. All three departments are said to perceive the effects of the pandemic, the political decisions, and the new legal situation most vehemently.

The sample achieved is n = 266 valid responses from the three departments, with 82 respondents from internal logistics, 101 respondents from purchasing and 83 respondents from sales.

The optional response categories in the entire questionnaire were presented to the respondents nominally by proficiency or ordinally by sorted proficiency using the Likert scale method.

The complexes of questions, each with specific individual questions, were either answered by all three departments (political measures regarding electromobility and pandemic effects), as they have comprehensive relevance. Other question complexes (supply chain law and assessment of the resilience of one's own risk management in relation to the supply chain) were only presented to two departments (purchasing/sales), as logistics does not have the same relevance and the required depth of information in certain areas. The respective departments are shown in writing and color-coded in the individual results. The question sets covered the following areas:

- Political measures and regulations from the perspective of the OEM departments
- Impact of a government supply chain bill
- Impact of the pandemic on the restructuring of processes for electric cars
- Perception and assessment of the OEM's own supply chain risk management departments

To answer the research questions, two hypotheses were set up in advance to be tested by the research approach:

Hypothesis 1: The influence of politics through framework planning and laws on electric Automobility is not perceived as positive and efficient by the OEMs in the three divisions in Europe.

Hypothesis 2: The individual divisions of the OEM are not sufficiently resilient in their risk management with regard to emergent risk-based factors.

The analysis was carried out using IBM SPSS Statistics for Windows software, version 26.0. [32] from IBM©. In the following results, only perceptual tendencies that can be read from the statistics are summarized and compared according to department.

RESULTS

Summary of the results from the survey

The 266 participants in the survey are allocated to the three departments in the respective OEM. No information can be given in the survey as to which OEMs participated in the questionnaires with a higher weighting. Likewise, the indication of a country code was waived in the interest of data protection. This was assured as a basis in the provisions for the publication of the results to all respondents. The cohort sizes of the individual departments break down as follows:

- Logistics: 82 subjects
- Purchase: 101 subjects
- Sales: 83 subjects

In the first block of questions, five questions were asked that depict the overarching framework 'Policy measures and regulations from the perspective of the OEM departments'.

The results for the three respective departments are summarized in tabular form and can thus be placed in a direct descriptive comparison. As the survey was based on the Likert scale method, the results can be summarized in a cluster. The three clusters were divided here in the sense that positive tendencies, neutrality and negative tendencies can be summarized. It should be noted for each that the rating 'sufficient' was rated as neutral for all cases, just as it was with the option 'neutral' Table 1.

Quality assurance as well as product and process innovations must be controlled, and risk management implemented across all suppliers. The resulting professionalization of procurement analyses and evaluates suppliers comprehensively in supplier audits. In addition to key issues such as delivery reliability, quality and process quality, new environmental and social sustainability criteria are currently being added - driven by the Supply Chain Act and the political requirements for climate neutrality, among other things [1].

Table 1
Scores of the thematic complex 'Politics' of the individual results of the survey

Department Questions	Logistics	Purchasing	Sales
I rate the political measures regarding electromobility as...	Negative tendency: 67.1% Neutral: 20.7% Positive trend: 12.2%	Negative tendency: 42.6% Neutral: 31.7% Positive trend: 25.7%	Negative tendency: 45.8% Neutral: 51.8% Positive trend: 2.4%
My company sees regulatory, fiscal and structural policy support for its internal restructuring processes.	Negative trend: 11.0% Neutral: 30.5% Positive trend: 58.5%	Negative tendency: 12.9% Neutral: 34.7% Positive trend: 52.4%	Negative trend: 4.8% Neutral: 7.2% Positive trend: 88.0%
The legal conditions in the area of climate protection and sustainability are sufficient for the e-car sector.	Negative tendency: 31.7% Neutral: 41.5% Positive trend: 26.8%	Negative tendency: 25.7% Neutral: 29.7% Positive trend: 44.6%	Negative trend: 14.5% Neutral: 44.6% Positive trend: 40.9%
The government subsidy has led to an increased demand for electric cars.	Negative tendency: 37.8% Neutral: 34.2% Positive trend: 28.0%	Negative tendency: 35.6% Neutral: 33.7% Positive trend: 30.7%	Negative tendency: 45.8% Neutral: 38.6% Positive trend: 15.6%
I rate what has been achieved so far in electromobility as	Negative tendency: 22.5% Neutral: 40.2% Positive trend: 44.3%	Negative tendency: 22.8% Neutral: 32.7% Positive trend: 44.5%	Negative tendency: 24.1% Neutral: 50.6% Positive trend: 25.3%

The following set of questions was based on the Supply Chain Act, which will be mandatory at EU level in the future but has not been clearly developed and adopted in all countries. To date, the United Kingdom (no longer an EU member) has adopted binding regulations since 2015, as have the Netherlands, Germany and France (cf. e.g. [16]. Since the effects here are most noticeable in purchasing and downstream sales, this complex of questions was only focused on these two cohorts. The individual questions asked in this regard were as shown in Table 2.

Table 2
Scores of the topic 'Supply Chain Act' of the individual results of the survey

Department Questions	Purchasing	Sales
Our company has already dealt with the potential impact of the new Supply Chain Act in terms of content.	Negative tendency: 14.8% Neutral: 22.8% Positive trend: 62.4%	Negative tendency: 10.8% Neutral: 33.7% Positive trend: 55.5%
The impact of the new supply chain law has an internal effect on the company's purchasing policy...	Negative tendency: 10.9% Neutral: 63.4% Positive trend: 25.7%	Negative tendency: 13.3% Neutral: 37.3% Positive trend: 49.4%
The concrete effects of the Supply Chain Act in connection with electromobility are...	Negative tendency: 25.7% Neutral: 44.6% Positive trend: 29.7%	Negative tendency: 21.7% Neutral: 51.8% Positive trend: 26.5%

In the following complex of questions, the influence of the COVID-19 pandemic on the conversion of the 'electric car' supply chain was asked. By temporarily closing borders and limiting the import of relevant physical goods for OEMs, existing supply bottlenecks were exacerbated and new supply bottlenecks were created. This situation, which can be described as an emergent crisis, shows in the research how OEMs have generally prepared for these situations. Furthermore, it also shows if risk management is not prepared for this, that OEMs will have to rework here in the future.

The questions asked are shown in Table 3.

Table 3
Scores of the thematic complex 'pandemic' of the individual results of the survey

Department Questions	Logistics	Purchasing	Sales
The pandemic has hindered the restructuring to electric cars. *Negative = disabled* *Positive = not disabled*	Negative tendency: 18.7% Neutral: 23.8% Positive trend: 57.5%	Negative tendency: 34.7% Neutral: 31.7% Positive trend: 33.6%	Negative tendency: 18.1% Neutral: 30.1% Positive trend: 51.8%
The pandemic exposed internal weaknesses in global supply chains during the lockdown. *Negative = weaknesses shown* *Positive = No weaknesses shown*	Negative tendency: 66.2% Neutral: 30.0% Positive trend: 3.8%	Negative tendency: 46.5% Neutral: 26.7% Positive trend: 26.8%	Negative tendency: 38.6% Neutral: 30.1% Positive trend: 31.3%
The pandemic has led to a reorientation with regard to emergent situations in our own supply chains. *Negative = No realignment* *Positive = realignment*	Negative trend: 7.5% Neutral: 25.0% Positive trend: 67.5%	Negative tendency: 11.9% Neutral: 31.7% Positive trend: 56.4%	Negative tendency: 21.7% Neutral: 36.1% Positive trend: 42.2%

The fourth and last grouping of questions dealt with the perceptions of risk management in the OEM value chain and goes beyond selling of goods. Here, various questions were set up dealing with the status, development and future perspectives.
The questions in detail are shown in Table 4. These questions were directed at the purchasing and sales departments, as this is where the most relevant references to the questions asked are seen.

Table 4

Scores towards the perception of risk management

Department Questions	Purchasing	Sales
Our company has created a special risk management for the new value chain 'electric car' beyond existing internal standards.	Negative tendency: 11.9% Neutral: 13.9% Positive trend: 74.2%	Negative trend: 1.2% Neutral: 6.0% Positive trend: 92.8%
Our company sees a need for specific risk management of the 'electric automobility' value chain. *Negative = demand Positive = No need*	Negative tendency: 43.6% Neutral: 38.6% Positive trend: 17.8%	Negative tendency: 38.5% Neutral: 44.6% Positive trend: 16.9%
Our company is transforming the value chain for electric cars ...	Negative tendency: 19.8% Neutral: 47.5% Positive trend: 32.7%	Negative tendency: 31.3% Neutral: 49.4% Positive trend: 19.3%
Risk-based factors in the new value chain will diminish.	Negative tendency: 46.5% Neutral: 30.7% Positive trend: 22.6%	Negative trend: 55.4% Neutral: 25.3% Positive trend: 19.3%
Our risk management in the value chain is in the point of holism ...	Negative tendency: 50.5% Neutral: 37.6% Positive trend: 11.9%	Negative tendency: 44.6% Neutral: 44.6% Positive trend: 10.8%

Evaluation of the results

In a summarizing conclusion, it can be said that the results of the assessments of the three cohorts are approximately the same in the mean value analysis. All cohorts have an average of more than 4 out of 7 possible evaluation points, which implements an approximately equal assessment. Nevertheless, the high proportion of neutral tendencies in the evaluations of the test persons is conspicuous, which on the one hand shows a high degree of reluctance on the part of the majority to implement the measures used so far. In addition, there seems to be a high degree of uncertainty as to what the future prospects are, since many external influences have an impact on the OEM, on which one can only exert a limited influence of one's own, and in the case of politics, people tend to act in a wait-and-see manner, since here, too, no comprehensive quick solutions are expected.

However, there are differences in the individual consideration of certain surveyed topics with individual evaluation peaks in a trend position (positive, neutral or negative). These are to be presented here as a summary of the results and continue into the discussion.

In the area of consideration and evaluation of the political factors that influence the OEM, the most striking point is in the perception of all political measures of electromobility. Here, at 2/3, logistics has an excessively negative attitude compared to the other two departmental cohorts. If one considers the time period of the results in this context, then retrospective perceptions are also co-determinants. For example, in the logistics sector during the lockdown periods, there were complaints that the provisions of the national logistics conditions were not softened in time and only too slightly. Driving bans at certain times of the night and all day on Sunday have not been uniformly suspended and the necessary product groups for the Automotive industry have not been taken into account. In addition, faster financial support was called for, but was not put in place. Against the background of a demanded rapid transformation in the Automotive industry on the part of politicians [33], this was not received positively in the logistics sector [34]. In addition, it was criticized that the shortage of personnel during the pandemic due to high levels of illness was not and is not being addressed by adequate rapid personnel solutions using workers from abroad (cf. e.g. [35, 36]). The poor position of logistics is further exacerbated by rising fuel costs, which have become even more strained as a result of the Ukraine war (cf. e.g. [37]), and in some countries, especially Germany, a high tax burden affects all logistics processes.

The situation is different in the policy measures generally implemented so far, which are assessed as positive by the majority.

When it comes to the question of climate protection regulations and sustainability regulations on the part of politicians, a high degree of restraint can be seen in the assessment, which also affects the assessment of what has been achieved so far in electric Automobility. For example, the targeted sales figures according to the political ideas in Germany as the leading car market in the EU have not been fulfilled, as the planning of 1 million e-cars by 2020 (cf. e.g. [38]) has been missed by far.

The subsidies, which were at times pushed very intensively politically, are not seen as a breakthrough by the three cohorts of OEMs, so that no extraordinary positive trend can be shown here either.

Nevertheless, the EU's demands regarding the implementation of climate targets are increasing and this plays into the OEM's assessments. These are imperative for the OEM to achieve, as massive penalties are to be expected in the event of non-compliance. In the current situation, this puts additional significant pressure on OEMs during the transformation period [39].

In addition, the current uncertainties for companies and private individuals regarding investments are to be considered bad, so that neither the Automotive industry can rely on further investments to advance the conditions of rapid and cheaper transformation. For citizens, e-cars remain a cost factor in the purchase, which currently does

not seem feasible for many households due to rising inflation and political measures in the energy sector.

In the case of the Supply Chain Act, it can be seen that OEMs have already predominantly dealt with the existing or emerging conditions and consequences of proposed legislation. However, this is not yet a valid indication for inclusion in internal risk management. However, reticence and open points in dealing with the Supply Chain Act are evident in the assessments of the impacts. Here, the results of the survey contain a very high proportion of neutrality. However, purchasing as a cohort is more negative in its assessments than sales in a direct comparison, as the impact can be assumed to be more noticeable here. Supply chains have to redesign themselves according to the new regulations and require intensive risk management during the redesign, including complete documentation [13], (cf. e.g. [16]). This redesign poses new challenges for the supply of the OEM with all necessary goods, which do not yet appear foreseeable.

> *"However, it is difficult for companies to understand whether critical sentiments exist beyond the Tier 1 level of the supply chain and require risk analysis due to a lack of information transparency. Companies are currently only able to verify the authenticity of incoming risk notices with a significant investment of resources. The implementability of the Supply Chain Act is therefore significantly influenced by the degree of transparency about one's own supply chains" (cf. e.g. [16]).*

This also explains a strong neutral position in the questions asked on this and a more negative tendency in purchasing. In 2022, the difficulty of the current intertwining of problem situations due to the pandemic and geopolitical uncertainty led to temporary demands that the time window for the implementation of supply chain legislation be suspended [13]. One of the most important reasons for the demand and the OEM's pessimistic view of the realignment lies in the severe limitation of countries that are eligible for both raw material supplies and parts supplies if one wants to comply with the requirements through the laws (cf. e.g. [11]). In principle, even with a new structure, new countries do not necessarily minimize the existing risk-based factors in the selection of suppliers. Although diversification would take place, international suppliers from Asia or Latin America would also face long transport routes, climate-related disruptions and geopolitical imponderables. In addition, with the high level of influence of Chinese companies worldwide, Chinese hegemony cannot be ruled out [13].

Overall, the results show that one must assume an existing reluctance. Either it still has to be determined how to finally imply compliance in one's own supply chain or there is no concrete draft law in the respective country yet to which one can adequately react.

Looking at the results in general terms for the transformation process 'BEV', the pandemic itself has not influenced the OEMs as much as assumed. This means that it can be assumed that if the problems are overcome in 2020/21 and the supply chains are further restructured, the OEMs will be able to complete the transformation [33]. In a comparison of European countries where large OEMs are located, Germany has weathered the pandemic economically better than France, Italy, and the UK [40], which can also be reflected in the results and supports the positive trend.

With regard to the pandemic, the cohort purchasing has the most negative perceptions of the restructuring of the supply chains. Logistics, which is intrinsically more affected, has taken less action as a result of the lockdowns, showing the higher neutrality of the assessment. Sales has focused its objectives and continued to sell within its means, regardless of electric cars.

In terms of the weaknesses identified during the pandemic, however, the logistics cohort shows a strong negative tendency, which is also consistent with the political measures taken during the pandemic in the results. In particular, it can be assumed that direct concern was strongest here. However, the weaknesses were also recognized by the other cohorts and confirmed in the survey.

With regard to the knowledge gained from the pandemic, there are positive effects at the OEMs in that they increasingly want to turn to emergent situations in risk management. This is confirmed by both logistics and purchasing. Here, the use of algorithm-based systems of artificial intelligence would be available as an improvement potential as a solution instrument, but this is still under development [41].

Sales do not seem to be equally positive here, with sales figures showing losses in the current pandemic year 2020 and beyond. The resilience of the supply chains and the necessary restructuring are perceived more negatively here.

The actual internal risk management at the OEMs appears secure to the purchasing and sales cohorts at the time of the survey and has been expanded. However, both cohorts realize at the same time that further development of management tools for risk detection is necessary to make the supply chains resilient. In terms of transformation, procurement is more positively aligned in its assessment as lessons have been learned from the 2020/21 events. Sales is more subdued, as it took longer for sales to catch up with pre-Corona levels. In addition, both cohorts believe that internal risk management requirements will become more complex, rather than simpler, as new situations and external requirements continue to flow in. This concerns both compliance, which the legislator is increasingly tightening, and the design of new supplier relationships that meet both corporate and legal requirements. What would be required, therefore, is a more proactive rather than reactive risk management, as is still widely prevalent (cf. e.g. [42]).

The fact that this resilience does not yet exist sufficiently is shown in the result of the assessment of the holistic nature of risk management in the OEMs, which are subject to a general negative tendency in the assessment. It can thus be assumed that an even more holistic view of OEM senior management is necessary in order to minimize competitive behavior between departments and thus

solve future challenges quickly and efficiently (cf. e.g. [43]). In an interview survey of over 80 scientific experts and managers from the ranks of OEMs and important supplier companies in 2021, the unanimous opinion was:

> *"The central element of risk management and scenario planning (not only) in pandemic times is, according to the respondents, in many cases not yet sufficiently developed to be able to react appropriately to future shocks in production and supply chains" (cf. e.g. [6]).*

From the results obtained, the following statements can be made with regard to the hypotheses put forward.

Hypothesis 1: The influence of politics through framework planning and laws on electric Automobility is not perceived as positive and efficient by the OEMs in the three divisions in Europe.

This hypothesis is not sustainable in its basic statement, as the departments show a slight positive tendency. Nevertheless, it can be stated that the OEMs express themselves in a restrained manner with regard to the political measures and influence. These vary according to the situation and the degree to which they are affected and show indications of a differentiated departmental view that continues to exist.

Hypothesis 2: The individual divisions of the OEM are not sufficiently resilient in their risk management with regard to emergent risk-based factors.

It can be stated here that the hypothesis is confirmed in that the OEMs see a need for holistically oriented risk management and are very inconsistent in their perception with regard to the risk-based factors presented here.

The conclusion is that the OEMs' internal adaptation to a holistic strategy and risk minimization is not yet complete and thus weakens resilience. This also tends to be confirmed by the results of the survey, as the perceptions of the influencing factors sometimes differ greatly and adjustments along the entire value chain have not been exhausted in all areas.

Statistical evaluation of the results of the survey

In the statistical analysis, a dimension reduction is carried out from the overall results. Here, the previously listed thematic complexes are merged as data sets with reduced dimensions.

Mathematically, these dimensions must still show as much variation/variance cumulatively as possible. This enables the use of the mathematical-statistical procedures in the evaluation analysis KMO (Kaiser-Meyer-Olkin measurement) [44]), Bartlett test (cf. e.g. [45]), single factor ANOVA [46]), Cronbachs alpha [47], and t-test [48].

It is important to emphasize that the analysis is always carried out with Varimax rotation as a factor analysis. The focus is on maximizing the information content of the topic complexes and assigning the questions to a complex [49].

In addition to the factor analysis, a reliability analysis is carried out per group. Although the factors of the variables relevant for the analysis are already calculated in advance (as part of the factor analysis), they must be checked for sufficient internal consistency [50]. This is ensured with the measure of internal consistency using the Cronbachs alpha method. The acceptable values have been given as a minimum with $\alpha = 0.7$. In addition, Cronbachs Alpha provides a measurement of whether the questions correlate to a group/factor.

After factor and reliability analysis, the scales are mapped for each of the merged groups.

Then differences between the departments are determined for each of the new variables. Since these formed variables are metric by construction, the t-tests for two relevant departments or the analysis of variance ANOVA for all three relevant departments are performed here as significance tests (cf. e.g. [50, 51, 52]).

The results of the analysis from the survey are presented, selected according to topic complexes and selected questions that have a reliability to the complexes.

Perception of e-mobility policies

The requirements for the KMO test were met in the group. The measure must be above 0.6 to index a sufficient number of items/questions for the factor/group. The Bartlett test must be significant, i.e. the significance must be below 0.05. From Table 5 it can be seen that

KMO = 0.637 > 0.6and the significance $p = 0.000 < 0.05$ are. This allows the analytical comparison of the departments with the subject complex.

Table 5

Factor analysis: Group 1, KMO and Bartlett

KMO– und Bartlett-Test

Measure of sample suitability according to Kaiser-Meyer-Olkin		0.637
Bartlett-test for sphericity	Approx. Chi-Square	151.416
	df	10
	Significance to Bartlett	0.000

Source: based on [32].

In Table 6 it can be seen that the Cronbachs alpha value is $\alpha = 0.714 > 0.7$ lies within the group. Thus, there was sufficient internal consistency and the individual questions could be combined into one group.

Table 6

Reliability analysis, group 'Politics'

Reliability statistics

Cronbachs Alpha	Number of items
0.714	5

Source: based on [32].

The calculation of the new group called 'Politics' was done by averaging (Fig. 2). The individual values were averaged per department, which made it possible to calculate an average. The mean values determined are shown.

Fig. 2 Group 'Politics': Bar chart of the mean values
Source: adapted from [32].

Furthermore, an inferential statistical analysis using ANOVA was carried out to determine whether significant differences could be found between the departments or whether there was a uniformity of opinion on the five questions regarding the topic complex 'politics' (Table 7).

Table 7
Group Politics: ANOVA
Factorial ANOVA

Politics

	Sum of squares	df	Means of squares	F	Significance
Between Departments	3.478	2	1.739	2.487	0.085
Within Departments	183.872	263	0.699		
Total	187.350	265			

Source: based on [32].

The results of the analysis of variance F (2.263) = 2.487 are not significant, as the significance p = 0.085 > 0.05. Thus, there are no significant differences between the divisions in terms of views on policies and regulations. These are summarized in all three divisions with a slight positive tendency (> 4 points out of 7 maximum).

Perception of the Supply Chain Act

The following are the results of the preliminary analyses. The KMO measure specified must be > 0.6 to index a sufficient number of items/questions for the factor/group. The Bartlett test must be significant, i.e. the significance must be below 0.05.

From Table 8 it can be seen that the KMO – *Measure* = 0.592 < 0.6 deviates only minimally from the limit value and the significance is p = 0.000 < 0.05amounts to. Thus, the requirements are fulfilled and a factor analysis can be carried out.

Table 8
Factor analysis: Group 2, KMO and Bartlett
KMO– und Bartlett-Test

Measure of sample suitability according to Kaiser-Meyer-Olkin		0.592
Bartlett-test for sphericity	Approx. Chi-Square	43.060
	df	3
	Significance to Bartlett	0.000

Source: based on [32].

In Table 9 it can be seen that the Cronbachs alpha value is α = 0.779 > 0.7 lies. Thus, there is sufficient internal consistency and the individual questions can be combined into a group.

Table 9
Reliability analysis, group 'Supply Chain Act'
Reliability statistics

Cronbachs Alpha	Number of items
0.779	3

Source: based on [32].

The calculation of the new group 'Supply Chain Act' is done by averaging. The individual values are averaged per group and the average is calculated. The two surveyed cohorts on the supply chain law can be compared with each other.

In Figure 3, the mean values of the variable 'supply chain law' are relatively equally distributed in both departments, so that the evaluation measure can be defined as similar.

Fig. 3 Group 'Supply Chain Act': bar chart of mean values
Source: adapted from [32].

In order to statistically confirm or refute a significant difference, an inferential statistical analysis is carried out using a t-test. The Levene test used here does not show significance because p = 0.478 > 0.05. Thus, the variances are to be assumed to be equivalent. The t-test $t(df$ = 182) = -0.522 is also not significant, since p = 0.603 > 0.05 Thus, there are no significant differences between the two departments regarding views on the Supply Chain Act. The values obtained are shown in Table 10. These are slightly positive/optimistic in both departments, as out of the seven options, > 4 were scored, confirming the slight positive trend.

Table 10
T-test for group 'supply chain law'
Test to independent samples

		Levene's-Test of equal variance		T-Test for mean equality						
		F	Significance	T	df	Significance (2-sided)	Mean difference	Standard error of the difference	95% confidence interval of difference	
									lower	upper
Supply Chain Law	Variances are equal	0.505	0.478	-0.522	182	0.603	-0.06911	0.13251	-0.33057	0.19235
	Variances are not equal			-0.517	167.888	0.606	-0.06911	0.13374	-0.33314	0.19492

Source: based on [32].

Perception of the pandemic situation

Here, all three departments were interviewed as cohorts in order to be able to generate comprehensive results in the comparative analysis.

From the Table 11, it can be concluded that the requirements can be met and proceed with a factor analysis, as KMO = 0.635 > 0.6and significance p = 0.000 < 0.05.

Table 11
Factor analysis: Group 3, KMO and Bartlett

KMO– und Bartlett-Test

Measure of sample suitability according to Kaiser-Meyer-Olkin		0.635
Bartlett-test for sphericity	Approx. Chi-Square	78.552
	df	3
	Significance to Bartlett	0.000

Source: based on [32].

In Table 12, the Cronbachs alpha value is α = 0.715 > 0.7. Thus, there is sufficient internal consistency and the individual questions can be combined into one group.

Table 12
Reliability analysis, group 'Pandemic'

Reliability statistics

Cronbachs Alpha	Number of items
0.715	3

Source: based on [37].

The calculation group 'pandemic' is again done by averaging. In Figure 4 we find the mean values of the variable 'pandemic' in all three divisions. One can see small differences between the cohorts, but on average a > 4 has been selected as the mean value.

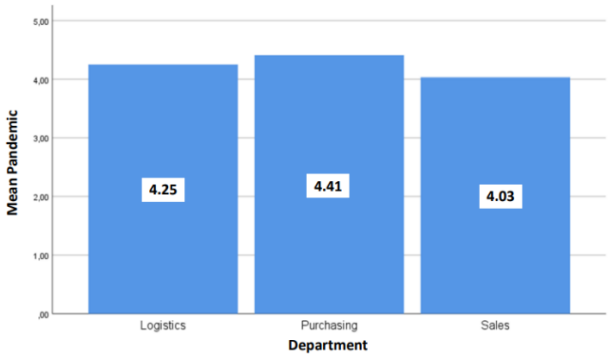

Fig. 4 Group 'Pandemic': Bar chart of the mean values
Source: adapted from [32].

The inferential statistical analysis by means of ANOVA shows the results of the analysis of variance F(2.261) = 3.242 and are therefore not significant, as the significance p = 0.55 > 0.05. Thus, there are no significant differences between the departments regarding views on the pandemic. Thus, the subjects agree with the weaknesses of the supply chains but negate a massive hindrance to internal restructuring to electric cars and see a planning direction to transform the supply chains to be more resilient. The values obtained are shown in Table 13.

Table 13
Pandemic group: ANOVA

Factorial ANOVA

Pandemic

	Sum of squares	df	Means of squares	F	Significance
Between the departments	6.486	2	3.243	2.937	0.55
In the department	288.221	261	1.104		
Total	294.707	263			

Source: based on [32].

Perception of own risk management for the risk-based factors

The evaluations were carried out exactly as in the 'Supply Chain Act' group (Table 14).

Table 14
Factor analysis: Group 4, KMO and Bartlett

KMO– und Bartlett-Test

Measure of sample suitability according to Kaiser-Meyer-Olkin		0.572
Bartlett-test for sphericity	Approx. Chi-Square	65.808
	df	10
	Significance to Bartlett	0.000

Source: based on [32].

The acceptance of the KMO and Bartlett test also allows the grouping into a superordinate group here. KMO = 0.572 < 0.6 with minimum deviation and likewise the Cronbachs alpha value α = 0.652 < 0.7 with minimal deviation (Table 15). Thus, there is sufficient internal consistency and the individual questions can be combined into a group.

Table 15
Reliability analysis, group 'Supply chain electric Automobility'

Reliability statistics

Cronbachs Alpha	Number of items
0.652	5

Source: based on [32].

In the mean determinations it can be seen that both cohorts have made an almost mirror image assessment and thus no significant differences are recognized (Fig. 5).

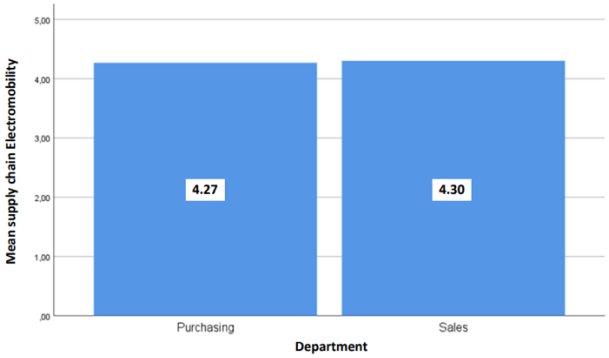

Fig. 5 Group 'Supply chain electric Automobility': Bar chart of the mean values
Source: adapted from [32].

This is also confirmed by the inferential statistical analysis using a t-test. The Levene test is not significant because $p = 0.174 > 0.05$. Thus, the variances in the group are assumed to be equal. The t-test $t(df = 182) = -0.300$ is also not significant, since $p = 0.765 > 0.05$ All the values determined can be taken from the following Table 16.

Table 16
T-test for group 'Supply chain electric Automobility'

Test to independent samples

		Levene's-Test of equal variance		T-Test for mean equality						
		F	Significance	T	df	Significance (2-sided)	Mean difference	Standard error of the difference	95% confidence interval of difference	
									lower	upper
Supply Chain Electro-Mobility	Variances are equal	1.859	0.174	-0.300	182	0.765	-0.06911	0.03388	-0.25702	0.18926
	Variances are not equal			-0.306	181.936	0.760	-0.06911	0.03388	-0.25239	0.18464

Source: based on [32].

DISCUSSION

The results of the survey allow the general conclusion that the risk management of OEMs in Europe does not yet have the level of resilience that is necessary for contingent management in the internal supply chains. Furthermore, the external influences also show that contingency is not consistently present, which shows that there is still a need to catch up overall. If the OEMs cannot position themselves appropriately resiliently in the relevant areas, then all participants in the market will find themselves in a similarly ambivalent situation, which will make new strategies necessary. Since Europe is dependent on relevant raw materials, components, and semi-finished goods, with batteries and electronic components being the most relevant factor, new approaches are intrinsically important here. The European OEMs can only reduce this dependency by adopting a stronger joint position, as all manufacturers have roughly the same prerequisites here. The results of the own empirical survey are a sectoral illustration and only concern the selected research references to supply chains of risk-based physical goods. The differentiation into three cohorts shows, with the sometimes-different results, that a consistent internal company risk assessment cannot yet be considered complete. Follow-up research is necessary and can help to clarify single open questions. However, the need is assessed as high, as shown by the results of a survey of experts by the Expert Group on Transformation of the Automotive Industry. The majority view geopolitical risk as high and it can be triggered by a wide variety of factors (climate, politics or war). For explanation, every green point is the position of one expert in the survey as shown in Figure 6.

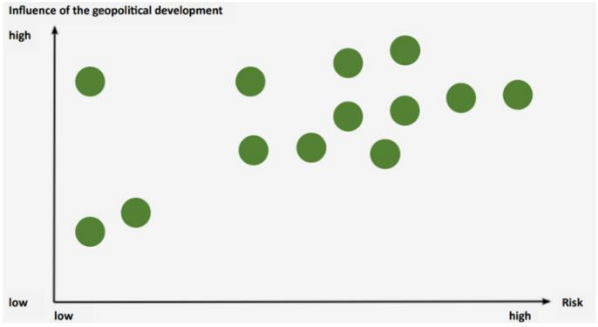

Fig. 6 Expert responses to the question: How do you assess the influence of the geopolitical situation on the supply situation and the associated risk?
Source: [17].

One of the most important factors here is Europe's dependence on raw materials, which is self-induced by decades of outsourcing to other global regions. The pandemic, the geopolitical tensions, and the political acceleration to achieve climate goals and human-oriented social compatibility in supply chains make it clear how fragile Europe in particular is positioned in its supply chains. This does not only affect the Automotive sector but can be seen in many other economic sectors.

For the European OEMs, however, the scope of the vulnerabilities must be assessed more strongly, as they are jointly responsible for making the field of individual mobility climate-neutral in the near future. To achieve this, the raw materials for batteries in the BEV sector are urgently needed, as are the batteries themselves. Various relevant raw materials are currently still being imported at 100%. Although the continent's own efforts to promote them are being initiated, in the medium term only ¼ of the raw materials needed for its own battery production will come from Europe. A stronger orientation towards recycling these raw materials would be a step towards more independence, but this is also planned but not yet implemented (cf. e.g. [11]). Especially in the area of raw materials for battery technologies, Europe is still treading water and it is not foreseeable that complete autonomy or resilience can be achieved in the next 10 years by unbundling the supply chains. Especially against the background that climate targets have been formulated for 2030, which probably cannot be met in this timeframe. Added to this are the demands placed on companies by EU-wide supply chain laws, which call for compliance but take place against the backdrop of global raw material distribution and especially further processing in nations whose social attitude appears questionable. Examples with a high impact are Congo in cobalt mining and China as a world leader in the further processing of various raw materials for battery production. The consequence is that cobalt continues to be a raw material that is shown to be questionable in terms of humanitarian and human rights concerns, which the EU claims for itself. Before the pandemic, a study by various NGOs stated:

> *"Despite selective attempts to identify risks, conduct audits, etc., not a single one of these companies can today 100% rule out the possibility of human rights violations occurring along its cobalt supply chain. Many*

carmakers acknowledge that their supply chains have become more transparent and traceable, but do not yet use this progress sufficiently to systematically analyze and eliminate human rights risks in their supply chains" [53]).

Due to the expansive access of Chinese companies to the raw material-producing countries in Africa and Central and South America, the opportunities for European companies to make their own contributions are increasingly limited (cf. e.g. [11]). As a result, there are always strong dependencies on the Chinese economy that cannot be eliminated in the medium term. This will also not succeed through the expansion of the extraction and processing of relevant raw materials that has been started.

"Covering the demand of European cell production from local raw material deposits in 2030 will not be possible. Importing raw materials and/or processed precursors will be necessary, new mining sites notwithstanding. Reliable trade partners have to be found to ensure a secure supply" (cf. e.g. [11]).

European OEMs will need to build additional strategies to reduce dependencies, obtain required volumes of raw materials while increasing supply chain resilience, and achieve full compliance with legislators at the supranational level.

In pure game theory, based on two players, cooperation would fail because the dominant strategy is to gain an advantage. However, the constellation of OEMs in Europe is such that more than 30 participants share the market and all have roughly the same problems. This is also due to the strong consolidation of the European market, which is organized in group structures, so that influences on one nation and its supply chains also affect other companies in Europe. In such an oligopolistic market, which must defend itself against international competition, cooperation is the best solution.

In the business management field of game theory, it is possible to use the models of the Prisoner's Dilemma to underpin strategic management decisions that are geared towards cooperation between OEMs. These cooperations support the European market position against American and Asian competition.

"New digital forms of cooperation and data sharing can contribute to improved supply chain transparency, which in turn enables faster responses to shock events. However, this requires a new culture of trust and data sharing between all actors along the value chain" [6].

An important approach to improving the design of value chains and their resilience is the planning and development of the GAIA-X project. This project was launched by the German Federal Government in 2019 and its structure represents a digital data infrastructure at EU level that will facilitate the exchange between various relevant areas of science, industry, and politics. It is also planned to expand the participation of market participants beyond the European Union [54]. The basic idea behind this approach is to prepare companies and the entire European economy more resiliently for exogenous and emergent situations and to keep competitiveness stable [21]. The basic concept can be seen in the following overview in Figure 7 and explains which approach is being pursued with GAIA-X.

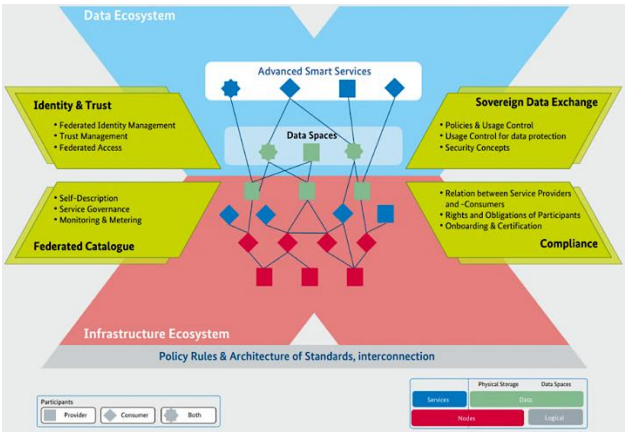

Fig. 7 Architecture of the GAIA-X approach at all involved and relevant levels
Source: adapted from [55].

The GAIA-X project is currently still under construction.
In relation to the Automotive industry, which has a high economic power across the EU, such an exchange principle will yield several benefits:

- Possibility of EU standardization of parts and components: Examples would be standardized battery installation components and connection parts or chip standardization in compatibility [17].
- Delimitations of dependencies of international supply chains
- Increasing market positioning vis-à-vis strong international competitors
- Coordinated R&D concepts to obtain further European patents
- Facilitation of raw material procurement through aggregation
- Maintaining unique selling propositions through OEM-specific innovations (in-house core services vs. outsourcing to third parties)
- Lower costs by bundling R&D activities in areas that are not relevant to competition
- Compliance with the EU directive of CO_2 emissions
- Compliance with supply chain regulations in terms of humanity and sustainability

The Catena-X Automotive Network e.V. formulates its own visions and guiding goals of the network as follows:

- Consensus of the pioneers: Significant need for action to meet the challenges of the Automotive industry. Create a [...] European investment in interoperable and secure information exchange and network-based services.
- Guiding principle: Community approach to the selection and implementation of scalable, system-relevant use cases. Covering the entire value chain of the Automotive industry, regardless of company size.
- Security & openness: Openness and non-discriminatory access to the network as the overriding principle for all market participants. Implementation of data

sovereignty, security & interoperability principles based on Gaia-X & concepts of IDSA (cf. e.g. [56]).
- Industry standards: Validation of the Gaia-X principles and management of industry-specific requirements by the association. Open exchange for the Catena-X standards and certifications, among others with industry-relevant standardization bodies [57]).

This will result in a scale effect in a positive sense for the participants if there is evidence that a cooperative strategy in areas of innocuous use cases leads to added value for all participants (cf. e.g. [56]. The goal orientation of Catena-X is designed as follows in Figure 8.

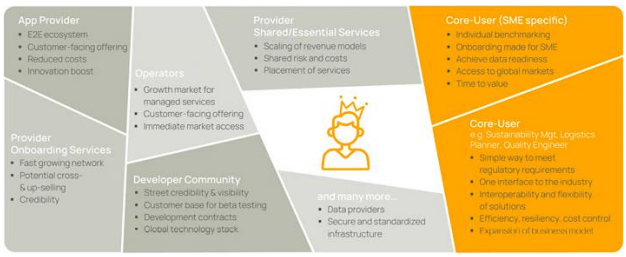

Fig. 8 Positive benefits from participation in Catena-X
Source: adapted from [58].

If we look at individual use cases as examples of positive benefits, synergy effects arise for the European Automotive industry in the face of growing and in some cases already superior international competition from the Asian and North American regions.

An important factor in terms of cost efficiency, the requirements for climate neutrality due to the increasing number of customers and the simultaneous compliance with climate-relevant legislation at EU level is the logistics of the manufacturers. The basis for these networks is:

> *"A typical logistics network in the Automotive industry includes tens of thousands of routes, and a six- to seven-digit number of variants exist for each transport scenario" [41].*

Since the OEMs are geographically located differently, the destinations of the finished products are sometimes congruent. And the transshipment locations of the products rely on the same transport routes of road, rail, or waterway in many areas. The transshipment locations themselves are usually the major European ports from which the final products are delivered internationally. Since the competitive situation of the individual OEMs would remain unaffected by cooperating transport logistics, the bundling of transports would be a first step towards more cost efficiency and a reduction of the company's internal CO_2 footprint. By means of the independent data network structure and the internal conflict-free transmission of information, Catena-X could be put to good use in this area. Bartlett-Mattis sees the synergy effects here very clearly.

> *"If you look at the currently still separately planned incoming and outgoing goods flows of the entire Automotive industry, the potential of such a holistic approach quickly becomes apparent. For the manufacturers, bundling their flows of goods would be a win-win situation because it serves both economic and ecological goals. Some initiatives such as the European Logistics Users Providers and Enablers Group (ELUPEG) are already working to address antitrust concerns about such cooperation" [41].*

Further possibilities for the implementation of use cases that are independent of competition lie in areas that are highly standardized or even standardized at EU level and are used uniformly by all car manufacturers. What is important with these use cases is that they do not have a unique selling point on the market as an innovation factor and can therefore be taken up by all participants in the industry without any problems.

These can thus be applied to individual components or assemblies that correspond to the previously mentioned parameters. If, for example, one takes the complex component wiring harness for the electrification of technical units in an Automobile, these can be constructed uniformly insofar as they meet all the requirements for the technology of a model. Thus, wiring harnesses can be more standardized according to Automobile classes, which also implies that some wires in the tree are not used by all models. If this concerns between 2-10 wires that do not perform a function, this would still be a usable component with the corresponding added values for all OEMs in this segment.

> *"[...] the data analysis shows that the active participation of data providers in the Catena-X industrial data ecosystem is already seen as an opportunity for differentiation. This is explained by the fact that, as written above, every Catena-X participant is expected to share data. This implies that every participant is forced to a certain extent to participate in the development of standards for e.g., data formats and data sharing technologies. The incentive for data providers here is the differentiation through possible learning effects in the development of the required data sharing standards" (cf. e.g. [59]).*

If the competitive situation thus allows components in general to have no unique selling proposition on the market, then the extent of willingness to participate in the form of give and take among the participants can be assumed to be high. In addition, a standardized construction method and a correspondingly high demand can create buyer power in the sector, which induces manufacturers and suppliers to cooperate on the terms of the European OEMs.

If (partial) battery manufacturing processes were standardized, several conditions on the compliance side could be fulfilled more easily here by pushing ahead with purely European battery production. This reduces dependencies on global suppliers and makes the supply situation more resilient by shortening the supply chain.

If we look at this under a simple comparison of services that are provided in-house or externally and the shares of the service in CO_2 pollution, then there are already clear advantages of reducing supply chain lengths when these services are provided in Europe in terms of climate sustainability and compliance with government requirements (Fig. 9).

"Transport is also among the sectors with the highest reduction potential, accompanied by energy and industry. Applying circular economy principles would be expected to yield significant potential for climate change mitigation" (cf. e.g. [60]).

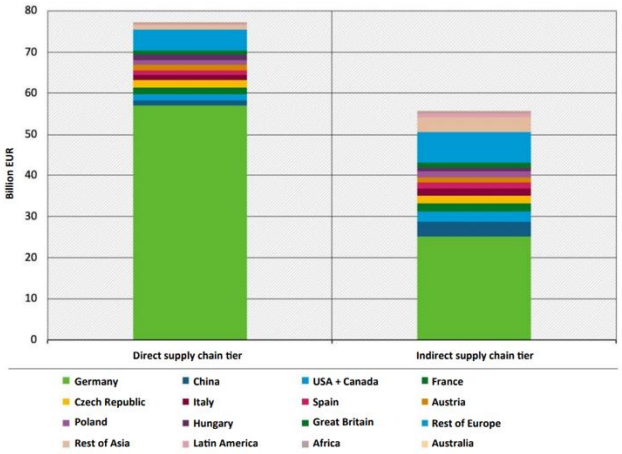

Fig. 9 Value added shares of direct suppliers to the German Automotive industry by country (in EUR billion)
Source: adapted from [43].

If the CO_2 loads are compared directly, the following Figure 10 emerges.

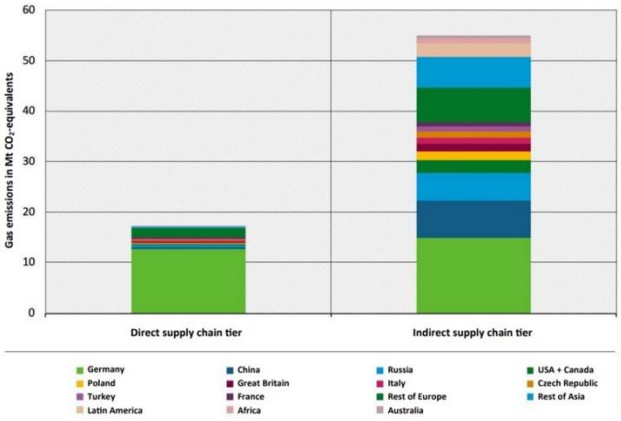

Fig. 10 Greenhouse gas emissions along the upstream value chain of German Automotive manufacturing
Source: adapted from [43].

In a direct comparison, it can be seen that a shift in the supply chains of European suppliers could reduce the carbon footprint by about 20 Mt CO_2 equivalents.
This also applies to the consideration of raw materials needed for manufacturing. First and foremost, in quantitative terms, are the elements lithium and cobalt, which are currently the most important core raw materials for battery production and are considered a major problem in the public debate. An overall European solution in this area could curb these problems and simplify the compliance required of OEMs. The basic prerequisite here would be a pan-European mining strategy that considers all relevant legal requirements while providing sufficient raw materials for battery production. With such a large demand market, which also appears to be easier to plan, the raw material suppliers are more willing to fulfil conditions in the interest of the customers (in this case all OEMs with the respective battery manufacturers). A separate mining strategy, as is being pursued by the USA and China geopolitically in various countries, would reduce the EU's dependence and represent a weighty counterbalance to the developing competitors - especially in Asia. With this aggregated supply of raw materials, the pure raw material dependencies on China regarding lithium would also decrease, which would put the competitive situation internationally on a new footing. Europe as a market can position itself more efficiently and the OEMs in the EU can continue to compete directly with each other through brand-specific innovations.
The results show that these solution patterns address the identified problem areas of the OEM departments in their own survey, depending on their relevance, and could lead to a relaxation. This applies to both individual OEMs and the continental industry as a whole. Geopolitical tensions, climate-related disruptions and compliance difficulties can be addressed holistically and lead to greater resilience.
What remains important in this view is that the national governments and the EU support the infrastructural conditions and push the further conversion of electromobility. In addition, the OEMs must be aware that as single players they will remain at a disadvantage compared to the large US and Asian suppliers if they do not engage in cooperative ventures and thus take advantage of synergy effects through their increased market presence.
For OEMs, it is important to examine the internal supply chains or rather value chains more closely in terms of their holistic nature and not to view risks as singular phenomena in individual areas. The results of our own survey of European OEMs have provided an initial overview of how the industry has perceived political measures to date, what influence and learning effects have been drawn from the pandemic and how they see themselves positioned in terms of the resilience of risk-based factors. In the general framework surveyed, it is evident that resilience is not universally represented, nor is it balanced. The non-uniform perception of risk-based factors in relation to change requirements at some points shows that there is potential in the area of internal integration for the holistic nature of risks. The harmonization of individual departments in the perception of risks and risk-based factors is seen as the key to successful positioning in the market and internal resilience of value creation and the development of new resilient supply chains [61]. This is an important indication for further individual case research to conduct even more intensive research in these areas and thereby find further approaches to the solution.
If the realignment of supply chains and cooperation across the OEM spectrum succeeds in improving delivery conditions and reducing costs at the same time, the European Automotive market can be positioned for the future as a resilient strong market player. The basic prerequisite for this is unity and alignment of views on risk-based factors in the individual companies and departments. Followed by building appropriate coordinated strategies to

minimize the risks. [62] predicted the Catena-X project in 2021 to be highly efficient in all value-added areas for the European supplier market.

> *"If Catena-X is successfully initialized, both the average productivity and the marginal productivities of the logistics and intralogistics production functions increase for the participating companies. The avoidance of bottlenecks primarily increases average productivity because transaction costs can be significantly reduced. In contrast, data exchange optimizes operations and processes so that output increases for the same input, increasing marginal productivity. With this effect on both productivity variables, the production elasticity for the capital employed is increased disproportionately. The increase in marginal productivity resulting from Catena-X generates a leverage effect, which leads to an improvement in operating results for companies and is reflected in the national economy in the form of an increased national product".*

To this end, the possibilities offered by the architecture of the GAIA-X networks and specifically for the Automotive sector in the form of Catena-X must be used and the expected synergy effects exploited. They work in their efficiency if they are applied in a sector-specific and practice-oriented manner (cf. e.g. [56]).

> *"Setting this up in an ecosystem context with a high number of partners involved (e.g. Catena-X of the Automotive industry) is challenging and may fail the traditional (alignment and error-avoidance) needs of a large corporation. Thus, delivering business model innovation in this context requires first and foremost top management understanding and support for a novel innovation approach. If this can be achieved, revamping the supply chain for sustainability is a real possibility".*

Nevertheless, it should be noted that the increasing impact of geopolitical contexts means that supply chains must also be examined for their suitability.

> *"Uncertainty and risk factors come more clearly into the picture, as they have massive consequences for economic action and political stability. The EU should set guidelines for suitable partner (structures), be it in the context of commodity partnerships, in the formation of new consortia, or in terms of the acceptance of central regulations and standards" [13].*

This raises the question of the costs that companies are not prepared to bear singularly. The state is therefore called upon, both nationally and supranationally, to offer targeted support here and also to share the costs of its own demands or to build up simple support that will make implementations viable in the medium term [17].

CONCLUSION

In this research, the topic of risk factors in the supply chain of European OEMs for physical goods was analyzed in detail. The relevant factors for European OEMs in this context were identified in particular in the ability to supply batteries for the conversion of production to all-electric automobility. Here, the factors of raw material procurement and the dependence of production and supply on the dominant Chinese suppliers have been confirmed. This is nothing new but continues to be a determining factor that affects the independence of the economically relevant automotive industry in Europe. Other external influences increase the risk factors and present companies with increasing challenges.

Under the core question: **How are political/legal influences and requirements from the experience of the pandemic and the geopolitical changes of recent years perceived by OEMs in dealing with risk-based factors?** A comprehensive and Europe-wide survey of the largest automotive OEMs was conducted in order to gain insights into the effects of the corona crisis, new geopolitical situations, impending tensions, and EU legal requirements. In addition, the sub-question: **Have the OEMs in Europe adequately adjusted their internal processes to the situational innovations and mitigated risk-based factors?** was answered. The following hypotheses were formulated in the dissertation:

Hypothesis 1: The influence of politics through framework planning and laws on electric Automobility is not perceived as positive and efficient by the OEMs in the three divisions in Europe.

Hypothesis 2: The individual divisions of the OEM are not sufficiently resilient in their risk management regarding emergent risk-based factors.

Hypotheses were confirmed in the inferential analysis of the survey evaluation and show that most OEMs have not stringently adapted their risk management to the new conditions. It shows that the OEMs' ability to react to and withstand emerging risks is inadequate and must be adjusted flexibly in the event of further events.

The results, which were compiled from the three automotive departments (purchasing, logistics and sales) of the respective OEMs, recognized that risk management is not yet sufficiently mature for the new conditions, as the departments achieved very different results in some areas. If risk management had been established for the entire supply chain, the differences in the respective analyses would not have been so great. A reorientation of risk management is required here, as the results of the survey do not show the necessary resilience and robustness for the companies. A high proportion of the OEMs surveyed were extremely cautious in their assessments and showed an ambivalent attitude towards the key areas surveyed.

Automotive OEMs must analyze their internal value chains more closely in terms of their holistic nature and not view risks as isolated phenomena in individual areas. The results of our own survey of European OEMs have provided an initial overview of how the industry has perceived the political measures to date, what influences and lessons have been learnt from the pandemic and how it sees itself positioned in terms of resilience to risk-based factors. It is clear from the general conditions surveyed that resilience is not universally present and is also not balanced. The inconsistent perception of risk-based factors in relation to the need for change in some areas shows that there is potential for holistic risk management

in the area of internal integration. The harmonization of the individual departments in the perception of risks and risk-based factors is seen as the key to successful positioning on the market and the internal resilience of value creation and the development of new, robust supply chains.
The basic prerequisite for this is a uniform and coordinated view of the individual departments regarding risk factors and the definition of suitable strategies to minimize these risks.
The possibilities offered by the GAIA-X network architectures and specifically for the automotive sector in the form of Catena-X can be utilized and the expected synergy effects exploited. They are effective in their efficiency if they are used in a sector-specific and practice-orientated manner.
This raises the question of the costs that companies are not prepared to bear alone. The state is therefore called upon at national and supranational level to offer targeted support and to contribute to the costs of its own requirements or to develop simple assistance programs that make implementation viable in the medium term. The results show that, depending on their relevance, the solution patterns can take up the recognized problem areas of the OEM departments in their own survey and lead to an easing of the situation. This applies both to individual OEMs and to the continental industry. Geopolitical tensions, climate-related disruptions and compliance difficulties must be tackled holistically and thus lead to greater robustness.
In this context, it remains important that national governments and the EU support the infrastructural framework conditions and drive forward the further expansion of electromobility. In addition, OEMs must realize that they will remain at a disadvantage as lone fighters compared to the large US and Asian suppliers if they do not enter into collaborations and thus exploit synergy effects from their increased market presence.
In the economic field of game theory, it is possible to use the prisoner's dilemma model to underpin strategic management decisions that are geared towards cooperation between OEMs. This co-operation supports the European market position against American and Asian competitors. Looking at individual use cases as examples of the positive benefits, there are synergy effects for the European automotive industry in the face of growing and in some cases already superior international competition, particularly from Asia and North America.
In a final consideration of the results, numerous further research is required to provide a complete picture from the initial results.

Further Research

It can be seen in the general framework of this work that resilience is not universally represented, nor is it balanced. The non-uniform perception of risk-based factors in relation to change requirements at some points shows that there is further potential in the area of internal integration for the holistic nature of risk-based factors. Harmonization of individual departments in the perception of risks and risk-based factors is seen as the key to successful positioning in the market and internal resilience of value creation and building new robust supply chains [61].
This is an important indication for further individual case research to conduct even more intensive research in these areas and thereby find further approaches to the solution.
Nevertheless, it should be noted that due to the increasing impact of geopolitical contexts, supply chains must always be examined for their feasibility. Uncertainty and risk factors come more clearly into the picture, as they have massive consequences for economic action and political stability. Guidelines for suitable partner (structures) must be set, be it in the context of commodity partnerships, in the formation of new consortia and in terms of acceptance of central regulations and standards [13].
This raises the question of the costs that companies are not prepared to bear alone. The state is therefore called upon, both nationally and supranationally, to offer targeted support and also to share the costs of its own demands or to build up simple support that will make implementations viable in the medium term [17].
Research is also needed to determine which drive technologies can reduce emissions during vehicle production and recycling in the most cost-effective way. This could also be used to assess which drive systems are worthwhile as an alternative to the pure BEV strategy [63].
Further research is needed in this area at the European level to further substantiate the expected synergy effects. This would also require a differentiated national view and survey of the OEMs, which was not done with the approach presented here. By differentiating the national automotive industries, clearly defined SWOT analyses can be carried out, which show where and to what intensity cooperation and collaboration through Catena-X generate added value.

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