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Supply chain risk management and flexibility to manage the disturbances of global crises

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ABSTRACT

A global crisis successfully creates conflicts, which endanger the performance of the automotive supply chain with its total actors. Risk management throughout a worldwide crisis necessitates dissimilar techniques and procedures to the risk management perspective and approaches practiced for a steady market and stable situations, in order to overcome the supply chain vulnerabilities and disruptions towards the triggered issues of suppliers and demand. The main purpose of this paper, unlike the previous works, is to implement innovative tactics and means to make the supply chain of the automotive industry more resilient and flexible towards global crises to minimize the damages, taking the automotive industry's performance within the Coronavirus pandemic as a field of study and the juxtaposed complications presented in parallel from suppliers and customers to result in a robust technique to create strategic flexibility and balance for production units to manage the jeopardies within and post the global crises. This research, using the analytical hierarchical process for the assessment of the vertical collaboration alternatives, enables the supply chain actors to adopt the most adequate alternative for each category of risks and actors. However, the limitations presented for this study are to overcome the need for risk mitigation by preventing the appearance and bringing the probability to zero percent of the presence of the risks in the whole supply chain of the automotive industry.

1. Introduction

The automotive supply chain is known for its various partners and flows. This complex nature of the supply chain makes it vulnerable throughout the global crises, which endangers the total actors and the natural logistical, financial and informative flow of the supply chain. The purpose of this paper is to examine the impacts of the global crises on the automotive supply chain, and the best alternatives that empower the organizations to assess and monitor the risk factor present in the supply chain and forecast the potential risks and prevent their appearance.

The process of achieving this ultimate goal starts with the identification of the risk factors and their evaluations. This step allows the partners to acknowledge the situation of the supply chain and have clear visibility of the risk factors. Once visibility is established, the controllability of the risk factors can be attained and achieved. Since the global crises impact the global supply chain, the collaboration among its total actors is the best alternative that will allow the risk mitigation, which will deliver a higher level of resilience to the supply chain and mostly, the production units, which are the most vulnerable and impacted actor of the automotive supply chain.

2. The supply chain risk management

The given definition of Risk in the literature on supply chain management is purely negative and leads to undesired results or consequences. The risk is the prospect of loss and the possibility of its penalties. Additionally, the risk from the perspective of the supply chain management is the menace that

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endangers the operational, tactical, and strategic features starting from the very short term to the long term (Koberg and Longoni, 2019).

Correspondingly, the supply chain is being defined and designed mainly by the numerous complex interactions and flows between different agents; centralizing the manufacturer or the production unit with the suppliers as the inbound part and the customers and retailers for the outbound side. It is the nature of this multipart relationship at a global level with several additional regional factors such as taxes, export regulations, and exchange rates (Ben-Daya et al., 2019) that trigger the diverse risks and the uncertainty issues. The supply chain can be also modeled as a network of partnerships as Fig. 1 shows.

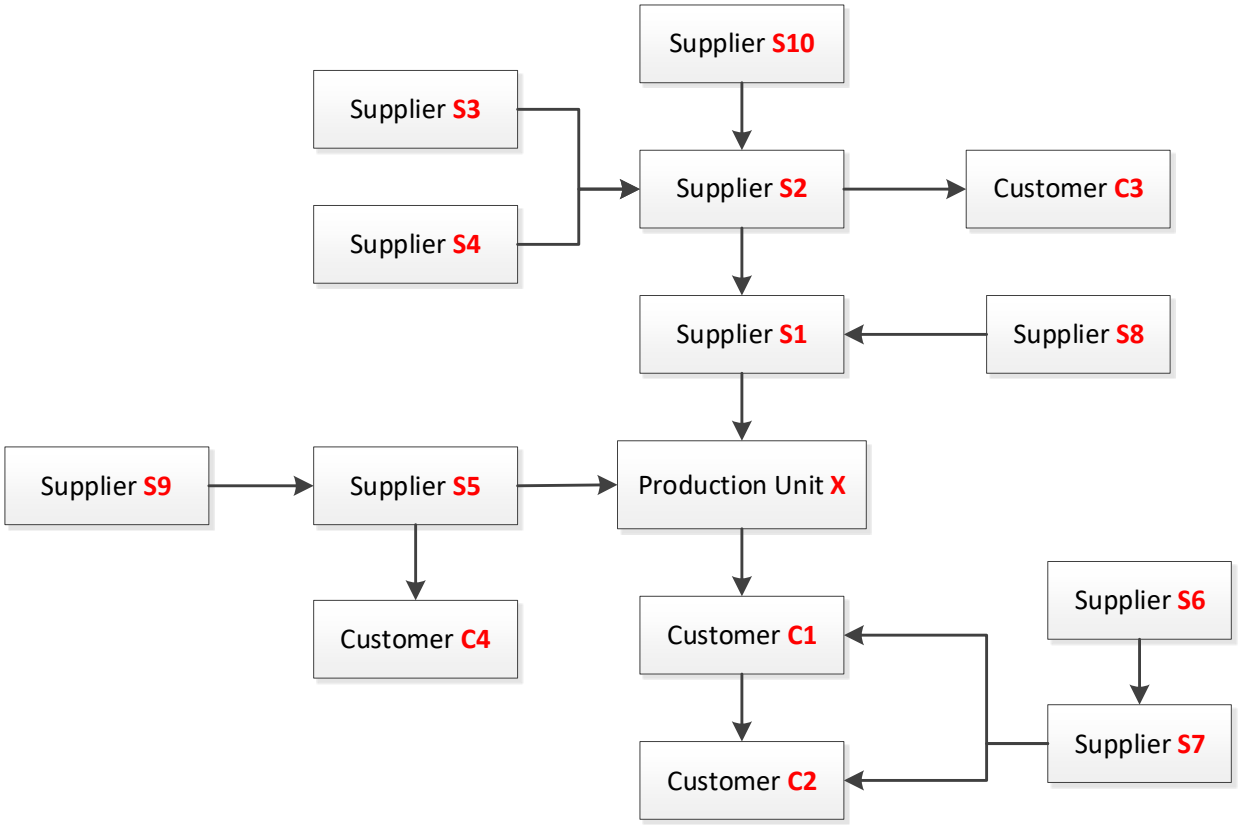

Fig. 1: Example of the summarized supply chain network

It is the emphasis on each partner, which identify the primary actors with direct and rapid impact, and the secondary agents, which delivers also an important source of uncertainties and risks even from a very distant indirect connection. The larger is a supply chain with a higher number of actors and contributors, the higher is the level of potential risk probabilities and possibilities (Fan et al., 2021).

These risks or uncertainties can endanger the normal flow and performance of the supply chain from different angles, and cause countless losses either financially, economically, socially, and environmentally. Therefore, there is an evolution in the sustainable commitment of diverse categories of companies, which functions at the global and regional scale, leading to numerous types of actions involving various organizations and stages within the supply chain related to social and environmental benefits (Multaharju et al., 2017).

The risk management process discusses the strategy to monitor, control and plan measures that are based on information resulting from the risk analysis event (Bai et al., 2022).

Supply chain risk management is considered a complete process with several steps with the main drive being the identification, assessment, and management of the potential risks (Chu et al., 2020).

2.1. The supply chain resilience and the risk management

The supply chain resilience or a resilient supply chain is the capacity of its contributing organizations to recuperate from troublesome events by being proactive. Resilience is linked as well to the capacity of the companies to develop a confident level of flexibility and adaptation throughout either negative or positive situations presented by the direct and indirect environment. The supply chain resilience is the main driver to promoting a strategic plan that is maintainable and proficient to provide and deliver outcomes at a good level compared to the described less resilient competitors.

The prodigious signification of the risk management culture is its link with the supply chain resilience thus, the organization and the total supply chain performance. Therefore, to establish the supply chain resilience, the organizations of a supply chain are motivated to adopt the risk management culture, especially throughout the global crises,

adopting a collaborative feature between the different supply chain actors and contributors, which plays a crucial role in eliminating the uncertainties towards the unknown problematic variations that may be present in the market. Instead of the single focalization by each entity on its own risk assessment, the suppliers, the customers, and the production unit as the bond that ties both sides of the supply chain should hold a global, collective, study of the market.

2.2. Risk management process

To ensure a fruitful tackling of the supply chain issues and problems, the implementation of a successful risk management process is driven by four main steps and actions:

1. Identification of all the possibilities, and significant risk factors presenting impacts on the supply chain growth and performance by employing numerous approaches.
2. Risk assessment of the previously identified risk factors. At this step, for each risk-generating action of the supply chain, the evaluation is based on their likelihood of appearance and their impact on the global supply attainment.
3. Risk management and countermeasures set. The countermeasures taken at this step have for objective the minimization and the contamination of the influence of the risks.
4. Risk Appearance observing. This step consists of sustaining the advancement of the risk management process by monitoring the manifestation of the risk while the supply chain activities and organizations are operating since the risk event is not a stationary event with a constant appearance variable.

These steps are certifying the visibility and controllability of the risk factors as shown in Fig. 2.

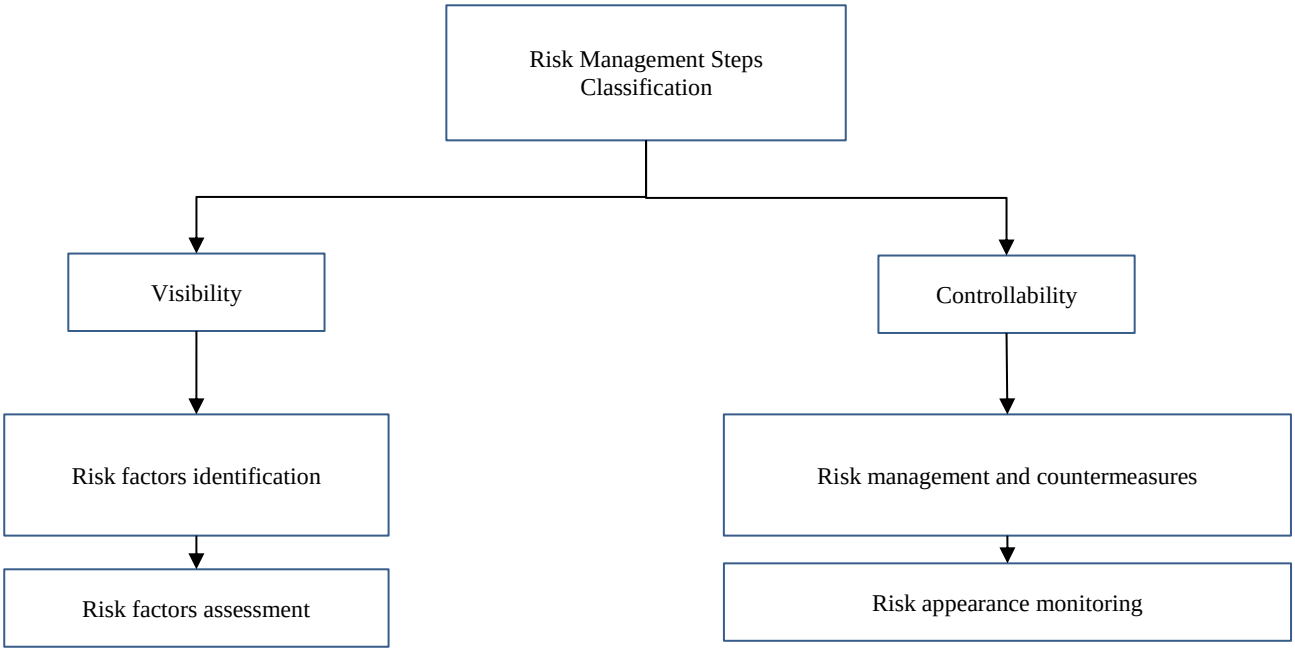

Fig. 2: The classification of the risk management process steps

Visibility: At the start of the implementation of the risk management process, the main objective is to have the status of the supply chain identified and visualized by identifying the potential risk factors, presented by the internal environment of each organization, and the external environment presented by the different actors of the supply chain with their impact valuation.

Controllability: In the second part of the risk management process, the controlling appearance of the risk factors and the mitigation of their impact.

3. Research methodology

To accomplish the research goals, and to examine the relevant risk factors of the supply chain of the automotive industry throughout global crises, the following research methodology is proficient for the desired results provision, which is clarified in Fig. 3.

3.1. Identification of the risk factors

The risk event is determined by the source and the nature of its impact as demonstrated in Fig.4 (Vilko et al., 2019).

The risk events or factors are also identified based on the nature of the risk event and their classification. These risks are classified as supply risks, environmental and sustainability risks, process and control risks, and demand risks (Van Poucke et al., 2019).

In the present research, the main goal and aim are to ensure the sustainability aspects of the supply chain of the automotive industry throughout the global crises. Therefore the potential risk factors are

identified based on the five-dimensional sustainability approach, which covers besides the social, environmental, and economic dimensions of the conventional sustainability approach, the technical and institutional approaches, as shown in Fig. 5 (Moktadir et al., 2021).

The Social dimension: Enable to identify the social risks. The social risk is charted as a sign of the influence of dangerous industrial activities on people, authorizing comparison with the tolerance standards set by the authorities and organizations.

The environmental dimension: Is related to the environmental risks that include the risk factors that participate in the deterioration of the environment. Moreover, the risks presented by the environment and have an impact on the supply chain such as natural disasters are considered under the environmental dimension.

The economic dimension includes the risk factors with a possibility to impact the financial flow of the supply chain, such as the investments, and the expenditures, where a direct and indirect impact on the costs generated negatively are measured.

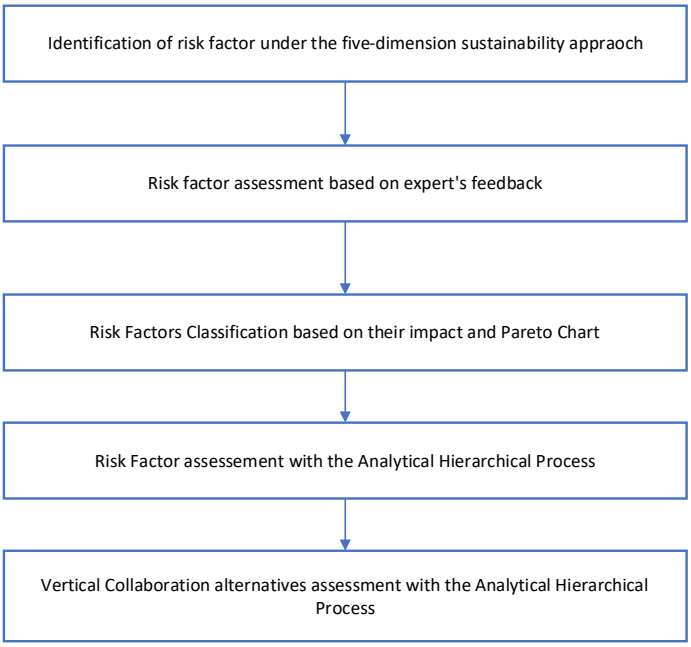

Fig. 3: The research methodology and steps

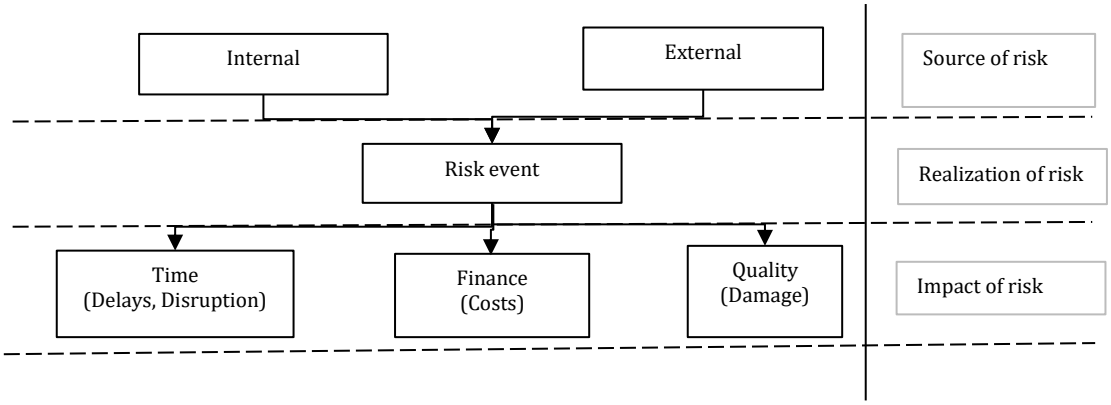

Fig. 4: The source of risk and the nature of risk impact

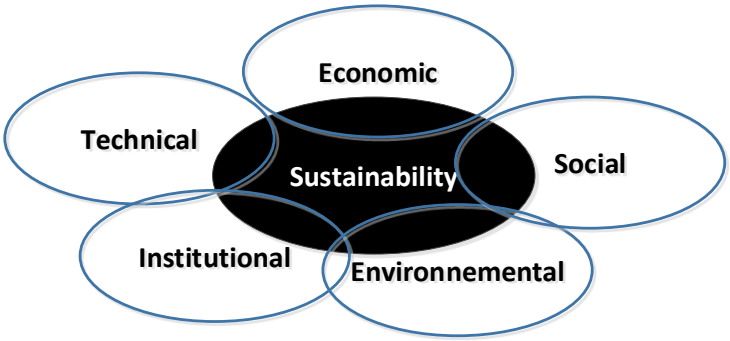

Fig. 5: Five-dimensional sustainability approaches

The technical dimension: Is reserved for the risk factors linked with the human and organizational mistakes of each organization. These mistakes have a direct impact on the human and technical systems of the organizations. The main aim of the technical dimension is to evaluate the impacts appearing due to the different processes and system defeats, besides the operational weaknesses.

The institutional dimension: Is destined for the risk factors that threaten the organizations' management and the risks that present threats to the validity of processes in form of the damage of reputation, responsibilities defeat.

Based on the automotive industry's supply chain actors' feedback and experience from different profiles, a list of potential risk factors that are capable of jeopardizing the material, financial and information flow of the supply chain is provided. The initial grouped list is examined, validated, and classified under the five-dimension sustainability approach. Table 1 presents the pertinent risk factors identified.

Table 1: Identified and validated risk factors based on the five dimensions of sustainability

Dimension of sustainability	Risk Factor
Economic	Instability of price and cost
	High cost for getting the dangerous wastes disposed
	elevated maintenance (corrective and protective) cost
	Fiscal fluctuations and deviations
	Product reputation decrease
	Fluctuations in foreign exchange and interest rates
	Unhealthy competition
	Endangered business activities
	Absence of strategic alliance and corporate allegation
	Absence of financing resources
	The sales levels of the produced harnesses
	Dependence on main customers
	Dependence on authorized sales agents
	Sharp benefits commitments
	Capital expenses and static cost ratio
	Deficiency loss on long-term possessions
Environmental	Natural catastrophes
	Global Crises
	Risky air emission
	Bursts, fires, chemical coincidences
	Inappropriate removal of solid excess
	Incompetent waste handling
	traffic accidents
	regional epidemic restrictions
Technical	Deficiency of technical proficiency
	Recurrent machine failure and collapse
	Damage of products in treatment and delivery
	Deprived process output at the supply source
	Alteration in customer preference
	Supplier catastrophe
	Raw materials insufficiency and shortage
	Mistaken choice of suppliers
	Unsuitable machine effectiveness
	Unfortunate material treatment
	Inappropriate site of storage facilities
	Inefficient sorting and grading of harnesses
	Carrying out process steps incorrectly
	Production procedure risks
	Deficient RAW materials, components and production facilities supplying
	Risks linked to outsourced production
	Maintain of production capacity at the demand level
	Quality of produced harnesses and procured raw materials
	transport limitations
	Variations in production plans by customer of custom products
Social	Unsafe working circumstances
	Poor personal defensive equipment
	Unfavorable relation between top management and employees
	Absence of work values
	Nonexistence of strong partnership among supply chain allies and associates
	Business ethics and morals unconventionality
	Strike
	Lack of acquiring human resources

3.2. Risk factors analysis and assessment

In this practical part of the research, the risk management process proceeds with the analysis of the impact concentration in the supply chain.

The risk impact is defined by the probability or the likelihood of appearance and the probability of its impact. Table 2 reveals the risk analysis results. The first two columns (Appearance probability and impact) in Table 2 indicate the average scores deducted from the experts' responses from which

the risk value is calculated. For each risk factor, the percentage of its share of the total sum value of all risks is calculated.

Furthermore, and based on the diverse experts' feedback, the nature of the impact of the risk is assessed. In addition, the risk concentration is calculated with the share of the higher impact from the total possible score of all the three possible impacts (time delay, additional costs, and quality damage).

Table 2: Risk factors impact and concentration

Risk event	Appearance probability	impact	Risk	percentage	Time delay	Additional costs	Quality damage	Sum	Risk concentration
Instability of price and cost	1.29	1.57	2.03	0.57%	1	4	0	5	80%
High cost for getting the dangerous wastes disposed	1.14	0.87	0.99	0.28%	1	4	2	7	57%
elevated maintenance (corrective and protective) cost	2.14	2.14	4.58	1.30%	2	2	2	6	33%
Fiscal fluctuations and deviations	1.33	2	2.66	0.75%	1	2	1	4	50%
Product reputation decrease	1.86	3	5.58	1.58%	1	1	2	4	50%
Fluctuations in foreign exchange and interest rates	1.29	1.57	2.03	0.57%	1	3	1	5	60%
Unhealthy competition	0.83	2.29	1.90	0.54%	0	2	2	4	50%
Endangered business activities	1.57	1.14	1.79	0.51%	1	2	1	4	50%
Absence of strategic alliance and corporate allegation	1	2.71	2.71	0.77%	2	3	1	6	50%
Absence of financing resources	1.29	2.43	3.13	0.89%	0	2	1	3	67%
The sales levels of the produced harnesses	1.86	2.71	5.04	1.43%	6	1	0	7	86%
Dependence on main customers	0.83	1.29	1.07	0.30%	1	2	1	4	50%
Dependence on authorized sales agents	1.33	1.29	1.72	0.49%	1	6	0	7	86%
Sharp benefits commitments	0.83	2	1.66	0.47%	1	5	1	7	71%
Capital expenses and static cost ratio	1.1	1	1.10	0.31%	1	5	0	6	83%
Deficiency loss on long-term possessions	1.86	1.57	2.92	0.83%	1	5	0	6	83%
Natural catastrophes	3	1.86	5.58	1.58%	2	5	0	7	71%
Global Crises	2.43	1.86	4.52	1.28%	3	4	0	7	57%
Risky air emission	1.29	1.57	2.03	0.57%	2	2	3	7	43%
Bursts, fires, chemical coincidences	1	1.2	1.20	0.34%	2	2	3	7	43%
Inappropriate removal of solid excess	0.52	1.67	0.87	0.25%	1	2	2	5	40%
Incompetent waste handling	1.47	1.28	1.88	0.53%	1	2	2	5	40%
Traffic accidents	3.29	2.14	7.04	1.99%	3	4	0	7	57%
regional epidemic restrictions	5.23	6.43	33.63	9.52%	3	4	0	7	57%
Deficiency of technical proficiency	2.15	3	6.45	1.83%	0	4	3	7	57%
Recurrent machine failure and collapse	3.86	1.29	4.98	1.41%	2	2	1	5	40%
Damage of products in treatment and delivery	1.14	2.14	2.44	0.69%	0	2	3	5	60%
Deprived process output at the supply source	1	4.14	4.14	1.17%	2	4	1	7	57%
Alteration in customer preference	5.29	3.86	20.42	5.78%	4	2	1	7	57%
Supplier catastrophe	5.9	4.43	26.14	7.40%	2	5	0	7	71%
Raw materials insufficiency and shortage	5.29	6.45	34.12	9.66%	2	5	0	7	71%
Mistaken choice of suppliers	2.43	2.41	5.86	1.66%	1	6	0	7	86%
Unsuitable machine effectiveness	1.29	4.72	6.09	1.72%	2	3	1	6	50%
Unfortunate material treatment	1.57	3	4.71	1.33%	1	3	3	7	43%
Inappropriate site of storage facilities	1	2.74	2.74	0.78%	1	2	3	6	50%
Inefficient sorting and grading of harnesses	2.74	2.74	7.51	2.13%	2	1	4	7	57%
Carrying out process steps incorrectly	3.29	2.45	8.06	2.28%	1	2	1	4	50%
Production procedure risks	3	6.45	19.35	5.48%	2	1	4	7	57%
Deficient RAW materials, components and production facilities supplying	2.71	3	8.13	2.30%	1	4	2	7	57%
Risks linked to outsourced production	3.86	4.14	15.98	4.53%	1	2	3	6	50%
Maintain of production capacity at the demand level	2.14	3.68	7.88	2.23%	2	5	0	7	71%
Quality of produced harnesses and procured raw materials	1.86	1.76	3.27	0.93%	2	0	4	6	67%
transport limitations	2.43	2.45	5.95	1.69%	2	4	0	6	67%
Variations in production plans by customer of custom products	5.28	6.44	34.00	9.63%	2	5	0	7	71%
Unsafe working circumstances	0.8	2.71	2.17	0.61%	1	2	4	7	57%
Poor personal defensive equipment	0.8	1.14	0.91	0.26%	2	0	2	4	50%
Unfavorable relation between top management and employees	0.2	2	0.40	0.11%	1	1	1	3	33%
Absence of work values	1.86	3.86	7.18	2.03%	1	1	1	3	33%
Nonexistence of strong partnership among supply chain allies and associates	1.33	2	2.66	0.75%	1	4	1	6	67%
Business ethics and morals unconventionality	1.29	1.57	2.03	0.57%	1	1	1	3	33%
Strikes	2.55	3.5	8.93	2.53%	4	3	0	7	57%
Lack of acquiring human resources	1.29	2.29	2.95	0.84%	2	3	1	6	50%

For the purpose of further analysis, and for enhanced visibility of the most impacting risks of the automotive industry through the global crisis, the cumulative percentage of the risk impact of the set of risk factors was determined for the Pareto analysis. From the executed Pareto analysis as shown in Fig. 6, it is stated that out of the 52 risk factors, 21 risk factors are responsible for 80% of the risk in the automotive industry facing a global crisis. These risk factors are: 'Raw materials insufficiency and shortage,' 'Variations in production plans by a customer of custom products,' 'regional epidemic restrictions,' 'Supplier catastrophe,' 'Alteration in customer preference,' 'Production procedure risks,' 'Risks linked to outsourced production,' 'Strikes,' 'Deficient RAW materials,' 'components and production facilities supplying,' 'Carrying out process steps incorrectly,' 'Maintain of production capacity at the demand level,' 'Inefficient sorting and grading of harnesses,' 'Absence of work values,' 'traffic accidents,' 'Deficiency of technical proficiency,' 'Unsuitable machine effectiveness,' 'transport limitations,' 'Mistaken choice of suppliers,' 'Product reputation decrease,' 'Natural catastrophes,' 'The sales levels of the produced harnesses.'

The most impacting risks with the higher impact are linked to the major actors of the supply chain; the manufacturers, the customers, and the suppliers, in addition to the transportation companies providing the transport services to the different companies. In addition, each of the risks identified provides a direct impact on an actor of the supply chain, which provides also an indirect yet important source of impact and jeopardy for another actor of the supply chain where the impact is being amplified. Therefore, in order to control the different risk factors, the first strategic option is collaboration amongst the supply chain partners.

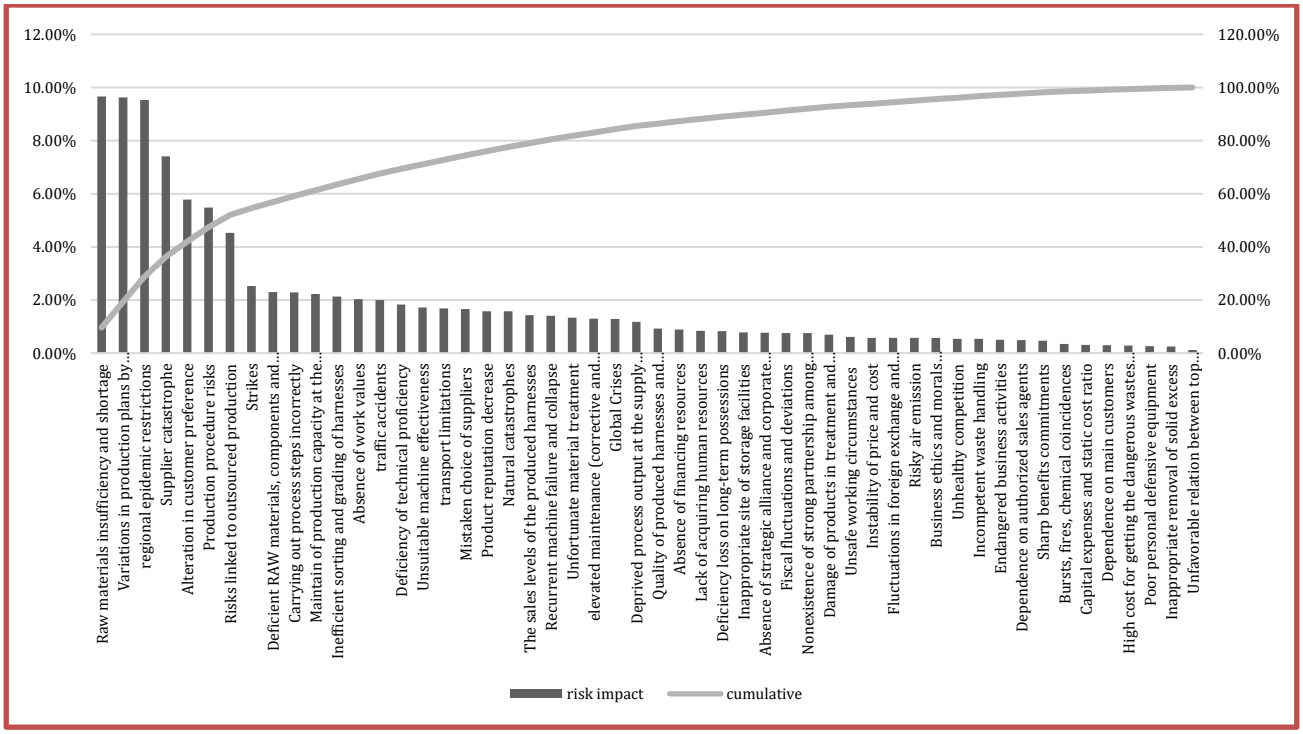

Fig. 6: Pareto analysis of identified risks factors

3.3. Risk management and supply chain collaboration

The collaboration in the supply chain could be explained as the assistance and the collaboration between the actors of the supply chain with the aim goal as to escape disturbances in logistics, material, and informational regular flows.

The procedure of collaboration comprises a respectable partnership between supply chain actors through the exchange of information, resources, and sharing of precise roles with a view to allowing mutual risk management. Collaboration is relying on the healthy partnership between all supply chain members and it necessitates the obtainability of combined information sharing and a great level of motivation and trust. Collaborative supply chain studies suggest a diverse concept, mainly vertical and horizontal collaboration (Yang and Lin, 2020).

The horizontal collaboration is targeting the interaction between the competitors, and other supply chain actors. This concept of collaboration is deployed in the case of two or more unconnected competing actors collaborating to share both reserved information and resources.

On the other hand, the vertical collaboration concept is more destined for the relationship between consumer and supplier. This concept of collaboration is deployed when the different actors of the supply chain; the producer, the supplier, the carrier, and the retailer gather their responsibilities, resources, and performance information to assist the same end customers. This concept is applied to build

long-term relationships, devotion, trust, and commitment.

3.4. The analytic hierarchical process and risk mitigation decisions

In order to make a reliable decision for the mitigation of these risks, the following part of the research will be focusing on the Analytical Hierarchy Process. The AHP is a performance process for making decisions in complex environments such as the automotive supply chain impacted by the global crisis. The great utility and distinguishing input of this process is that this process allows the conversion of the comparison from empirical to numeric values permitting further analysis and comparison. The weight and score of each factor permit the valuation of each element inside the defined hierarchy.

The process of AHP comprises three main parts: Problem structuring with the identification of the definitive goal or problem to solve, the Evaluation where all the potential solutions called alternatives are defined, and the criteria to use for the purpose of judging the alternatives two at a time, with a fair-wise comparison are also determined, then, the last step is the decision making based on the values delivered from the previous steps and calculations.

To ensure the successful deployment of the Analytical Hierarchical Process, the main parts of the process are decorticated into the following steps:

1- Defining the decision problem and goal
2- Identify and structure decision criteria and alternatives
3- Judge the relative value of the alternatives on each decision criterion
4- Judge the relative rank of the decision criteria
5- Analysis of judgments and evaluation of each alternative's performance
6- Calculations of the weights of the criteria and the importance of the alternatives
7- Conducting decisions.

As illustrated in the previous part of the research, the ultimate goal is the mitigation of the risks identified and selected as the most impacting risk factor to the automotive supply chain in global crises. As the first launching step to achieving this goal, the list of 21 risk factors can be grouped and diminished to a concise list of risk factors with similar impact and jeopardized actors or parts of the automotive supply chain. For the Supplier actor, all the identified risks are presenting a procurement risk, a material quality risk, and an order accomplishment risk. While for the production unit, the totality of risks are presenting the capacity and distribution risks of the production unit beside the risks related to the forecast, and the several risk factors of other actors with the impact extended to the production unit. As for the customer side, the risks offered are related to demand and variation risks, besides delay risks as well as other risk factors endangering several other actors with the impact spreading out until the customer and presenting production interruption risk. The services required in the automotive supply chain, which are mainly linked with the transport companies, can be jeopardized by the regional strikes, the transport limitations, and the traffic accidents. As for the environment of the automotive supply chain, it can be endangered by the natural disasters, regional epidemic restrictions, and the environmental risks of each company contributing to the supply chain. Moreover, the risks related to the deficiency of technical proficiency endanger information and technology aspects of the supply chain.

In order to have both anticipated and estimated visibility and controllability over these risk factors, all the actors of the supply chain are brought to act as one individual, combined organization and provide a high incentive and collaboration motivation on a global level, and dedicate their resources in order to attain the: Information distribution collaboration, the incentive arrangement collaboration, the decision management collaboration, Resources and expertise sharing collaboration and Knowledge management collaboration. Fig. 7 shows the hierarchical diagram for the risk mitigation decision.

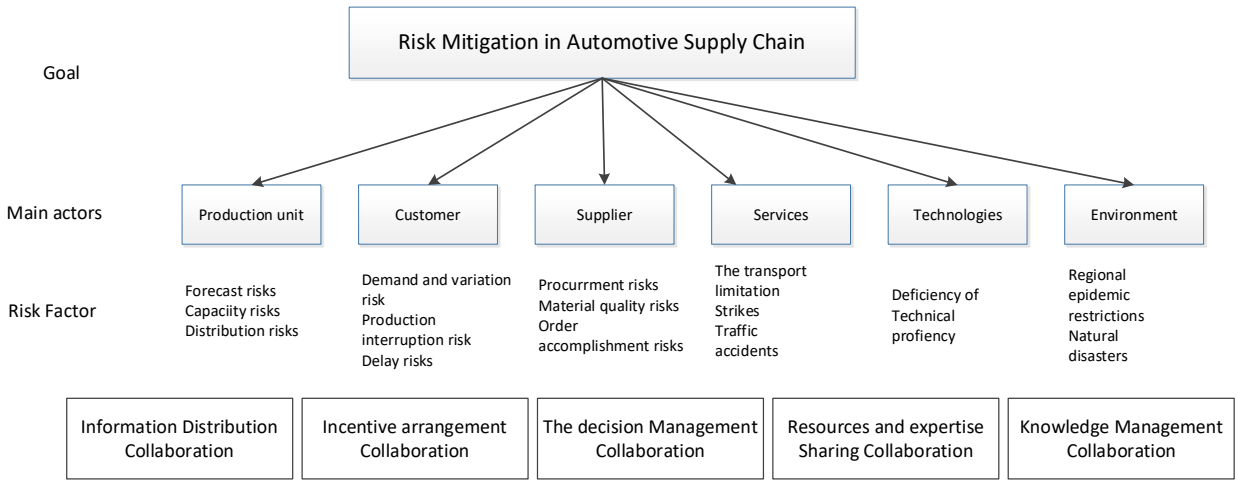

Fig. 7: The hierarchical diagram for assessing the risk mitigation decision

The information distribution collaboration is considered a key factor in the success of the automotive supply chain. The most relevant information, which can be provided by the actors of the supply chain, is the supply capacity and ability and the delivery lead times. The information sharing and collaboration can result in updating the organizations' forecasts with the upcoming changes and ensuring greater transparency among the supply chain organizations and partners. The forward and backward information sharing flow will enable the partners to have great visibility and controllability of the existing and future risk factors (Rajagopal et al., 2017).

The incentive arrangement collaboration ensures a rearrangement of the profits and limitations, which sustained during the processes changes in the supply chain throughout the global crises. Its ultimate goal is to encourage the different actors to align their comportment and performance with the global overall supply chain and to offer a quicker reply to the end customer requests. This alternative requires that the actors provide a complete picture of the measures and procedures where both risks and gains are justifiably assigned.

The decision management collaboration where the partners are collaborating on their planning and operational actions along with the differences and conflict resolution and the founding of procedures and instructions for the purpose of optimizing the supply chain gains and ensuring beneficial risk mitigation.

The resources and expertise-sharing collaboration aims for a mutual benefit investment between the partners of the supply chain for maintainable risk management and mitigation.

The knowledge management collaboration helps develop and provide a mutual positive level of performance and competitiveness, which allows attaining a sustainable product innovation; projects lead times reduction and the quality and customer satisfaction development.

In order to assess and evaluate the potential, suggested forms of collaboration, as well as the risk factors the below scale of comparison is adopted as shown in Table 3 based on the Saaty scale where all the factors are evaluated with a scale from 1 to 9, as demonstrated in Table 3.

3.5. Risk assessment in vertical collaborative supply chain

To classify the comparative importance of the risk factors, the pairs of these risk factors were assessed on a 9-point scale. The paired comparison is more reliable than a comparison of all criteria or alternatives at once. Given 15 risk factors, 105 pairwise comparisons were subtracted and the final weight for each risk factor consistent with the concept of vertical collaboration was provided. For each risk factor and being compared to other risk factors on the list, a priority evaluation is provided and the results are presented in Table 4 with the final weight of the risk factors in the vertical collaborative concept.

Table 3: Saaty scale of relative importance

Intensity of Importance	Definition for risk factor evaluation	Definition for alternative evaluation
1	Equal importance	Equal preference
2	Equal to moderate importance	Equal to moderate preference
3	Moderate importance	Moderate preference
4	Moderate to strong importance	Moderate to strong preference
5	Strong importance	Strong preference
6	Strong to very strongly more importance	Strong to very strong preference
7	Very strongly more importance	Very strong preference
8	Very strongly to extremely more importance	very strong to extreme preference
9	Extremely more importance	extreme preference

Table 4: Final weight of risk factors in vertical collaboration

Risk Factors	Weights
Production interruption Risk	0.1183814
Order accomplishment Risk	0.1100725
Material Quality Risk	0.0883578
Capacity Risk	0.0852247
Demand and variation Risk	0.0832880
Regional Epidemic restrictions	0.0708622
Delay Risks	0.0623185
Natural Disasters	0.0559687
Distribution Risk	0.0543847
Procurement Risk	0.0543765
Deficiency of technical proficiency	0.0518590
Traffic accidents	0.0454515
Strikes	0.0434139
Forecast Risk	0.0406928
The transport Limitation	0.0353477

The results obtained in Table 4 highlight that the use of the concept of vertical collaboration in the supply chain shows that the main focus of the partners should be aimed towards the risk of Production interruption of the end customer since it is the most blocking risk factor to the supply chain

and also the order accomplishment risk that provides a high priority as well (Majumdar et al., 2021).

3.6. Alternatives assessment

The key goal of the AHP classification was to define and conclude the finest collaboration alternative for vertical collaboration indispensable for a respectable partnership that can forecast future risk factors which may be occurring due to the changes of business procedures applied, along with the existing risks from the global crises. The final calculated weights for each alternative, which were achieved in a similar way to the assessment process of the risk factors comparison, are present in Table 5.

4. Conclusion

The results disclose that the decision management collaboration and the resources and expertise sharing collaboration are the main driver alternatives that can help the organizations to prevent the potential risks and to manage and monitor the risks present in the supply chain.

Table 5: The calculated weights of alternatives for vertical collaboration

Weight	Alternatives
0.1549289	Information Distribution Collaboration
0.1205451	Incentive Arrangement Collaboration
0.3341306	The Decision Management Collaboration
0.3053329	Resources and Expertise Sharing Collaboration
0.0850625	Knowledge Management Collaboration

In this paper, the risk identification, analysis, and assessment of the automotive supply chain throughout global crises have been studied profoundly for achieving a high level of resilience. Firstly, the risk factors were identified and assessed. Then, the classification of these risks was performed using the Pareto method to confine the most impacting risk factors.

Once the link between the risks and both impacting and impacted actors has been established, showing that all the actors of the supply chain are contributing to the risk-origination process, the vertical collaboration is manifested as the best solution for the risk mitigation and management of the supply chain resilience and mainly for the production units. The Analytical hierarchical process, being the most effective process for the decision making in a complex environment helps decide which collaborative aspects the partners of the supply chain need to allocate their priority towards.

Compliance with ethical standards

Conflict of interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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