Q-sort Evaluation of Risk Factors by Automotive Experts

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Abstract: The high level of standardization within the automotive industry may support avoiding the occurrence of common and unforeseen risks. There are several risk management methods available, but effective actions need to understand current challenges. Automotive risk management requires a comprehensive measure and evaluation approach. The research aims to map the risk factors of managing the automotive industry for preparing a decision support model through a pilot study. The analysis used a list of risk factors based on the literature and idiographic data collection among 22 experts in 2023. The study used the Q-methodology to create characteristic patterns of opinions. Three factors were separated and entitled based on their expressed opinions Factor 1 "Follow Standards!", Factor 2 "Take Control!" and Factor 3 "Be Flexible!". Factor 1 respects mostly the automotive standards (e.g., IATF, VDA, and FMEA). Factor 2 consists of opinions to support actions that can increase overall control. Factor 3 supports every aspect to increase flexibility. There is consensus among the three factors on the high importance of Total Productive Maintenance (TPM) and proper supplier selection among the respondents. Relative opinions in the field may contribute to developing company-level risk mitigation strategies and understanding supply chain-level challenges. The study confirms the applicability of Q-methodology to discover opinion groups and, therefore, can be considered a novel contribution to the research field, from a methodological perspective.

Keywords: Automotive industry; Q-sort, Risk management

1 Introduction

Happenings in the automotive industry have an extensive impact on the economy since it is one of the most globalized industries [1] [2]. The Global, European and Hungarian vehicle industry has recovered after the COVID-19 pandemic and lockdowns, and the growth has continued in 2022 [3] [4]. A lesson learned from the situation is rethinking risk management in the field. Due to the complexity of the automotive supply chain, important measures have been taken to organize necessary activities on the topic of Supply Chain Risk Management (SCRM) [5]. There is a growing consumer expectation for vehicles, including product quality [6], sustainability [7], and technological innovation [8]. The competition and the increasing pressure of legal regulations result in a challenging entrepreneurial and technological environment. The changing environment raises new forms and sources of risks that require updated solutions. Automotive supply chains are changing rapidly and becoming more complex over time. As a result, the emphasis on the proper approach to risk management is valued. The study deals with the practical opportunities of the Q-methodology, for this purpose and contributes to renewing the knowledge base of automotive risk management by exploring the relative importance of risk factors, by expert opinions. The analysis uses the Q-methodology to establish a ranking. The fundamental goal of this study is to exploit possibilities, in order to support risk management actions, within the industry, to foster financial growth and the secure, safe introduction of new products.

2 Literature Review

2.1 Automotive Supply Chain Risks

A wide range of information is available regarding the definition of risks, risk management, and its relation to project management [9]. The early studies on risk management started in the 1980s and continued to develop in the past decades. A database from the 1980s showed that “many projects met their time-target - the average slippage was 17% - but there was a clear over-run on costs - the average over-spend was 88%”. Williams’ article [10] shows a comprehensive review of the topic.

Brustbauer [11] analyzed the risk management practices of SMEs, based on a questionnaire in 2014. He suggests that companies should apply a passive (defensive strategy) or active (offensive strategy) risk management method [11]. The chosen method should be based mainly on company size, sector affiliation, and ownership structure. Risk management is a major issue for SMEs, mostly because of the lack of resources for this activity, and about two-thirds of the analyzed companies have a passive risk management approach. The author interprets that applying risk management increases competitiveness and success. A key factor for effective risk management is the awareness of the company regarding possible risks. If a company is not able to define the risk in itself and its surroundings, it is not possible to create an effective action plan for risk mitigation [11].

A study across Brazil [12] in 2017 was performed in two stages (first: face-to-face interviews, second: online survey) regarding the risk management behavior of startups. Pearson's correlation was used to explore patterns of risk management at the companies. ISO31000 procedure is recommended by the author, which standard offers a simple and easy-to-implement procedure.

Automotive risk management has extensive literature, including supply chain risks. Regardless of the qualitative or quantitative nature of the suggested procedures, there is an agreement on the main knowledge areas covering risk classification, risk factor analysis, risk management methods, and risk gap identification [13]. The researchers emphasize the importance of supply chain risk management (SCRM) [14].

The general approach to the risk management process consists of four steps, even for supply chains [14]:

1. Risk identification
2. Risk assessment
3. Risk management decision and implementation
4. Risk monitoring

There are competing models and approaches to risk management. Some authors focused on empirical analysis; others argued in favor of literature-based, theoretical model creation followed by empirical confirmation [15-19]. A case study investigated two Hungarian supply chains in 2006 to understand the dynamics of cooperation where the connection between corporate strategy and supply chain management has been confirmed [20]. Considering the effects of the 2008 economic crisis, a study proposed policy recommendations to support risk mitigation of suppliers [21]. A comprehensive review of the Hungarian automotive industry compared to the V4 countries was performed in 2017 with historical intent. The study proposed two possible future development paths for V4 countries with recommendations to support the intensive development of the vehicle industry [22]. A current case study from 2022 categorized the risks according to their effect on the company into five groups, entitled Operational, Process, Suppliers, Security, and Labor Rights, and provided a probability-impact matrix for the investigated companies. The broadly accepted Analytic Hierarchy Process (AHP) was used for a systematic weight calculation; the results highlighted the bad quality of the final product as the most significant risk [23].

Huang et al. [24] focused on the disruptions of automotive supply chains based on the literature review of 866 journal articles. According to the results, automotive supply chain risk management has attracted increasingly more attention from society and scholars over the past decades.

KPMG [25] also stated that supply chains are highly vulnerable. 78% of global automotive executives rated that recent volatility in commodity prices would impact their business, and 80% believed that labor shortages would impact their business. Material shortages, demand uncertainties, increasing environmental regulations, labor market scarcity, disruptions due to the globalized nature of the automotive industry, and increasing complexity of tariffs and trade regulations are considered the main vulnerability factors. To ease the effect of such risks, it is recommended to regionalize the supply chain, ensure supply chain diversity, establish a task force to manage critical commodities, establish strategic partnerships or joint ventures and ensure the appropriate level of transparency [25].

The risk mitigation activities in automotive supply chains tend toward technical and financial risk management actions; however, the studies in the field emphasize more attention to the strategic and methodological tools for risk mitigation. The ultimate goal is to develop effective risk mitigation strategies. Methodological development suggests considering multi-criteria decision-making (MCDM), multi-objective decision-making (MODM) [26] and ISO 31000 [27], and probability and impact analysis [28]. The experience of the German automotive industry [29] provides professional support to the efforts. The categorization of risks has been investigated, and it is the basis of the initial concept for grouping, as presented in Table 1 [30].

Table 1
Input data for risk mitigation actions and statement list

Risk mitigation category	Risk mitigation action
Financial risk management	Insurance
	Forward of futures contracts
	Real options approach
Avoidance	Dropping specific products/ geographical markets/supplier or customer organizations
Control	Delay new market entry
	Vendor selection methodologies
	Vertical integration
	Horizontal mergers and acquisitions
	Inventory system: Increased stockpiling and the use of buffer inventory
	Maintaining excess capacity in production, storage, handling and/or transport
	Imposing contractual obligations on suppliers and customers
	Gain market power
	Long-term contractual agreements and commitments with suppliers and customers

Cooperation	Collaborative relationship management (e.g., partnerships, alliances, or joint ventures
	Joint efforts to improve visibility, transparency, information transmission/sharing, and understanding within supply chain
	Risk sharing
	Aligning incentives and revenue sharing policies in a supply chain
	Joint efforts to prepare supply chain continuity plans
Imitation	Imitation of product and process technologies
	Follow other firms in moving into new markets
Flexibility	Product diversification
	Geographic diversification
	Increase overall flexibility
	Flexible input sourcing (e.g., Dual sourcing and multiple sourcing)
	Back-up supplier
	Localized sourcing
	Flexible workforce size and skills, plants, and equipment
	Multinational production
	Postponement
	Flexible supply contracts
	Flexible manufacturing
	Flexible distribution

2.2 Q-methodology

Evaluation of the relative importance of risk factors cannot be uniform by the activity, size, or other company and supply chain characteristics. Individual evaluations may be available, and exploring opinion patterns may promote establishing effective risk-mitigation strategies. Due to the subjective aspects of the topic, it is necessary to apply a method that can objectify opinions. Although using a set of questions evaluated on a Likert scale offers results that are easy to interpret, distortions of the evaluation can be misleading [31]. A direct or paired ranking method is relatively more expedient; however, the huge number of considerable risk factors makes the workload unreasonably difficult for the respondents. Q-methodology offers an optimal solution to rank a higher number of factors and effectively create opinion groups by statistical evaluation. The method was developed by physicist and psychologist William Stephenson in the 1930s and widely used in several areas like marketing, psychology, or any study which analyzes subjective opinions [32].

Q-methodology is a combination of qualitative and quantitative analysis. The respondents are asked to express their opinions by sorting a set of statements, whether they agree or disagree, according to a specified question. Data processing can be performed manually onsite, but online support is available. The traditional process uses prepared cards with the statements, which must be placed on a board to represent the ordered opinions individually. After gathering data, a wide range of software is available for evaluation [33]. The main steps of Q-methodology can be summarized as follows (based on [34-36]):

- Making the initial data matrix of the evaluations
- Calculating the correlations
- Selecting the number of factors
- Calculating rotated factors loadings
- Determining factor weights and scores
- Analysis of distinguishing statements
- Presenting patterns of opinions by the final factors

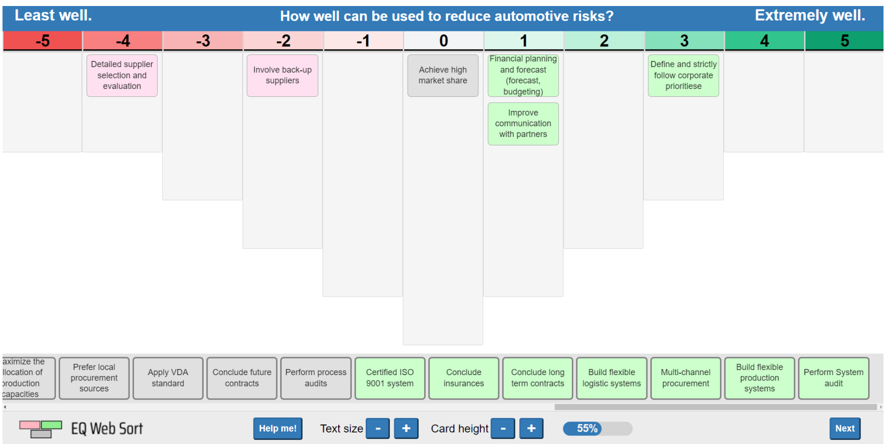

Figure 1

Q-sort pattern

The question for evaluation asked the respondents to sort the items by their importance in their opinion. The forced sort pattern assures normal distribution of the evaluations of the participants [32]. Figure 1, shows the design for evaluations in the original language. A supplementary questionnaire is proposed for collecting additional data for further groupings and evaluations.

3 Research Design

3.1 Research Goal

The need for effective risk mitigation strategies raises the question of what risk factors are remarkable in the automotive industry. However, considering that the individual challenges of the companies are inevitable, a core set of factors must be identified to support supply chains. The study aims to explore the characteristic patterns of expert opinion to contribute to a common understanding of automotive risks. Moreover, based on experts' opinions offer an initial point for developing risk mitigation strategies. We consider the results a pilot study, regardless of the opportunities of the methods.

3.2 Research Method

A preliminary list of risk factors based on an international literature review was refined and supplemented by interviews with Hungarian automotive industry experts for the analysis. The next step was preparing the statements for evaluation by the Q-methodology [37]. The process configuration is summarized in Table 2, including support tools and steps.

Table 2
Data collection and analysis process

Main Activity	Steps & tools				
1. Topic selection	Interview with industry experts	Risk factors from the literature	Confirmation of risk factors (Google Forms)		
2. Survey development and data collection	Programming (EQ Web Configurator)	Survey publishing (Netlify)	Data Collection (link via e-mail)	Data management (Firebase)	Data output (JSON format)
3. Q-sort analysis	KADE input	Calculate correlations	Principal component analysis	Varimax rotation for a selected number of factors based on scree-plot	Output tables: Factor loadings, Z-scores, Factor visualizations
4. Further analysis and presentation of results	Factor presentation	Cross-tabulation Rank orders	Developing new surveys		

The statement list of the questionnaire used an item collection by Ceryno [17], and additional categories were defined, including common automotive tools and standards (Table 1). The study was designed for a voluntary online survey managed by the software EQ Web Sort version 2.0.0, and data processing was performed with the free Ken-Q Analysis Desktop Edition (KADE) software version 1.2.1. The factors were defined by considering the scree plot by eigenvalues, and principal component analysis with Varimax rotation was for maximizing the sum of the variances of the squared correlations between variables and factors. The software also allows centroid factors and other types of analysis, but this explorative solution was selected since preliminary knowledge of the possible factor numbers and contents was missing.

3.3 Sample Characteristics

Data was collected online from respondents between 20th January 2023 and 27th January 2023. An invitation was sent to 38 automotive experts at three different international Tier-1 supplier-level automotive companies located in Hungary. The research sample consists of 22 evaluations. Sample characteristics are summarized in Table 3.

Table 3
Sample composition

	Grouping factors	Number	% sample
Total work experience in the automotive industry	< 5 years	2	9.1%
	5 years – 10 years	10	45.5%
	11 years – 15 years	6	27.3%
	16 years – 20 years	4	18.2%
Area of current job	HR, administration	3	13.6%
	Engineering I (production, maintenance, facility, IT)	4	18.2%
	Engineering II (development, testing, project management)	4	18.2%
	Quality, supplier quality assurance	5	22.7%
	Production	3	13.6%
	Supply chain (logistics, procurement)	3	13.6%

Furthermore, respondents were asked after completion of Q-sort to rate six questions related to current challenges of automotive risks on a five-point scale (higher values mean higher risk). They were asked to judge how much they think automotive depends on these factors. The highest average rating was received for supply issues related to microchips, while the lowest average rating was received for local political decisions (Figure 2).

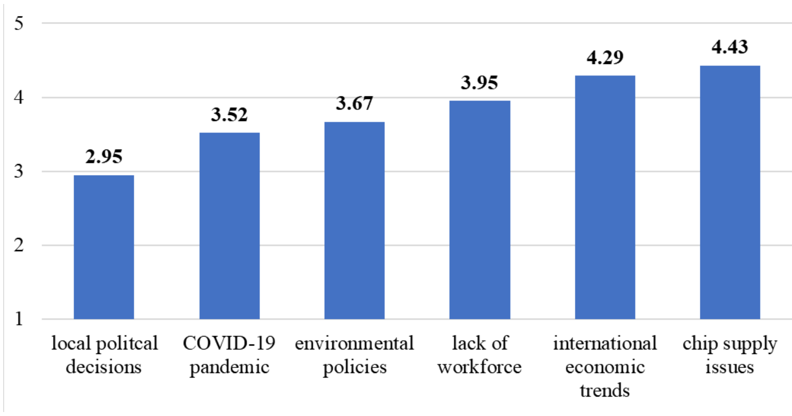

Figure 2
Average ratings of risk factors

4 Results

4.1 Demarcation of the Factors

The principal component analysis offered a maximum of eight factors based on the 22 responses, seven of which were at a greater eigenvalue than 1 (Figure 3). The variance explained is 32% for the first factor, and the total variance explained is 43% for two factors and 52% for three factors. The scree plot (Figure 3) suggested establishing three factors. It is worth noting that the total variance explained is a maximum of 77% with eight factors, but the differences between the further factors are not remarkable. Factor characteristics are summarized in Table 4.

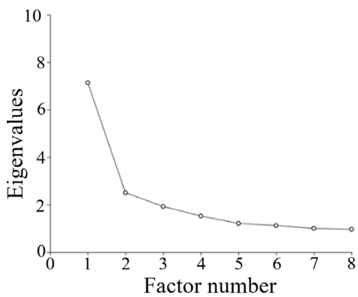

Figure 3
Scree plot (KADE output)

Table 4

Factor characteristics

	Factor 1	Factor 2	Factor 3
Eigenvalues	7.1415	2.5047	1.9244
% explained variance	32	11	9
Total % explained variance	32	43	52
% explained variance after VARIMAX rotation	21	19	12
Number of members (% of total respondents)	8 (40%)	8 (40%)	4 (20%)
The ratio of flagged within the factor	88.89%	100.00%	80.00%
Correlation with Factor 1	1	0.5255	0.2201
Correlation with Factor 2	0.5255	1	0.3347
Correlation with Factor 3	0.2201	0.3347	1

4.2 Factor Scores

The z-score is a weighted average of the values that the Q-sorts most closely related to the factor given to a statement, and it is continuous [38]. It is calculated as a mathematical expression of the distance between a particular absolute score and the mean average score of the measured sample [36]. Based on the z-core analysis, significant similarities and differences can be found between the factors (Table 5). Most significant differences in z-scores were discovered with statements in “Flexible and well-trained employees”, “Apply IATF standard” and “Use FMEA method”. Most significant similarities of z-scores were discovered with statements in “Total Productive Maintenance (TPM)” and “Budget planning and forecast”. The analysis of z-cores mainly supports the recognition of patterns of opinions in Factors.

Table 5

Factor scores filtered on threshold level P < 0.0001

Factor	Threshold	Q Sort Value	Statement
Factor 1	P < 0.0001	4	Use FMEA method
	P < 0.0001	5	Apply IATF standard
	P < 0.0001	3	Apply ISO 9001 standard
	P < 0.0001	4	Apply LEAN principles
	P < 0.0001	1	Flexible production systems
	P < 0.0001	5	Apply VDA standard
	P < 0.0001	4	Process audit
Factor 2	P < 0.0001	-5	Aim for high market share
	P < 0.0001	-2	Flexible production systems
	P < 0.0001	5	Standardized production
	P < 0.0001	-4	Build wide range of product-portfolio
	P < 0.0001	4	Maximize allocation of production capacities

Factor 3	P < 0.0001	5	Flexible and well-trained employees
	P < 0.0001	5	Flexible production systems
	P < 0.0001	3	Flexible logistics systems
	P < 0.0001	2	Avoid too much expansion by rejecting new projects
	P < 0.0001	-3	System audit

4.3 Patterns of Opinions in Factors

The ranking orders by the three factors are represented in Figures 4-6. Based on the results, there are several consensus statements (marked with blue background), like “Total Productive Maintenance (TMP)”, “Strong cooperation with customers and suppliers”, and “Copy technologies and processes of competitors”. The distinguishing statements are displayed in the figures at a maximum p=0.05 threshold value. These statements show the items of the evaluation that draw the idiographic patterns. According to Factor 1, 23 of 38 statements are listed; in the cases of Factor 2 and Factor 3, 18 and 20 items are listed. The figures suggest characteristic opinion patterns. It is to note that the distinguishing statements are focused on the leftmost and rightmost sides of the evaluations.

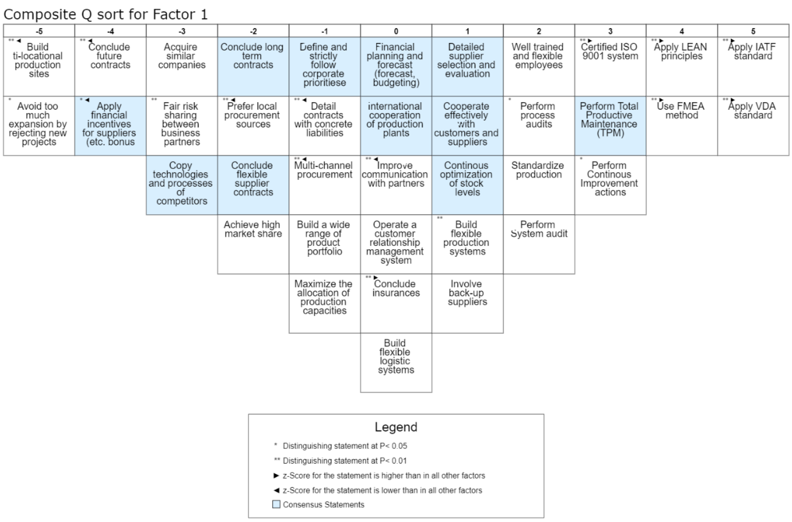

Figure 4

Factor 1 ranking order

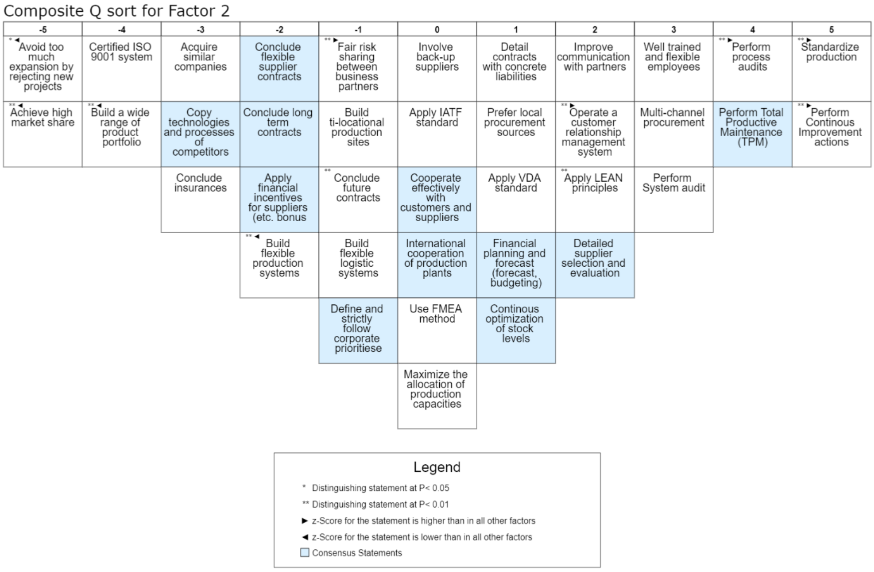

Figure 5
Factor 2 ranking order

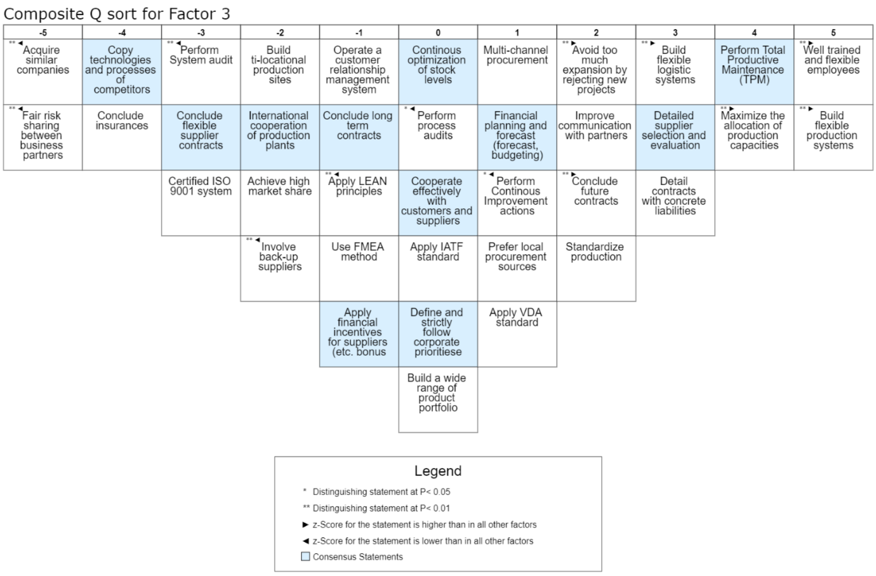

Figure 6
Factor 3 ranking order

4.4 Dependency of the Automotive Industry on some Issues

An additional question in the survey asked to evaluate the dependence of the automotive industry on some issues. The respondents were asked to mark their opinion on a five-point scale (1: not dependent on it, 5: extremely dependent on it). Figure 8 shows the issues and the mean values of the evaluations by factors as a simplified visualization.

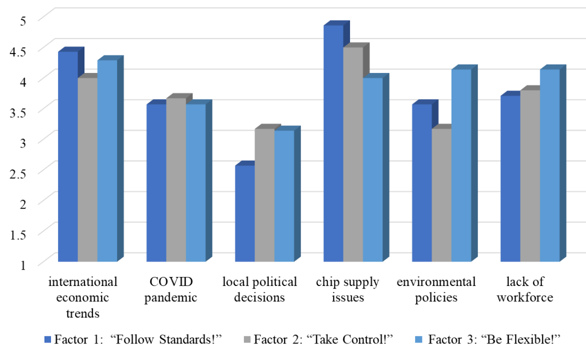

Figure 7

Cross-tabulation results

The COVID-19 pandemic and local political decisions were not considered the most relevant issues regarding the dependence of the automotive industry. The impact of environmental policies is high among the respondents of Factor 3. Chip supply and international trends are at the top of the list, but visible differences exist between the factors. The lack of a workforce is considered a more serious issue than the COVID-19 pandemic or local politics.

The non-parametric Kruskal-Wallis H test was used to check the significance of the differences (Table 6).

Table 6

Kruskal-Wallis H-test results by factors

Survey item	Kruskal-Wallis H	d_f	Asymp. Sig.
international economic trends	1.683	2	0.431
COVID pandemic	0.132	2	0.936
local political decisions	1.446	2	0.485
chip supply issues	2.341	2	0.310
environmental policies	3.341	2	0.188
lack of workforce	0.726	2	0.696

Despite the visual differences, the variance analysis test did not find statistically significant differences between the factors. The detailed analysis confirmed a significant difference between Factor 2 and Factor 3 regarding the role of environmental policies (Kruskal-Wallis H=4.158, d_f=1, sig.=0.041).

5 Discussion

The main target of the study is to discover opinions in the field that may contribute to developing company-level risk mitigation strategies and understanding supply chain-level challenges. To define mitigation strategies, we need to show and understand the differences between the discovered opinion groups. According to the most and least preferred items of the survey statements (Table 7), the three opinion groups about the relative importance of risk factors can be entitled as follows:

- Factor 1 – "Follow Standards!"
- Factor 2 – "Take Control!"
- Factor 3 – "Be Flexible!"

Table 7

Summary table of factor statements with mitigation categories

	Factor 1 "Follow Standards!"	**Factor 2 "Take Control!"**	**Factor 3 "Be Flexible!"**
Most significant statements	Apply IATF standard (AUT)	Standardized production (CTRL)	Flexible and well-trained employees (FLEX)
	Apply VDA standard (AUT)	Continuous Improvement actions (AUT)	Flexible production systems (FLEX)
	Apply LEAN principles (AUT)	Process audit (CTRL)	Total Productive Maintenance (TPM) (AUT)
	Use FMEA method (AUT)	Total Productive Maintenance (TPM) (AUT)	Maximize allocation of production capabilities (FLEX)
Least significant statements	Multi-locational production (FLEX)	Avoid too much expansion by rejecting new projects (AVOID)	Acquisition of similar companies (CTRL)
	Avoid too much expansion by rejecting new projects (AVOID)	Aim for high market share (CTRL)	Fair risk sharing between customers and suppliers (COOP)
	Conclude futures contracts (FIN)	Apply ISO 9001 standard (AUT)	Copy technologies and processes of competitors (IMIT)
	Financial incentives for suppliers (FIN)	Build wide range of product portfolio (CTRL)	Insurance (FIN)

The Q-methodology suggests asking for reasoning about the most and least preferred selection. Taking the qualitative information and the responses into consideration, we can define the most significant characteristics of the groups. Risk mitigation categories (based on Table 1) have been added to Table 7 for better visualization.

Factor 1 “Follow Standards!” can be described as a group of individuals with a strong belief in well-established automotive standards and tools. They think that avoiding most of the risks is possible by following the rules and strongly reject anything related to expansion as they see high risk in any expansion activities. They do not prefer local suppliers or even multi-channel procurement; probably, they believe that if we apply the right standards in the supply chain, we can avoid risks. They rate low the efficiency of financial risk mitigation actions. This group rated lowest the importance of communication (but still on a neutral level).

Factor 2 “Take Control!” can be described as a group of individuals with a strong belief in self-driven standardization activities. They rate the importance of general automotive standards rather low/neutral. They would like to have risks in “their own hands” rather than rely on systems. Conscious prevention and control are key factors for them. They refuse high market share and wide product portfolio as it increases the uncontrollable activities. Flexibility is rated low, except for employee flexibility, which is rated higher than Factor 1, which shows they rely on people’s capabilities rather than general standards.

Factor 3 “Be Flexible!” can be described as a group of individuals with a strong belief in actions to increase overall flexibility, especially regarding production and employee flexibility. They think people, production, and logistics should all be as flexible as possible. Maximized allocation of available capacities preferred by them. They prefer future contracts, which are also a form to support financial flexibility. The highest rejection rate towards company acquisitions was observed within this group. Only this opinion group rated the application of LEAN principles lower than neutral. Continuous Improvement (CI) actions were rated lower than those rated by Factor 1 or Factor 2 groups.

Consensus statements show that the experts agree about the statement’s rating and therefore represent the opinion of all respondents statistically. The high-rated statements mean that most respondents agree on the greater efficiency of the item in reducing risks compared to lower-rated ones. Neutral-rated statements cover a medium level. Consensus statements represent the items with a high agreement among the respondents regardless of which they belong. An interesting future research question is the reason for the consensus statement ratings and their possible effect on risk mitigation. Maybe an increase in the usage of some actions from neutral statements could increase the efficiency of an organization to mitigate risks, but it can be judged after objectively understanding the effect of the applied actions.

The highest-rated consensus statements:

- Total Productive Maintenance (TPM)
- Detailed supplier selection and evaluation

Neutral consensus statements:

- Budget planning and forecast
- Continuous optimization of stocks
- Strong cooperation with customers and suppliers
- Define enterprise priorities and strictly follow them
- International cooperation of production plants
- Long term contracts

The lowest-rated consensus statements:

- Copy technologies and processes of competitors
- Financial incentives for suppliers
- Flexible supplier contracts

Although the mean values of the evaluation of the impact of some general topics affecting the economy and society show visible patterns by the factors, the Kruskal-Wallis analysis of variance test could not confirm those. The high variance of the evaluations can be in line with the variety of the companies in products or the level of contribution. The result suggests the need for company-level risk evaluations, but the common trends can provide valuable input.

Conclusions

This study aimed to explore the characteristic patterns of expert opinion on risk factors in the automotive industry for a current understanding. A Q-sort evaluation separated three distinct opinion groups as factors. Factor 1, called "Follow Standards!", respects mostly, the automotive standards (e.g., IATF, VDA, and FMEA) and rejects flexible reactions. Factor 2, called "Take Control", consists of opinions to support actions that can increase overall control. Factor 3, called "Be Flexible!", supports every aspect to increase flexibility, including people, production, and logistics, but the effectiveness of conscious development activities at a lower rate.

Although there are three opinion groups explored, some remarkable similarities are reflected in consensus statements. There is consensus on the high importance of Total Productive Maintenance (TPM) and proper supplier selection among the respondents. Budget planning and customer-supplier relationship management activities were rated neutral, which might raise attention to these areas as the literature highlights their importance [12][16][19]. Financial risk management and competitor imitation actions were rated least efficient, suggesting that experts prefer actions and systems that give them the power to handle risks internally.

The analysis of general risk factors in the automotive industry shows differences in the perception of the respondents regarding the disruption in chip supply, environmental policies, and the lack of workforce. The experts agreed on the moderate impact level of the COVID-19 pandemic on automotive supply chains, compared to other issues.

A theoretical implication is the applicability of Q-methodology to discover characteristic patterns of expert opinion in the automotive industry; therefore, it is recommended to continue further research in the field. However, supply chain integration has been measured by Q-sort, but it is not directly relevant to risk management [32][33]. The measurement of opinions about the risk factors in the automotive industry by the Q-methodology can be considered a theoretical contribution to the field.

The findings can be used to enhance risk management tools and provide input for more effective risk management. Based on the weighted opinions, it is intended to provide input to establish complex risk mitigation strategies. As an output, organizations can define actions for their risk management practice and discover areas that could require strategic management attention and resources. Despite the thorough design of the survey and the combination of various methods during the research, there are some limitations to the generalization of the results.

The study is limited to Hungary; future research could consist of a broader range of respondents, including experts from various European countries and a more focused approach, based on the opinion groups revealed in this study, concentrating on a systematic selection of samples.

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