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SUPPLIER RELATED DIFFICULTIES, RISK PROFILES AND ORGANISATIONAL DETERMINANTS IN MANUFACTURING FIRMS

Abstract: *The study aims to assess the intensity and configuration of supplier-related difficulties in manufacturing firms, identify distinct supplier-risk profiles, and determine organizational predictors of high risk. A survey of firms in Poland from the automotive, chemical, and electromechanical sectors examined eleven types of supplier difficulties alongside organizational characteristics such as size, ownership, and management system adoption. The reported difficulty levels were moderate (means 3.30–3.60), with unjustified price increases and low supplier flexibility rated highest. K-means clustering ($k=3$) revealed three profiles: high, moderate, and low risk, with a similar share of high-risk firms (about 22–24%) across sectors. Logistic regression indicated that foreign ownership significantly increases the likelihood of belonging to the high-risk group, while sector, size, and management systems are not significant predictors. The findings highlight the need to segment supplier relationships by risk and prioritize price control and flexibility improvements.*

Keywords: *supplier relationship management; supply chain risk management; clustering; manufacturing firms; quality and environmental management systems*

1. Introduction

Supplier performance has become a structurally significant determinant of operational stability in contemporary industrial systems, particularly in sectors characterised by complex production architectures and stringent quality requirements. In such environments, even moderate disruptions originating from suppliers—ranging from delivery delays to recurrent product defects—can propagate across the entire value chain, generating financial losses, reducing production predictability, and intensifying cost pressures. The supply-chain management literature increasingly recognises that operational

problems are not merely incidental events but manifestations of deeper structural interdependencies linked to organisational maturity, the degree of partner integration, and the configuration of quality systems. Yet despite substantial progress in supplier-evaluation methods, there remains a lack of approaches that integrate statistical analyses with the interpretation of latent risk structures reflecting the genuine heterogeneity of firms' operational experiences.

Assessing supplier-related problems calls for analytical procedures capable of reflecting the layered structure of operational interactions. Single indicators are insufficient, because difficulties such as limited supplier flexibility, delivery delays,

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recurring errors or reduced technical quality rarely arise in isolation; instead, they cluster into patterned configurations that propagate instability across the buyer–supplier interface. This necessitates a methodological stance that extends beyond the inspection of mean values and enables the detection of recurrent structures, allowing firms to be grouped according to shared constellations of risk.

Cluster analysis and regression modelling provide such a lens, as they make it possible to reconstruct not only the intensity of the underlying problems but also the organisational profiles in which these problems are most pronounced. When organisational attributes—capital origin, firm size or the adoption of quality-management systems—are integrated into the analysis, the resulting picture becomes structurally richer. It becomes feasible to identify which characteristics contribute to resilient supplier relations and which, conversely, predispose firms to heightened operational frictions.

The objective of this article is to empirically examine supplier-related problems in industrial enterprises operating in Poland and to identify organisational factors that determine the risk of disruptions in the supply chain. The study combines descriptive statistical analysis, k-means clustering for segmenting problem profiles, and logistic regression assessing the probability of belonging to the high-risk cluster. This integrated approach enables a structural rather than incidental view of supplier relationships, clarifying whether the intensity of problems arises from supplier characteristics, sector-specific conditions, or internal organisational properties. The article contributes to the literature by demonstrating that supplier risk is not homogeneous but strongly concentrated within specific segments of firms, with capital origin emerging as a key predictor—highlighting persistent differences between domestic and foreign production structures.

In this paper the following research questions were formulated:

RQ1. How prevalent and structurally differentiated are the operational, quality-related, and communication problems reported by industrial firms in their relationships with suppliers, when evaluated through descriptive statistical measures?

RQ2. What distinct supplier-risk segments emerge from the application of k-means clustering, and how do these segments differ across sectors, firm sizes, and capital origins?

RQ3. To what extent do organizational characteristics-sector, size, capital origin, and adopted management systems - predict the likelihood of a firm belonging to the high-risk supplier cluster, as assessed through logistic regression?

2. Theoretical background

Supplier relationship management constitutes one of the key challenges faced by contemporary firms, particularly in industrial sectors characterised by high levels of operational and technological complexity (Dalvi et al., 2025; Pikos et al., 2024; Emrouznejad et al., 2023; Akbay & Hafeez, 2025). This challenge stems from multiple constraints related to suppliers' flexibility and operational capabilities (e.g., low flexibility, limited production capacity, delayed responsiveness), product quality and performance (e.g., low innovativeness, poor environmental efficiency, frequent defects, low technical quality), delivery timeliness and reliability, as well as the nature of relational and communication processes between buyers and suppliers. Accordingly, a growing body of literature criticises traditional supplier evaluation frameworks for relying on single or narrowly defined performance indicators (Madzík et al., 2023; Fagundes et al., 2021; Chen, 2011). Aouadni et al. (2019) argue that supplier-related research remains dominated by quantitative methods, which, despite their popularity, suffer from significant limitations. Empirical

studies demonstrate that operational, quality-related, and communication problems tend to co-occur, forming recurrent configurations rather than emerging as random or independent events (Patrucco et al., 2022). This observation has prompted a shift toward multidimensional approaches that conceptualise supplier performance as a set of interrelated attributes (Holmes et al., 2025). Within this stream, supplier-related issues are increasingly examined as interconnected sets of factors that differentiate firms according to shared risk profiles (Santos et al., 2025). These configurations are shaped not only by supplier capabilities but also by buyers' internal organisational characteristics, including purchasing maturity, coordination practices, degree of integration, firm size, industry affiliation, and capital structure. Despite the growing recognition that supplier-related problems are multidimensional and interdependent, a substantial proportion of empirical research continues to rely on descriptive statistics and simple linear association measures (Saputro et al., 2022). When problems such as delivery delays, quality defects, limited flexibility, or communication barriers are assessed independently, their tendency to cluster into coherent patterns often remains obscured. To overcome these limitations, recent studies increasingly employ methods that enable the identification of recurring configurations rather than isolated effects (Mavi et al., 2023; Andrade Ferreira et al., 2025). In particular, cluster analysis has gained prominence as a means of segmenting firms based on similarities in their experiences with supplier-related difficulties. By grouping organisations according to response patterns across multiple indicators, cluster analysis facilitates the identification of distinct risk profiles coexisting within the same market or sector. Importantly, this approach shifts the analytical focus from the severity of individual problems toward their co-occurrence, more accurately reflecting the systemic nature of supply chain risk (Torabi et al., 2025). Supplier segmentation

represents one of the dominant approaches in the literature for identifying heterogeneous risk profiles. These approaches encompass both traditional decision-making methods based on indicators such as quality, price, and delivery performance, as well as more advanced statistical techniques that reveal hidden data structures and allow firms to be grouped according to similarities in operational experiences (Lajimi & Majidi, 2021). Supplier clustering enables the identification of segments characterised by similar intensities of problems and provides a clearer understanding of experiential heterogeneity, even within a single market. Empirical studies indicate that such segments differ in the severity of operational and quality-related issues as well as in relational characteristics, pointing to the necessity of adopting differentiated supplier relationship management strategies (Rahiminia et al., 2023). In this context, the application of statistical methods such as cluster analysis enables more precise modelling of risk structures and the delineation of enterprise segments exhibiting varying levels of vulnerability to supply chain disruptions (Lajimi & Majidi, 2021).

In light of these considerations, the present study incorporates structural firm-level variables such as implemented management systems, sector of activity, organisational size, and capital origin and examines their relationship with firms' membership in the identified risk segments. Standardised management systems, including ISO 9001, ISO 14001, Lean Management, and Kaizen, are frequently portrayed in the literature as stabilising mechanisms that enhance predictability and control within supply chains (Leung et al., 2023; Vanichchinchai, 2022). A substantial body of research documents their positive effects on internal process standardisation, documentation discipline, and cross-functional coordination (Dellana et al., 2020; Limón-Romero, 2024). Dellana et al. (2020) suggest that ISO 9001 certified firms make better use of risk-based approaches, which translates into improved

collaboration with partners (including suppliers) in both logistical and cost-related contexts compared to non-certified firms. From this perspective, standardised management systems can be viewed as elements supporting collaboration with suppliers within supply chains (Zimon et al., 2022). A similar point of view is expressed by Nawrocka et al. (2009), who indicate that the implementation of ISO 14001 can support collaboration with suppliers and improve communication of environmental requirements; however, the lack of integration between purchasing and environmental functions, as well as the non-mandatory nature of certification for suppliers, limits the effectiveness of the standard, particularly in larger supply networks. However, empirical evidence increasingly challenges this assumption as analytical focus shifts from intraorganizational outcomes to interorganizational dynamics (Aamer et al., 2021; Su et al., 2020). Although standardised management systems may enhance firms' capabilities to improve internal processes, their ability to shape supplier behaviour is inherently limited (Zimon et al., 2020). As a result, the transfer of standards across organisations is not automatic and may itself generate frictions (Romano, 2002). Some studies suggest that the effectiveness of formal systems in managing supplier risk depends less on nominal adoption and more on how these systems are embedded within relational governance structures (Urbaniak et al., 2024). Bastas and Liyanage (2019) thus rightly observe that standardised management systems yield tangible benefits only when accompanied by intensive supplier development initiatives, shared problem-solving routines, and mechanisms of mutual adaptation. The mere implementation of formal quality systems such as ISO 9001 does not guarantee automatic changes in supplier behaviour or supply network dynamics; their effectiveness increases when supported by collaboration, integration with SCM practices, active partner engagement, and

network-level coordination. In complex and international supply chains where suppliers operate under heterogeneous regulatory, cultural, and technological regimes, such relational mechanisms become particularly critical for achieving substantive outcomes (Vanichchinchai & Igel, 2009).

Capital origin remains a relatively underdeveloped yet increasingly salient dimension in supply chain and supplier relationship research. Literature reviews indicate that different forms of foreign ownership and investor origin can significantly influence organisational structures, managerial strategies, and adaptive capacities in environments characterized by diverse institutional and cultural conditions (Roedder & Schmid, 2025). Firms embedded in foreign ownership structures often coordinate suppliers across multiple countries and institutional contexts, exposing them to currency risks, regulatory diversity, logistical variability, and cultural distance. These conditions may increase delivery delays, constrain responsiveness, and create information asymmetries (Jing & Zhan, 2024). Conversely, foreign-owned firms frequently operate under globally formalized corporate procedures and draw on diversified supplier bases, potentially enhancing supply chain resilience (Zhang, 2025). Consequently, the net effect of capital origin on supplier-related risk remains theoretically ambiguous and warrants further structural investigation (Iwasaki et al., 2022). In this context, capital origin emerges as a promising yet still insufficiently explored predictor. Systematic literature reviews on the effects of foreign ownership on firm strategies and performance suggest that outcomes are multidimensional, context-dependent, and often moderated by institutional environments and network structures, limiting straightforward generalization (Roedder & Schmid, 2025). Moreover, Sharma et al. (2022) emphasize that the complexity of global networks—arising from cross-border coordination and heterogeneous regulatory and cultural

conditions—is associated with higher levels of operational and coordination risk, which may be particularly pronounced in firms with foreign capital involvement.

In the scholarly literature on supplier relationship management, findings regarding firm size are diverse and frequently inconclusive (Yang et al., 2023; Qian et al., 2023; Ateş & Luzzini, 2024). This suggests that the relationship between firm size and supplier relationship quality is neither straightforward nor linear. Studies focusing on network structures show that larger firms are typically embedded in more complex supply networks, maintain relationships with a greater number of partners, and participate in multiple supply chain networks, increasing managerial complexity and potentially leading to coordination, communication, and process integration challenges (Pech et al., 2021). At the same time, larger firms are commonly perceived as benefiting from greater bargaining power, more formalized supplier management processes, and superior analytical capabilities, which should theoretically mitigate disruptions (Diem et al., 2022; Kumar et al., 2019). Conversely, their scale often entails increased organizational complexity, multi-tier supplier structures, and geographically dispersed sourcing, which may elevate coordination costs and reduce control over supplier behavior (Ateş et al., 2022). El Baz and Ruel (2021) suggest that larger firms have greater capabilities to identify and mitigate risks due to their available resources and processes. At the same time, they did not find a significant direct effect of firm size on risk assessment and control, indicating that small and large firms can adopt similar approaches in these areas, with differences emerging only at certain stages of supply chain risk management and not always to the extent one might expect. Moreover, studies examining the determinants of supply chain risk mitigation strategies do not consistently confirm that larger firms always implement more advanced risk-related supplier relationship practices (Foli et al., 2024).

Sectoral context constitutes another recurrent explanatory factor. Industries characterized by high technological complexity and stringent regulatory or quality requirements—such as automotive, chemical, or electromechanical sectors—frequently employ more formalized supplier qualification procedures and extensive auditing practices (Serdarasan, 2013). Supply chain risk management literature emphasizes that business sectors differ substantially in the types of risks and challenges encountered in supplier relationships, reflecting sector-specific technologies, production processes, and market conditions (Irsyadillah & Dadang, 2020; Heckmann et al., 2015). Empirical evidence suggests that sector characteristics primarily influence the type of supplier problems encountered, indicating that sectoral context may shape the nature and sources of risk even if it does not uniformly determine their intensity (Gurtu & Johny, 2021).

Empirical literature clearly demonstrates that sector characteristics shape both the intensity and nature of supplier-related problems. In the automotive industry, high levels of process formalisation and multi-tier supplier structures partially mitigate operational risk, yet the complexity and interdependence of components continue to generate significant challenges related to quality and delivery reliability (Raaymann & Spinler, 2024). Similarly, in the chemical industry, dependence on critical raw materials, transportation requirements, and stringent environmental and safety regulations mean that even minor supply disruptions can lead to severe production stoppages and financial losses (Rajeev et al., 2019). In the electromechanical sector, which involves the production of mechanical devices incorporating electrical and electronic components, multi-tier, technologically complex supplier networks and geographically dispersed sourcing make coordination and quality control particularly demanding. The prevalence of numerous partners and complex verification processes

for materials and subcomponents increases the likelihood of delays and necessitates advanced risk management tools and close collaboration across the entire supply chain (Farrukh & Sajjad, 2025). Despite technological and regulatory differences, all three sectors share a common feature: multi-tier supplier networks and complex production processes that require both procedural formalisation and a systemic approach to monitoring and collaboration throughout the supply chain. Supply chain management literature emphasises that disruptions such as delivery delays, frequent product defects, or limited supplier flexibility do not arise in isolation but are manifestations of deeper organisational interdependencies and partner characteristics (Gurtu & Johny, 2021). Consequently, supplier risk analysis requires a systemic approach that accounts for both firm-level organisational attributes and the recurrent nature of problems in buyer–supplier interactions.

The literature review indicates that most studies focus primarily on supplier-specific characteristics, devoting relatively limited attention to the structural attributes of purchasing firms that condition how supplier-related problems emerge and accumulate within inter-organisational relationships. Organisational features such as firm size, sectoral context, capital origin, and the degree of formalisation of managerial practices affect not only the level of exposure to disruptions but also firms' capacity to absorb, interpret, and manage them. This limitation becomes particularly salient in manufacturing industries, where complex, multi-tier supply networks and technological and institutional heterogeneity reinforce the systemic nature of operational risk. Taken together, these findings point to the need for analytical approaches that link recurrent configurations of supplier-related problems with the structural characteristics of firms. Such a perspective facilitates a shift away from treating disruptions as isolated incidents towards understanding them as manifestations of underlying organisational

and structural conditions, thereby providing a substantive foundation for further theoretical development and empirical inquiry.

3. Materials and Methods

The subject of the research conducted was to define the difficulties in building partner relationships. The research was conducted using the Computer-Assisted Telephone Interview (CATI) technique. The research covered 101 producers (employing over 49 people) who were suppliers for enterprises from the automotive, electromechanical and chemical sectors operating in the Polish B2B market. More than half of the surveyed economic entities (67.33%) were enterprises that had implemented a quality management system compliant with the guidelines contained in the ISO 9001 standard. The study was commissioned to a specialised research agency that conducted a targeted selection of companies registered in the Bisnode database, which is a business directory search platform. The objectives of the research were to determine the importance of the criteria, which are difficulties in building partner relationships, such as:

- low supplier flexibility (lack of/reluctance to make changes to orders)
- low level of product innovation
- unjustified price increases
- low production capacity
- insufficient/delayed supplier response to buyer-reported problems
- low level of environmental friendliness of products
- frequent product defects resulting in complaints
- delays in delivery
- low level of technical quality
- defects in deliveries
- difficulties in communication with the supplier (in exchanging information regarding orders).

The study was conceived as an empirical investigation into the structural determinants of supplier-related problems, implemented through a set of quantitative techniques that integrate descriptive statistics, cluster analysis, logistic regression, and profiling by sector and capital origin. Its empirical base is a survey administered to firms operating in three major industrial domains—automotive, chemical, and electromechanical—yielding a dataset that captures organisational characteristics (sector, employment size, capital origin), the adoption of management systems (ISO 9001, ISO 14001, Lean Management, Kaizen), and evaluations of eleven supplier-related difficulties scored on a five-point Likert scale. These inputs support three classes of dependent outcomes: (1) the intensity of individual problems, (2) cluster membership reflecting supplier-risk configurations, and (3) the probability of belonging to the high-risk segment.

Before modelling, all variables underwent range verification, inspection for missingness, and outlier screening. The dataset proved complete, and no imputation procedures were required. The first stage of the analysis involved computing descriptive statistics—mean, median, standard deviation, skewness and kurtosis—to characterise the distributions of perceived supplier-related issues. This provided the interpretive groundwork for the structural analyses, as the dispersion and shape of these distributions indicate both the heterogeneity of organisational experiences and the latent coherence of assessments across the sample. All computations were conducted using Statistica 13 and Python.

Cluster analysis was employed to uncover latent structures of operational risk among the surveyed enterprises. The k-means algorithm ($k = 3$) was selected on the basis of exploratory tests of stability across multiple cluster specifications. Choosing three segments had empirical justification: both the elbow plot and the analysis of within-cluster sum of squares indicated an optimal balance between representational precision and

structural interpretability.

Prior to clustering, all variables describing supplier problems were standardised using the z-score. Standardisation was necessary because the variables exhibited similar but not identical variances, which could distort the algorithm by disproportionately amplifying the influence of dimensions with higher dispersion. Cluster analysis was carried out in Python (scikit-learn library).

The second methodological component concerned the structural analysis of relationships between clusters and organisational characteristics. This procedure was descriptive-comparative in nature but grounded in the cluster assignments generated in the preceding step. Tables 3–5 present the results of profiling by sector, firm size, and capital origin. This approach makes it possible to determine in which market segments supplier-related problems are most concentrated and where they appear in more stable and predictable forms.

Profiling was conducted by calculating the percentage shares of enterprises within each cluster. This technique was selected because it captures structural differences that are not necessarily visible in mean-based analyses or in regression. A qualitative interpretive framework, supported by distributional comparisons, was applied, as cluster structure is inherently categorical and requires a narrative built around configurations rather than isolated effects.

To determine which organisational attributes shape the likelihood of a firm being classified into the high-risk cluster, a binary logistic regression model was employed. The dependent variable was coded as 1 for enterprises assigned to the segment characterised by the highest intensity of supplier-related difficulties, and 0 for all others. Predictor selection—sector, firm size, capital origin, and the implementation of ISO 9001, ISO 14001, Lean Management, and Kaizen—followed both their empirical availability and their conceptual relevance within supply-chain management research.

Model estimation proceeded via maximum likelihood. For each predictor, regression coefficients, p-values, and 95% confidence intervals were calculated to evaluate statistical significance and the directional patterns of influence. Pseudo- R^2 measures were reported to characterise overall model fit, with the recognition that supplier-relationship dynamics are multifactorial and that predictive performance in this domain is typically modest due to the inherent complexity of organisational interactions.

4. The results

4.1. The analysis of supplier problems

Table 1 summarises the essential descriptive statistics for eleven difficulties experienced within supplier relationships along three major operational, quality-related, and communication dimensions. The means are confined within the narrow range of 3.30–3.60 on the five-point scale, which indicates that firms perceive all these problems at a moderate or at best moderately high intensity. Such regularities signal structural tensions

along the supply chains. In the order of the means, the most important difficulties are unjustified price increases and restricted supplier flexibility, which suggest asymmetries in cost exposure and constrained bargaining positions on the buyer's side. Medians around 3 suggest relatively stable perceptions and no polarised evaluation, which might describe normalised, recurrent operational issues.

The large standard deviations of 1.05–1.15 suggest that supplier-related challenges significantly vary across firms. Although the averages are very similar, the wide dispersion implies significant variations in the performance of suppliers that may reflect sectoral backgrounds, incomplete diffusion of management structures, or capital backgrounds. High variance for challenges related to frequent product defects or delivery mistakes would indicate that some firms experience much more severe quality-related shocks than others. This is in line with a fragmented supplier market where some suppliers provide stability in operational routines while others create recurrent disturbances in the value chain.

Table 1. Descriptive statistic of supplier-problems

Variable	Mean	Median	Standard Deviation	Skewness	Kurtosis
Low flexibility of the supplier	3.495	3.0	1.089	-0.064	-0.803
Low level of product innovation	3.406	3.0	1.147	-0.103	-0.559
Unjustified price increases	3.604	4.0	1.063	-0.390	-0.791
Low level of production capacity	3.347	3.0	1.105	0.011	-0.574
Delayed reaction of the supplier	3.455	3.0	1.056	-0.111	-1.008
Low environmental performance of products	3.297	3.0	1.071	-0.165	-0.892
Frequent product defects	3.416	3.0	1.121	-0.269	-0.733
Delays in delivery	3.347	3.0	1.110	-0.302	-0.640
Low technical quality	3.317	3.0	1.110	-0.281	-0.774
Delivery errors	3.416	3.0	1.135	-0.297	-0.904
Difficulties in communicating with the supplier	3.307	3.0	1.092	-0.165	-0.673

The mostly slightly negative values of the coefficients of skewness show a slight asymmetry towards higher ratings of problem intensity. This suggests that there is no tendency by the respondents to downgrade

the severity of the problems. Rather, the ratings bunch up around the higher middle values. The overall small magnitude of asymmetry for these variables indicates that such problems are common enough to

become persistent behavioural regularities and not isolated anomalies. Consideration of relatively converging assessments in areas such as timeliness of delivery, responsiveness in dealing with reported incidents, and technical quality indicates a pervasive systemic structural burden at the level of routine transactions between suppliers and buyers.

Kurtosis values are negative, meaning the distributions are flatter than the normal distribution. Such a statistical structure is typical in populations where a wide variety of responses occur without concentration around extremes. In this context, related to supplier-relationship management, it may mean that firms operate under diverse collaboration models that differ in their degree of formalisation, quality standards, and operational flexibility. These differences generate varied experiences across the assessed problem areas. Negative kurtosis reinforces the interpretation that the difficulties are dispersed and arise both from qualitative deficiencies on the supplier side and from varying levels of managerial maturity on the buyer side.

The mean values for all eleven supplier-related problems fall within a tight range of 3.297–3.604, indicating that firms tend to experience these difficulties at consistently moderate to moderately high levels. None of the indicators approaches a neutral midpoint, suggesting that organisations perceive cooperation with suppliers as constrained in a more structural and recurrent way than as a set of occasional disruptions. This pattern of means is clearly shaped above all by operational and cost pressures, and this configuration is broadly similar across different sectors and firm sizes.

Unjustified price increases bear the highest mean, 3.604, suggesting that economic pressures are currently the most important source of tension in buyer-supplier relations. Backed by low supplier flexibility, with a mean of 3.495, this constraint keeps production planning weak and decreases the

firms' responsiveness to changes in demand. Both factors seem to be continuous and destabilising, underlining suppliers' limited responsiveness along both financial and operational dimensions.

Quality-related issues fall in the mid-range of the distribution. Product defects (mean = 3.416), low technical quality (mean = 3.317) and weak innovation performance (mean = 3.406) indicate that firms continue to face technology- and quality-based limitations, even if these do not overshadow cost or flexibility concerns. Still, mean values above 3.3 show that quality deficits remain a meaningful source of operational risk, adding variability to production processes and reducing their overall reliability.

Logistical and communication problems—late deliveries (average = 3.347), delivery errors (average = 3.416) and delayed response by suppliers to the emergence of problems that have been reported to them (average = 3.455)—represent a coherent set of causes of moderately serious disruption. Their averages are higher than those recorded for narrowly technical parameters, which suggests that deficits in information exchange, delivery execution and service responsiveness retain a structurally embedded role within supplier–buyer relationships. The configuration of findings here is that elementary operational bottlenecks, particularly those related to temporal reliability, the accuracy of delivery and the sufficiency of suppliers' reactive capabilities, continue to destabilise modern supply chains.

The lowest mean values in the dataset concern environmental performance (mean = 3.297) and suppliers' production-capacity limitations (mean = 3.347). Although the differences are modest, they capture a hierarchy of perceived risks: environmental issues and production capacity are not viewed as the most urgent areas of concern. This is noteworthy given the rising prominence of ESG requirements—these data suggest that, for many firms, environmental challenges have not yet reached an intensity comparable to logistical,

cost-related, or quality problems. Nonetheless, mean values above 3 confirm that these dimensions remain embedded within the broader, systemic landscape of difficulties shaping buyer-supplier relationships.

4.2. Cluster analysis

The use of k-means clustering allowed the analysis to move beneath the surface of the descriptive results and uncover structures that are not directly visible in raw responses. By grouping firms according to similarities in their patterns of reported supplier-related problems, the method provided a clearer picture of how heterogeneous these experiences actually are, even within a single market environment. Standardising the variables before clustering ensured that no single feature dominated the process simply because it exhibited higher variance, keeping the partitioning balanced and methodologically sound.

The procedure yielded three well-separated clusters. Each represents a distinct configuration of operational and quality-related risks stemming from suppliers, and together they show that firms do not face a uniform set of challenges. Instead, they

gravitate toward different “risk profiles,” shaped by the intensity and combination of issues they encounter. This result is analytically useful: it extends the insight gained from descriptive statistics and makes it possible to identify groups of firms that share similar underlying difficulties, even when their individual indicator scores may appear uneven or only partially aligned.

The k-means clustering procedure revealed the latent structural patterns in the dataset describing supplier-related problems, which enabled a more fine-grained interpretation of the extent to which heterogeneous firms' operational experiences are across a single market. By classifying observations according to the similarity in their response vectors-after standardising all variables to preclude dominance by high-variance indicators-the algorithm yielded three sharply delineated clusters. Each of these clusters (see Table 2) stands for a distinct configuration of operational, quality-related and communication risks originating from suppliers. In analytical terms, this method goes well beyond the reach of descriptive statistics because it singles out structurally coherent groups of firms facing comparable constellations of problems even when their absolute ratings differ.

Table 2. Cluster analysis results

Variable	Cluster 0	Cluster 1	Cluster 2
Low flexibility of the supplier	3.375	4.583	2.793
Low level of product innovation	3.333	4.458	2.655
Unjustified price increases	3.708	4.750	2.483
Low level of production capacity	3.312	4.625	2.448
Delayed reaction of the supplier	3.396	4.708	2.552
Low environmental performance of products	3.229	4.500	2.310
Frequent product defects	3.542	4.750	2.103
Delays in delivery	3.542	4.917	2.759
Low technical quality	3.625	4.750	2.552
Delivery errors	3.438	4.792	2.448
Difficult communication with supplier	3.479	4.833	2.310

Cluster 1 represents the segment exposed to the highest intensity of supplier-induced strain. The mean values across most indicators lie in the 4.5–4.9 interval, showing

that there are sustained difficulties regarding delivery reliability, product conformity, responsiveness, and price stability. In essence, firms in this segment are operating

under conditions of near-continuous disruption, where supplier inefficiencies directly impact production volatility and downstream service constraints. Such a diagnosis presents straightforward value wherein strategic firms require interventions through either the renegotiation of supply contracts, diversification of sourcing portfolios, or deployment of more rigorous monitoring and audit mechanisms.

Cluster 0 represents those organisations that face moderate, generally typical levels of difficulty. Their mean scores are very close to the sample average and epitomise typical operational frictions: limited flexibility, periodic quality deviations, and occasional delays. This segment is illustrative of a state of functional equilibrium-problems occur, yet they do not threaten to disrupt the continuity of collaboration. From an analytic perspective, this cluster serves as a comparative baseline, highlighting more clearly the distinction between systemic deficiencies and episodic disturbances evident in the more extreme groups. Cluster 2 consists of firms that report the lowest levels of supplier-related problems. This implies more mature relationships between companies and suppliers, more stable procurement routines, and more consistently applied quality-control practices. The mean values fall between 2.1 and 2.8, indicating minimal disruption along the supply chain. Such a configuration may stem from the selection of high-performing suppliers, from closer internal coordination, or from advanced organisational capabilities. Conceptually, this segment represents a benchmark of "effective operational practice," when referring to the criteria that guide strategic and qualitative standards in managing supplier relationships.

While this dominance is typical, Cluster 0, representing a middle level of supplier-related problems' intensity for each of the analysed sectors (Table 3), shows its highest share in the automotive industry, amounting to 51.6%. From this pattern, it emerges that automotive firms are usually subject to

standard supply-chain frictions that recur but rarely attain extreme-risk conditions. The result is at least partly consistent with the high degree of process formalisation characterising the sector, whereby stabilised contracting procedures and stringent quality-control routines maintain problems around manageable, medium-range levels.

Table 3. Sectoral Profiling of Clusters

Sector	Cluster 0 (%)	Cluster 1 (%)	Cluster 2 (%)
Automotive	51.6	22.6	25.8
Chemical	46.7	24.4	28.9
Electro-mechanical	44.0	24.0	32.0

Cluster 1, consisting of enterprises that have faced the highest level of cumulative burden caused by their suppliers, represents a remarkably stable sectoral presence: 22–24% in each of the three industries. The remarkable regularity suggests that the most severe disruptions are not linked to sector-specific logics of production but, instead, to more systemic drivers, such as relational structures, communication channels, or vulnerabilities to global supply-chain shocks. The symmetry across the three sectors suggests that particularly risky supplier environments tend to emerge independently of technological complexity and associated forms of industrial specialisation.

The most distinct separation is seen in Cluster 2, the segment with low risk. In this cluster, the highest share comes from firms of the electromechanical industry, at 32.0%, followed by chemical enterprises, at 28.9%, and automotive firms, at 25.8%. Such a spread indicates that electromechanical companies tend to have more stable supplier interfaces, stronger coordination in their procurement processes, and relatively favourable sourcing conditions. This contrasts with the automotive industry, wherein, while dominant in the moderate-risk cluster, automotive firms are the smallest in the low-risk group. This may be due to the high complexity of automotive components,

the demanding architecture of tiered supply networks, and greater susceptibility to quality perturbations.

Table 4 refines the above analysis by focusing on cluster membership according to firm size. Large enterprises of 250+ employees are predominant in the moderate-risk cluster, indicating supplier relationships that remain generally stable but still show signs of recurring operational tensions. Only a limited number of these firms are found in the low-risk cluster, suggesting that highly resilient supplier coordination is less common among the largest organisations, possibly because of the scale and complexity of their procurement systems.

The distribution is more scattered for medium-sized enterprises with between 50 and 249 employees. A large percentage falls into the low-risk cluster, while another significant percentage is in the moderate-risk group. This dualism suggests that medium-sized firms exhibit a broad range of supplier-management performance: some have extremely well-organised and reactive supplier relations, but for others, the difficulties remain more long-lasting. With this category, there is great internal variation in the stability and quality of supplier cooperation.

Table 4. Size Profiling of Clusters

Firm Size	Cluster 0 (%)	Cluster 1 (%)	Cluster 2 (%)
250+ employees	60.6	30.3	9.1
50–249 employees	41.2	20.6	38.2

Table 5 illustrates how the intensity of supplier-related problems differs by capital origin, revealing distinct structural contrasts between foreign-owned and domestically owned firms. Foreign-capital enterprises are markedly concentrated in the high-risk cluster (45.8%), suggesting that they encounter severe and recurrent disruptions—ranging from delivery delays to quality inconsistencies and insufficient supplier

responsiveness. Their minimal presence in the low-risk cluster (12.5%) indicates that stable, low-friction supplier relationships are comparatively uncommon. This distribution is consistent with the operational demands of globally dispersed supply networks. It can be observed that coordination challenges and variability in performance tend to be amplified.

Polish-capital firms display a more balanced configuration. They constitute the largest share of the moderate-risk cluster (49.4%), and their substantial presence in the low-risk group (33.8%) implies a stronger capacity to maintain steady, cooperative, and less conflict-intensive supplier relations. Their relatively small share in the high-risk cluster (16.9%) suggests a lower likelihood of facing compounded, multidimensional supplier difficulties. The pattern indicates a structural advantage for domestically owned enterprises. They are likely rooted in shorter supply chains, more intimate knowledge of the local market environment, and closer, trust-based ties with regionally embedded suppliers.

Table 5. Origin Profiling of Clusters

Capital Origin	Cluster 0 (%)	Cluster 1 (%)	Cluster 2 (%)
Foreign capital	41.7	45.8	12.5
Polish capital	49.4	16.9	33.8

4.3. Logistic regression model

Logistic regression was applied to identify the organisational factors that determine the probability that a firm will be classified into the segment with the highest level of supplier-related risk (Table 6). The model, which uses membership in the high-risk cluster as the dependent variable, enables an assessment of the relative importance of structural characteristics and implemented management systems in shaping the perception of problems in supplier relationships. The logit framework, as a tool for modelling

dichotomous outcomes, not only identifies significant predictors but also allows for a precise estimation of the direction and magnitude of effects through odds ratios. For

the analysed sample, the findings are unambiguous: among the seven predictors included, only capital origin emerges as statistically significant.

Table 6. Logistic Regression Results – High-Risk Supplier Cluster

Variable	Coefficient β	p-value	95% CI Low	95% CI High
Const	-2.9220	0.0076	-5.0687	-0.7753
Sector	-0.2669	0.4293	-0.9287	0.3949
Size	-0.1114	0.8415	-1.2030	0.9802
Capital origin	1.4607	0.0109	0.3367	2.5848
ISO 9001	0.6285	0.3016	-0.5641	1.8210
ISO 14001	-0.0117	0.9821	-1.0287	1.0053
Lean	-0.7817	0.5085	-3.0990	1.5356
Kaizen	1.0066	0.2904	-0.8595	2.8727

The strongest-and the only statistically significant-predictor was foreign capital ownership. The positive coefficient ($\beta = 1.4607$, $p = 0.011$) suggests that foreign-owned enterprises are several-fold more likely to fall into the high-risk supplier cluster than domestically owned firms. An odds ratio greater than four suggests that the effect is statistically robust but also substantively meaningful. This might indicate that foreign entities operate under more demanding or less stable supply-chain settings, perhaps due to stricter formalised requirements, more frequent cross-border interactions, or different levels of operational standards.

These regression results show that sector and firm size do not exert statistically significant effects on the probability of high supplier-risk exposure. Therefore, enterprises-the chemical, electromechanical, and automotive industries-experience a structure that is broadly similar in the case of supplier-related difficulties. The absence of a scale effect indicates that employing more staff does not necessarily improve or worsen purchasing-relationship management. This may indicate that the key drivers of such problems lie outside traditional organisational characteristics. They are rooted more in operational mechanisms rather than structural attributes.

Interesting but not wholly unexpected, the results show that there is no statistically

significant association of ISO 9001, ISO 14001, Lean Management, and Kaizen management systems with membership in the high-risk cluster. This can be seen from the fact that organisations declaring advanced management standards do not differ significantly in their assessments of supplier problems. Two interpretations are plausible: first, the formal possession of a system does not automatically translate into an organisation's ability to reduce supply-chain problems, particularly when suppliers are external actors not governed by the same standards; second, such systems may turn out to be more effective in stabilising internal environments than in managing interorganisational relationships where process heterogeneity and divergent quality cultures prevail.

The pseudo R^2 of 0.096 testifies that the model explains part of the variance but is far from fully capturing the complexity of the phenomenon. This is typical in the studies of supplier relationships, which are multidimensional and strongly context dependent, often characterised by information asymmetry. In the supply-chain management literature, predicting risk wholly from organisational characteristics seldom yields models with a high explanatory power. The result, therefore, reinforces the notion that the most influential factors are likely operational rather than structural: timeliness

of communication, contract quality, supplier diversification, and dependence on key partners.

The results of the model point to several practical implications: foreign-owned firms should strengthen the monitoring of supply-chain stability, develop credible alternative sourcing paths and introduce more sophisticated mechanisms of controlling supply-side risk. At the same time, the absence of significant effects for the remaining predictors implies that measures in isolation, but the introduction of a single ISO standard or selected Lean tools, is unlikely to bring about single causes of supplier-related problems. On the other hand, what is called for are integrated approaches in which closer collaboration with suppliers is combined with structured audit routines, system-oriented quality management, and initiatives aimed at enhancing relational performance.

5. Discussion

The findings indicate that supplier-related operational, quality and communication difficulties are not sporadic events but recurring features of day-to-day collaboration. Across all eleven items, the mean scores concentrate in a narrow, moderately-high band (3.30-3.60), while dispersion remains sizeable, signalling substantial heterogeneity in how firms experience supplier tensions. Taken together, this supports a configurational view of supplier-related risk: rather than isolated issues, firms face bundles of interrelated frictions that vary in intensity across organisational contexts (Kache & Seuring, 2014; Gurtu & Johny, 2021; El Baz & Ruel, 2021).

The k-means results reveal three distinct supplier-risk profiles (Lajimi & Majidi, 2021; Rahiminia et al., 2023). Cluster 0 (the largest segment) represents firms facing routine frictions - periodic delays, coordination problems and quality deviations - at moderate intensity, consistent with complexity-related

everyday disturbances observed in industrial supply settings (Serdarasan, 2013; Ateş & Luzzini, 2024). Cluster 2 captures firms reporting consistently low difficulty levels, suggesting more stable procurement routines and more effective supplier coordination. Cluster 1 isolates organisations exposed to persistently high risk, where late deliveries, recurring defects, limited responsiveness and price escalation co-occur. Importantly, the high-risk profile is disproportionately associated with foreign-owned firms (Roedder & Schmid, 2025; Iwasaki et al., 2022), which is consistent with the heightened coordination and governance challenges typically present in internationally dispersed supply networks (Ateş et al., 2022; Sharma et al., 2022).

Logistic regression corroborates the profile evidence: among the tested predictors, ownership origin is the only statistically significant correlate of high-risk membership (Roedder & Schmid, 2025; Jing & Zhan, 2024). In contrast, sector and size do not differentiate the likelihood of high-risk exposure, suggesting that severe supplier difficulties can cut across industrial domains. The non-significant effects of ISO 9001/14001 and Lean/Kaizen should be interpreted cautiously: nominal adoption may be insufficient to alter inter-organisational risk without mature implementation and boundary-spanning deployment (Dellana et al., 2020; Vanichchinchai, 2022). In other words, formal systems may stabilise internal routines, yet remain limited in shaping suppliers' autonomous processes - especially under heterogeneous standards and quality cultures (Aamer et al., 2021; Zimon et al., 2022). The low explanatory power further implies that relationship-level and network-level mechanisms (e.g., dependence, contract governance, information exchange, multi-tier visibility) likely account for a substantial part of the variance (Heckmann et al., 2015; El Baz & Ruel, 2021).

The relatively low mean scores for environmental performance and suppliers' production-capacity limitations indicate that

firms perceive these areas as less pressing compared with other operational risks. This pattern suggests that environmental concerns, despite the growing prominence of ESG frameworks, have not yet translated into a heightened sense of urgency within managerial practice (Lin et al., 2025). These findings imply that organizations may still prioritize short-term logistical, cost, and quality issues over longer-term sustainability and resilience considerations, potentially delaying strategic adjustments in these domains.

This study contributes by combining a configurational segmentation of supplier difficulties with an explanatory test of organisational correlates (Emrouznejad et al., 2023; Saputro et al., 2022). Empirically, it shows that supplier-related problems form co-occurring profiles rather than isolated incidents, and that ownership origin is the key structural correlate of concentrated high-risk exposure. The results also qualify the common expectation that certification or tool adoption alone stabilises buyer-supplier interactions (Su et al., 2020; Dellana et al., 2020; Vanichchinchai, 2022), pointing instead to the role of cross-border governance and complexity-related coordination challenges (Ateş et al., 2022; Sharma et al., 2022).

Finally, although the evidence is based on one country, the ownership effect provides a plausible mechanism linking internationalisation to supplier-risk concentration - an issue of clear relevance for globally dispersed supply chains operating under disruption and volatility.

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6. Conclusion

This study demonstrates that supplier-related operational, quality and communication difficulties tend to co-occur as recurring profiles rather than isolated incidents. Using survey data from manufacturing firms in Poland, three distinct supplier-risk profiles were identified (low, moderate and high). The most salient difficulties relate to price escalation and limited supplier flexibility, indicating that cost and adaptability tensions remain central to buyer-supplier relationships. Importantly, foreign ownership is the only organisational attribute that significantly increases the likelihood of belonging to the high-risk profile, whereas sector, firm size and the nominal adoption of ISO 9001/14001 and Lean/Kaizen do not differentiate high-risk membership.

The findings contribute a profile-based view of supplier difficulties and suggest that risk concentration may be linked to governance and coordination challenges that are more prevalent in internationally embedded supply networks. For managers, the results support adopting differentiated supplier relationship strategies based on risk profiles, prioritising contractual and data-driven price governance, flexibility-building measures (e.g., capacity coordination and alternative sourcing), and boundary-spanning supplier development practices.

Given the cross-sectional, perception-based and single-country design, future research should triangulate perceptions with operational and network-level measures (e.g., dependence, complexity and multi-tier visibility) and test the generalisability of the ownership effect across institutional contexts.

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