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MULTI-CONTOUR PROFILE-MATRIX DIAGNOSTICS OF THE ECONOMIC RESILIENCE OF FREIGHT ROAD TRANSPORT ENTERPRISES UNDER HIGH-TECH TRANSFORMATION

Abstract

The article substantiates a multi-contour profile-matrix methodology for diagnosing the economic resilience of freight road transport enterprises under high-tech transformation. The approach is based on the premise that resilience cannot be reliably represented by a single integral score because strong values in one domain may conceal critical vulnerabilities in another. The proposed methodology combines five autonomous diagnostic profiles: financial-economic, operational-market, resource-technical, innovation-technological, and risk-recovery. It integrates verified data provenance, threshold zoning, dynamic indicators of resistance and recovery, cluster typology and panel modelling. A two-level information design is proposed, combining a broad panel based on official registration and financial data with an in-depth subsample containing operational and technological indicators. Four diagnostic zones—critical, vulnerable, acceptable and resilient—are used without compensatory aggregation across profiles. The methodology also distinguishes the depth of functional decline, recovery time, completeness of recovery and cumulative loss of functionality. Its practical value lies in preserving causal traceability from an observed deviation to the underlying vulnerability and in creating a direct analytical transition from diagnosis to differentiated managerial measures, scenario trajectories and investment decisions.

Keywords: economic resilience, freight road transport, profile-matrix diagnostics, high-tech transformation, non-compensatory assessment, recovery trajectory, cluster analysis, panel modelling.

Problem statement. Freight road transport enterprises operate as network-dependent businesses whose financial results are inseparable from the continuity of transport operations, technical readiness of rolling stock, availability of drivers, access to routes and border infrastructure, fuel and maintenance costs, data quality and the reliability of digital systems. Under high-tech transformation, these interdependencies intensify: transport management systems, telematics, electronic documents, analytics, predictive maintenance and platform integration may increase efficiency, but they can also introduce new technological, cyber, investment and competence-related vulnerabilities. Consequently, an enterprise may demonstrate acceptable financial ratios while remaining operationally fragile, or may possess advanced digital tools while being unable to restore critical transport functions after a disruption. A diagnostic approach focused only on financial stability or a general rating therefore provides an incomplete representation of resilience [1–4].

The methodological problem is aggravated by heterogeneity of available data. Official financial reporting is comparatively standardized and can support broad inter-firm analysis, whereas information on empty mileage, technical downtime, fleet condition, telematics coverage, TMS integration, cyber incidents or recovery procedures is generally available only from corporate sources. A robust methodology must therefore distinguish data with different levels of verification, avoid filling informational gaps with sector averages, and preserve the difference between an observed fact, an author’s calculation and a scenario assumption. The diagnostic result should explain what exactly supports or constrains resilience rather than merely assign a position in a ranking.

Analysis of research. Contemporary resilience research increasingly interprets resilience as a dynamic capability rather than a static reserve of strength. Organizational resilience is associated with anticipation, resistance, recovery, adaptation and transformation, while supply-chain research emphasizes the relationship between vulnerabilities and capabilities and the need to maintain critical functions under disruption [1–4]. These approaches are particularly relevant to freight road transport because the transport service cannot be stored, rolling stock is mobile, operations are geographically distributed, and performance depends on a combination of internal resources and external infrastructure.

A second group of methodological studies concerns measurement. Composite indicators are useful for compression and comparison, but their results depend on normalization, weights and aggregation rules. The OECD/JRC methodological guidance explicitly warns that composite results are sensitive to design choices [9]. For resilience diagnostics this issue is fundamental: a high value of liquidity should not compensate for a critical technical vulnerability, just as strong asset turnover should not cancel persistent losses. This supports a non-compensatory profile logic in which dimensions remain analytically separate.

A third group of studies provides tools for constructing a reproducible empirical design. Sampling theory supports stratification when a complete population cannot be analyzed [10; 11]; missing-data methodology requires distinguishing missingness from true zero values [12]; cluster analysis can reveal internally coherent types of enterprises [13; 14]; and panel econometrics makes it possible to test temporal persistence and common shocks without reducing resilience to one synthetic score [15]. The unresolved task is to integrate these elements into a single procedure that links data provenance, profile diagnostics, dynamic recovery metrics and differentiated managerial interpretation.

Purpose of the article. The purpose of the article is to substantiate a multi-contour profile-matrix methodology for diagnosing the economic resilience of

freight road transport enterprises under high-tech transformation, to define its information architecture and diagnostic profiles, and to establish a non-compensatory transition from observed indicators to threshold zones, recovery trajectories, statistical typology and managerial decisions.

Results. The starting principle of the proposed methodology is that economic resilience should be diagnosed as a multidimensional dynamic capacity rather than as a single state variable. The object of preservation is the enterprise's critical transport function: the ability to perform freight transportation safely and with acceptable quality while maintaining financial viability. The diagnostic system therefore combines outcome variables with resource and capability variables and with dynamic characteristics that describe the enterprise before, during and after a disruption.

The methodology is organized around five autonomous profiles. The financial-economic profile reflects profitability, solvency, capital structure, asset turnover, revenue dynamics and labour productivity. The operational-market profile captures continuity of transportation, order fulfilment, route and customer diversification, downtime and the quality of the transport cycle. The resource-technical profile characterizes the actual availability and readiness of vehicles, drivers, maintenance capacity and other critical resources. The innovation-technological profile assesses not only the presence of digital technologies but also the depth of their integration into decisions and business processes. The risk-recovery profile describes vulnerability to disruptions, resistance, recovery capacity, business continuity and the ability to operate in a reserve mode. The profiles are intentionally not summed into a common score.

Information architecture precedes indicator calculation. Five data contours are distinguished: registration, financial, official statistical, corporate-operational and scenario data. Each variable receives a provenance status: official registration data, official statistics, official financial statements, corporately verified

information, author calculation or scenario assumption. This rule prevents an analytical estimate from being presented as an official statistic and prevents scenario values from being interpreted as observed outcomes. For every indicator, the source, date of extraction, transformation rule and formula should be documented.

The empirical design is two-level. The first level is a complete or representative panel of enterprises with verified registration and financial data. If complete observation is not feasible, stratified sampling by region and enterprise size is preferable to ad hoc selection; the required sample can be planned using standard sampling procedures [10; 11]. The second level is an in-depth technological subsample containing confirmed operational and digital indicators. Its purpose is not mechanical extrapolation to the entire population, but causal interpretation of how technology, process design and organizational capabilities influence resilience.

Data preparation follows a conservative logic. Duplicate identifiers, unit inconsistencies and arithmetic contradictions are checked; monetary indicators are adjusted where necessary for comparability; missing values are not replaced by zeros; and structural breaks are documented rather than hidden. Extreme observations are not automatically deleted, because large losses, abrupt revenue decline or unusual leverage may represent genuine manifestations of instability. Where statistical models require robust treatment, adjusted and unadjusted results should be compared. These rules are consistent with established approaches to sampling and missing-data analysis [10–12].

The profile matrix converts individual indicators into four diagnostic zones: critical, vulnerable, acceptable and resilient. A critical zone indicates a threat to viability or to the performance of a critical function; a vulnerable zone reflects a material gap that requires corrective action; an acceptable zone indicates the absence of an immediate threat while preserving room for improvement; and a

resilient zone indicates a sufficient level supported by evidence of stable performance. An enterprise may simultaneously occupy different zones across different profiles. This is not a defect of the methodology but its principal analytical advantage.

For visual comparison, heterogeneous indicators may be normalized to a common scale, but normalization is used only for profile maps and radar-type representations. Normalized values are not summed across profiles. This restriction directly addresses the compensatory problem of integral indices [9]. It ensures that a critical weakness retains its managerial significance even when another dimension is strong. Thus, the diagnostic question changes from “Which enterprise has the highest score?” to “Which specific vulnerability can interrupt the critical transport function, and what evidence supports this conclusion?”

The matrix is supplemented by a dynamic contour. Resistance is reflected by the depth of the initial decline in a selected functionality indicator relative to a pre-disruption baseline. Recoverability is described by the time required to return to an acceptable corridor and by the completeness of recovery at a specified moment. A cumulative loss-of-function indicator combines the depth and duration of the deficit. This logic adapts the functional-trajectory approach used in quantitative resilience research to discrete economic series of enterprises [5]. For freight carriers, the functionality variable may be real revenue, the number of completed trips, technical availability, on-time order fulfilment or another directly relevant positive measure.

Adaptability and transformational capacity require a different form of evidence. They should be recorded through a “change–cause–economic result” matrix. Rerouting operations, for example, constitutes adaptation only if it restores an acceptable level of service and cost. Installing a TMS should be classified as transformation only when it changes planning, data flows and managerial practice and produces a verified operational or financial result. This prevents technological

modernization from being treated as resilience merely because a new system has been purchased.

Risk analysis is integrated without substituting the profiles. Expected losses are assessed by linking the probability of a risk event with its economic consequences, with technical, operational, financial, cyber and wartime-logistics risks considered separately. ISO 31000 and IEC 31010 provide a consistent basis for this risk-oriented logic [7; 8], while ISO 22316 supports the broader interpretation of resilience as an organizational attribute that must be adapted to the objectives and context of the enterprise [6].

After the profile calculation, statistical methods are used to identify patterns rather than to produce an artificial overall score. Hierarchical clustering can form enterprise types with internally similar configurations; Ward's method is appropriate for initial grouping, while silhouette diagnostics help assess the interpretability of the cluster structure [13; 14]. Panel models may then test whether selected outcomes, such as profitability or recovery indicators, exhibit temporal persistence and whether their variation is associated with financial, resource, technological or external factors [15]. The dependent variables remain economically interpretable indicators rather than a synthetic resilience index.

The final diagnostic product is therefore a profile passport rather than a rating. It contains the origin of each indicator, the observed value, the relevant threshold, the diagnostic zone, the dynamic trajectory where available, the identified vulnerability, and the managerial implication. The same architecture creates a direct link to differentiated measures: asset-efficiency initiatives for financially strengthened firms, controlled scaling for growing but more leveraged firms, break-even recovery for crisis profiles, and margin restoration for operationally intensive enterprises with weak profitability. The selection of a measure is consequently grounded in a diagnosed causal gap rather than in a universal list of "best practices."

An important operational feature of the methodology is the hierarchy of diagnostic benchmarks. The threshold for an indicator is not selected from a single universal source. Where a legally or technically justified norm exists, it has priority; where no such norm exists, the benchmark is determined from empirical distributions of comparable enterprises, historical dynamics, or a verified enterprise-specific target. This distinction is especially important for freight road transport, because the same numerical value may have different economic meanings depending on fleet structure, route geography, customer concentration and the stage of technological modernization. The four diagnostic zones therefore represent evidence-based corridors rather than arbitrary colour coding. In practical use, the analyst records not only the zone but also the origin of the threshold and the reason why it is applicable to the observed enterprise.

The financial-economic profile is operationalized through indicators that can be reproduced from financial statements and compared over time. Net margin reflects the relationship between the net financial result and net revenue; the autonomy ratio shows the share of assets financed by equity; asset turnover measures the revenue generated per unit of assets; and labour productivity is expressed as revenue per employee. These indicators are interpreted jointly but not aggregated. For example, high autonomy may coexist with losses, while high turnover may coexist with an extremely weak margin. Such combinations are analytically more informative than an average score because they reveal different mechanisms of vulnerability: insufficient profitability, excessive debt dependence, underutilized assets or a cost structure that absorbs the benefits of intensive operations.

The operational, resource-technical and technological profiles extend the diagnosis beyond published accounting data. The operational contour should include completed trips, order fulfilment, route deviations, empty mileage, delivery delays, downtime and concentration by major customers or routes. The

resource-technical contour records the actual technical readiness of the fleet, availability of drivers, maintenance capacity, access to spare parts and the ability to substitute a critical resource. The technological contour distinguishes simple availability of TMS, telematics, electronic documents, analytical tools or predictive maintenance from their actual integration into decision-making. A technology receives a positive resilience interpretation only where the chain "technology - process change - measurable economic or operational effect" can be demonstrated. Otherwise, it is recorded as technological availability without confirmed resilience effect.

A practical application of the methodology in the dissertation used a regionally and size-balanced reference subsample of freight road transport enterprises for 2021-2025. Twelve enterprises were initially included in the reference dataset, while structurally transformed cases were separated when changes in scale or business configuration impaired comparability. Ten comparable enterprises were then used for cluster and panel analysis. This procedure illustrates the principle that representativeness should not be confused with mechanical extrapolation. The purpose of the reference subsample is to test the diagnostic architecture, identify recurring profile configurations and establish empirically grounded hypotheses. Enterprises with structural breaks remain analytically important, but they require a new baseline instead of being forced into a historical comparison that no longer reflects the same economic system.

The empirical profile configuration confirmed the need for a non-compensatory approach. Four typological groups were identified. The financially strengthened group had a cluster-centre net margin of 5.98%, an autonomy ratio of 76.95%, asset turnover of 1.63 times and real revenue per employee of UAH 2.14 million. The growing group with more limited autonomy combined a 3.86% margin with 42.68% autonomy, turnover of 1.93 times and labour productivity of UAH 2.54 million. The crisis and loss-making profile showed a negative margin

of approximately -7.90% despite autonomy of 68.90%, while turnover was 1.24 times and revenue per employee UAH 1.34 million. The operationally intensive low-margin profile combined very high asset turnover of 4.97 times and labour productivity of UAH 11.62 million with a margin of only 0.05% and autonomy of 79.90%. These configurations demonstrate why a single integral index would be misleading: strong capital independence or high operational intensity cannot eliminate the managerial significance of persistent losses or an almost zero margin.

The typology also creates a direct bridge between diagnosis and differentiated managerial response. For financially strengthened enterprises, the principal task is not emergency stabilization but increasing the productivity and economic return of assets without creating new technological dependence. For growing enterprises with lower autonomy, expansion should be combined with control of leverage, liquidity and the pace of investment. For a crisis and loss-making enterprise, the priority is restoration of break-even through route economics, cost decomposition, customer and contract review, and stabilization of the operating cycle. For the operationally intensive low-margin profile, the key issue is conversion of high turnover and productivity into sustainable margin through detailed trip-level costing, fuel and maintenance analytics and control of unprofitable routes. The methodology therefore does not generate one universal recommendation; it identifies a management regime that corresponds to the diagnosed configuration.

The dynamic component of the empirical application adds an additional layer of evidence. A panel model of net margin was estimated on 40 observations representing ten enterprises over four annual periods after the lag structure was formed. The coefficient of the lagged net margin was 0.689 with $p < 0.001$, indicating statistically significant persistence of profitability. The annual revenue growth coefficient was -0.043 with $p = 0.219$, and the logarithm of revenue had a

coefficient of 0.407 with p = 0.506; neither effect was independently confirmed. The 2025 time effect was -4.642 with p = 0.040 relative to the 2022 base period. The model had R2 of 0.508 and adjusted R2 of 0.419. These results are not interpreted as a causal forecast, but they support an important diagnostic conclusion: deterioration in margin can become inertial, whereas revenue growth or enterprise scale alone does not guarantee improvement in resilience.

The same logic applies to high-tech transformation. Integration of TMS, telematics, electronic transport documents, data analytics and predictive maintenance can reduce empty mileage, fuel losses, documentary delays and unplanned downtime, but it can also create new vulnerabilities related to data quality, cyber incidents, incompatible systems, vendor lock-in and insufficient staff competence. The profile-matrix methodology records both sides of this effect. A technological project is treated as resilience-enhancing only if the baseline is documented, the expected mechanism is specified, the relevant KPI or KRI changes in the expected direction, and the benefit is not offset by unacceptable financial or operational risk. This requirement protects the diagnosis from a common methodological error in which digitalization is automatically treated as evidence of modernization and modernization is automatically treated as evidence of resilience.

For repeated use, the methodology should function as a closed diagnostic cycle. The initial profile establishes a baseline; threshold deviations identify the priority vulnerability; a targeted measure is selected; implementation is monitored through indicators; and the profile is recalculated after sufficient evidence has accumulated. If the measure does not produce the expected effect, scaling should be stopped or revised rather than justified by sunk costs. This creates a practical link between profile diagnostics and stop/go management logic. Over time, the enterprise accumulates its own verified threshold history, recovery trajectories and

response effectiveness, making subsequent diagnosis more precise and less dependent on external averages.

The proposed methodology has several advantages. It preserves causal traceability, avoids compensating critical weaknesses with unrelated strengths, makes data limitations explicit, and combines broad financial comparability with deeper technological interpretation. Its principal limitation is greater analytical complexity: profile maps, threshold matrices, provenance records and dynamic indicators require more data and more disciplined interpretation than a one-number ranking. This limitation is acceptable where the objective is managerial diagnosis rather than simplified public ranking.

Conclusions. The multi-contour profile-matrix methodology provides a coherent framework for diagnosing the economic resilience of freight road transport enterprises under high-tech transformation. Its scientific contribution lies in combining five autonomous profiles, verified data provenance, four threshold zones, dynamic resistance and recovery indicators, cluster typology and panel modelling within a non-compensatory architecture. The methodology does not seek to identify a universally “most resilient” enterprise. Instead, it reveals which specific financial, operational, technical, technological or recovery characteristics support or threaten the continuity of the transport function and how these weaknesses should be translated into differentiated managerial actions. Further empirical application should expand the panel of enterprises, deepen access to operational and technological data, and test the stability of thresholds and cluster profiles over time.

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