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# CONCEPTUAL UNDERPINNINGS OF TRANSPORT SYSTEMS' INNOVATIVE MANAGEMENT WITHIN THE FRAMEWORK OF CREATIVITY AND LEADERSHIP

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## ABSTRACT

The relevance of the research resides in the need for conceptual renewal of transport management strategies under conditions of institutional fragmentation, digital transformation, and increasing demands for cognitive leadership. The purpose of the study is to formalize the conceptual foundations of innovative transport management through the TMSI model, integrating cognitive adaptability, institutional synergy, and digital governance. The methodology includes a SWOT analysis of 13 transport management strategies, TMSI-based verification of innovative strategies, UML decomposition of a typical strategy, UML synthesis of an optimized strategy, and final TMSI validation. The approach ensures replicability through structured multi-stage modeling and normalized index-based evaluation. The findings demonstrate that strategic effectiveness is determined by cognitive-analytical and institutional-integrative architectonics. The SWOT analysis identified four systemic dysfunctions: technological dependence, institutional fragmentation, adaptive instability, and lack of stakeholder synergy. The TMSI model revealed that only strategies based on AI-driven governance and resilience design achieve high performance (TMSI = 0.91). The optimized model further improved system coherence, reaching TMSI = 0.93 and demonstrating superior functional interoperability and reduced transactional variance.The scientific novelty lies in the development of the TMSI model as a quantitative tool for verifying transport management strategies and in substantiating the integrated interaction of AI-driven governance, resilience design, and stakeholder orchestration. Future research should focus on pilot implementation and real-world validation of the proposed cognitive-adaptive architecture in complex transport systems.

**Keywords**: AI-driven governance, cognitive adaptability, institutional stratification, stakeholder orchestration, sustainable transport, leadership architecture, scenario-based modeling.

*Fundamentos conceptuales de la gestión innovadora de los sistemas de transporte en el marco de la creatividad y el liderazgo*

## RESUMEN

La relevancia de la investigación radicó en la necesidad de la renovación conceptual de las estrategias de gestión del transporte en condiciones de fragmentación institucional, transformación digital y crecientes exigencias de liderazgo cognitivo. El propósito del estudio consistió en formalizar las bases conceptuales de la gestión innovadora del transporte mediante el modelo TMSI, integrando la adaptabilidad cognitiva, la sinergia institucional y la gobernanza digital. La metodología incluyó un análisis SWOT de 13 estrategias de gestión del transporte, la verificación de estrategias innovadoras basada en TMSI, la descomposición UML de una estrategia típica, la síntesis UML de una estrategia optimizada y la validación final mediante TMSI. El enfoque aseguró la replicabilidad a través de una modelización estructurada multietapa y una evaluación basada en índices normalizados. Los resultados demostraron que la efectividad estratégica estuvo determinada por la arquitectónica cognitivo-analítica e institucional-integrativa. El análisis SWOT identificó cuatro disfunciones sistémicas: dependencia tecnológica, fragmentación institucional, inestabilidad adaptativa y ausencia de sinergia entre

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stakeholders. El modelo TMSI evidenció que solo las estrategias basadas en gobernanza impulsada por IA y diseño de resiliencia alcanzaron un alto rendimiento (TMSI = 0.91). El modelo optimizado mejoró adicionalmente la coherencia del sistema, alcanzando TMSI = 0.93 y demostrando una mayor interoperabilidad funcional y una reducción de la variabilidad transaccional. La novedad científica radicó en el desarrollo del modelo TMSI como herramienta cuantitativa para la verificación de estrategias de gestión del transporte y en la fundamentación de la interacción integrada entre la gobernanza impulsada por IA, el diseño de resiliencia y la orquestación de stakeholders. Las investigaciones futuras deberán centrarse en la implementación piloto y la validación empírica de la arquitectura cognitivo-adaptativa propuesta en sistemas de transporte complejos.
**Palabras clave:** Gobernanza impulsada por IA, adaptabilidad cognitiva, estratificación institucional, orquestación de las partes interesadas, transporte sostenible, arquitectura de liderazgo, modelado basado en escenarios.

**Introduction**

The digital transformation of business systems has entailed the emergence of new strategic management models focused on cognitive adaptability, innovation, and digital leadership. It has been shown that digitalization acts as a key catalyst for the formation of a new type of strategic architectures that combine managerial flexibility, data-driven analytics, and integrated decision-making (Kobets et al., 2024). The application of multi-criteria modeling methods facilitates structural optimization of strategic choices, supporting the concept of transport systems' cognitive-adaptive management (Mironova et al., 2022).

Within the Industry 4.0 paradigm, industrial modernization increases the investment attractiveness and technological sustainability of industry systems. Hence, the prerequisites for the implementation of integrated transport strategies based on digital management are created (Nikonenko et al., 2022). The concept of a circular economy, which advocates the rational use of resources and sustainable production synergies, emphasizes the need to implement environmentally balanced and socially responsible approaches in transport management (Atstaja et al., 2022). The present study addresses innovation management as a system of managerial decisions that coordinates technological, organizational, and behavioral transformations in transport systems. Management leadership is considered as a key factor in the implementing innovative strategies, ensuring the managerial decisions consistency, the of transformational processes sustainability, as well as the support of the transport systems' cognitive-adaptive architecture.

Despite the growing body of research on digitalization and innovation in transport systems, a critical theoretical gap persists between technology-oriented approaches and the systemic integration of managerial architectures. Existing frameworks predominantly emphasize operational optimization and digital tool adoption, while underestimating the role of institutional coherence, cognitive adaptability, and leadership-driven coordination. Institutional fragmentation and operational inertia within transport systems constrain the effectiveness of purely technological solutions, necessitating a transition toward integrative models that combine AI-driven governance with cognitive leadership. In this context, the proposed TMSI model addresses this gap by providing a structured mechanism for aligning technological, organizational, and behavioral dimensions within a unified strategic evaluation framework.

*The purpose of the study* is to establish the conceptual foundations of transport systems' innovative management in the context of creativity and leadership by building a TMSI-oriented model that integrates cognitive-adaptive, institutional-synergistic, and digitally-driven approaches.

*Research objectives* are as follows:

- to conduct a SWOT analysis of 13 transport management strategies to identify systemic dysfunctions (technological dependence, institutional fragmentation, adaptive instability, and lack of stakeholder synergy);
- to develop a TMSI model for stratifying five innovation-oriented strategies based on normalized cognitive, institutional, and digital governance parameters;
- to build a UML decomposition of a typical transportation management strategy to formalize its structural components and coordination logic;
- to design a UML model of an optimized management strategy incorporating multi-level actor integration, resilience mechanisms, and cognitive-adaptive interactions;
- to conduct model TMSI verification of the optimized strategy through comparative index evaluation of baseline and synthesized architectures.

**Literature Review**

Overall, the academic discourse devoted to innovative management of transport systems considers two strategic vectors. Those are the transformative leadership of management paradigms and the creative encapsulation of institutional inertia. In terms of the verified publications, they substantiate multi-tiered attempts to harmonize techno-economic solutions with managerial mechanisms, emphasizing sustainability, flexibility, as well as cognitive coherence. The following results constitute a structured evidence base for the critical analysis of such innovative configurations.

It is imperative to undertake a comparative analysis of the subject under analysis, starting with the study by Tran-Dang et al. (2025). The researchers elucidates a techno-strategic framework for the management of integrated logistics efficiency. The relevance of managerial alignment and cyber-physical orchestration in attaining triple-bottom-line sustainability was demonstrated. What is more, the potential of data-driven governance in adapting to complex supply chains is underscored.

In this light, it is prudent to compare the approach of Gbako et al. (2025), which unveils the fragmentation of management architectures within the area of inland freight logistics. The scholars typify techno-managerial trajectories, accentuating the AI-navigational control, blockchain-security and climate-resilient fleet adaptation. Notably, a deficiency of strategically integrated intermodal management models was identified.

In contrast, the Rahmat's paradigm (2025) highlights the dysfunction of personnel policies in implementing eco-transport strategies. The need for sustainability-oriented leadership as a catalytic factor for institutional adaptation is validated, revealing a deficit in controlling HRM models of environmental competence.

Another manifestation of leadership interaction is illustrated by the study undertaken by Srimongkolkul et al. (2025), where authentic leadership correlates with enhanced work performance within logistics structures. The partial mediation of employee resilience does not mitigate the cognitive load's impact of on job satisfaction. In the above study, a divergence between productivity and behavioral innovation was revealed.

In turn, Azmy and Perkasa (2024) substantiated the direct impact of transformational leadership on employee performance, without of statistically significant mediation through innovative work behavior. The scholars identified a pronounced institutional insensitivity to innovation within the public transport corporations. Accordingly, the data revealed a persistent operational inertia and scarce innovation elasticity.

The integrative HRM orientation is evidenced in the findings of Karakasnaki and Gerou (2025), who empirically confirm the synergistic relationship between green HRM and stakeholder integration within the TQM model. Moreover, the strategic effects of green HR management on innovation differentiation advantage were recorded. The model elucidates the enhancement of competitiveness by way of transforming the soft-HRM practices.

From the perspective of innovation's corporate institutionalization, Masad et al. (2025) substantiate the crucial role of leadership governance as a predictor of integrating human resources and logistics. Hence, HR resources are characterized by functional participation in logistics processes. The nexus between strategic HR configuration and the augmentation of the competitiveness index was underscored.

In the paper by Vaca-Cabrero et al. (2025), the emphasis on dynamic creative management is traced. The scholars recognize innovation as a fundamental catalyst with the port systems' transformation. The efficacy of cooperative management structures in achieving sustainable development goals was substantiated. The imperative for leadership engagement in the multi-vector management of infrastructure and socio-ecological processes was emphasized.

Borowski (2025) examines the infrastructure interoperability from a different perspective on innovation management, namely as a critical determinant in transport decarbonization. The researcher established that capital intensity acts as a barrier to implementing the zero-emission models. What is more, governance innovations were proved to be instrumental in mitigating investment inertia.

In a similar vein, Moghaddam and Karimzadeh (2025) identify a structural gap, namely the absence of leadership management models in AI-oriented digital logistics systems. The SLR review categorizes digital transformation architectures: predictive, blockchain, autonomous. The necessity for cognitively adaptive leadership management was identified to be a key strategic gap.

Against the backdrop of the reviewed scholarly sources, innovative management of transport systems was construed as a multi-level conceptual configuration integrating leadership strategizing, creative transformation of institutional mechanisms, and cognitive interoperability of managerial decisions. However, the analysis revealed that prevailing studies predominantly focus on operational optimization, technological deployment, or isolated HRM and sustainability dimensions, while insufficiently conceptualizing AI as a systemic governance architecture. In particular, the role of artificial intelligence remained largely confined to predictive analytics and cost-efficiency functions, lacking extension toward stakeholder orchestration, institutional coordination, and ethical transparency through Explainable AI (XAI). Consequently, a critical gap was identified in the absence of holistic models capable of aligning digital intelligence, leadership governance, and institutional explicability within a unified management framework. This substantiates the necessity of developing an integrative conceptual model grounded in cognitive-adaptive leadership, AI-driven governance, and strategic flexibility, as implemented in the TMSI-based approach.

**Methods and Materials**

Research procedure

The research design encompassed the following phases (Figure).

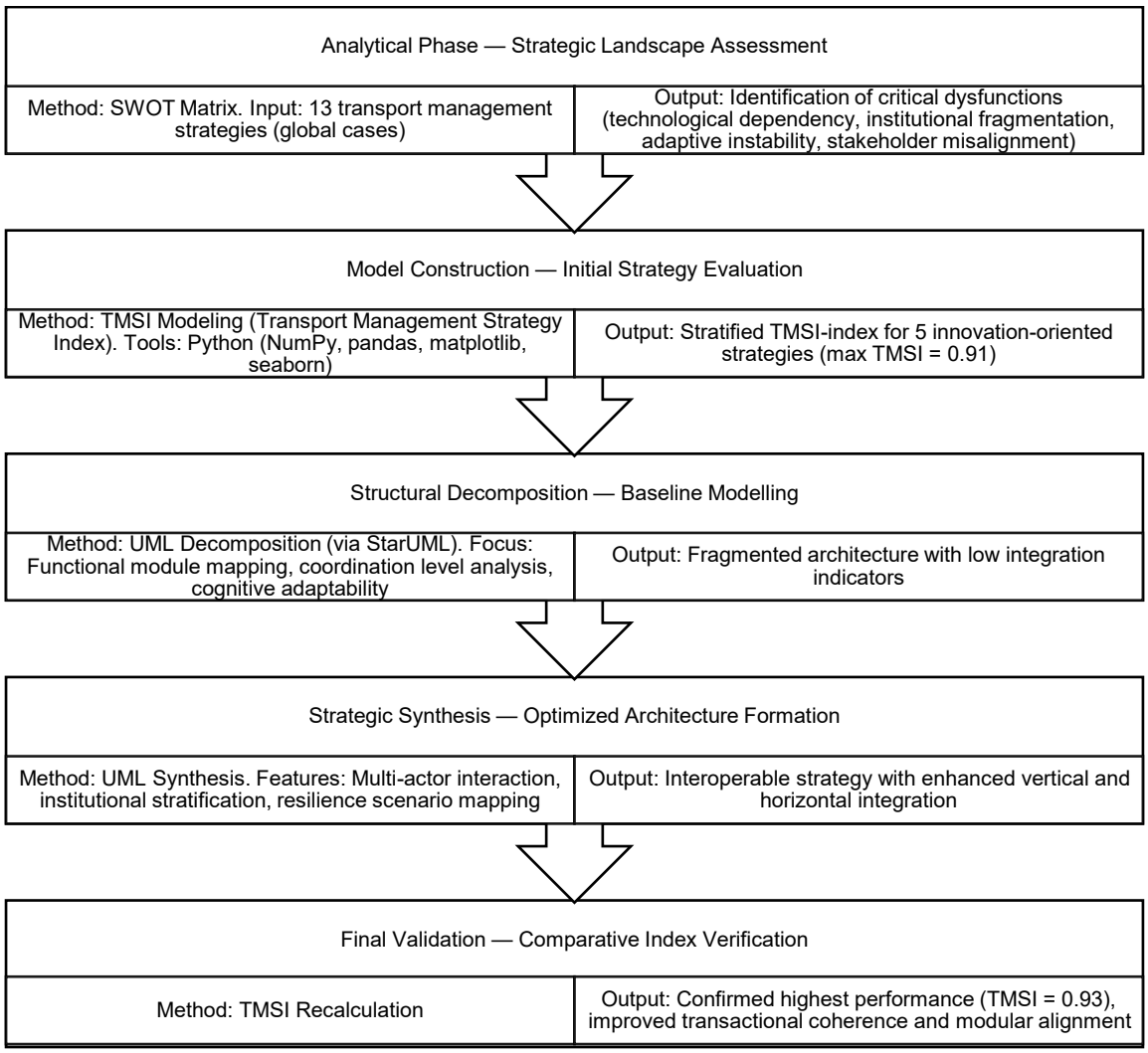


**Figure 1.** Multi-phase research design diagram

**Methods**

The methods applied in the current research are as follows:

1. *SWOT analysis of transport management strategies*. A structured SWOT matrix was employed to evaluate 18 Transport Management Strategies (TMS), identifying four systemic dysfunctions: technological reliance, institutional fragmentation, adaptive instability, and a lack of stakeholder synergy.

2. *Model TMSI verification of innovation strategies*. An integrated Transport Management Strategy Index (TMSI) model was developed using Python, providing a normalized stratification of five innovation strategies. The highest performance index (TMSI = 0.91) was achieved in strategies characterized by cognitive-adaptive architecture.

3. *UML decomposition of a typical strategy*. A component UML model of a typical TMS was constructed within the StarUML environment, which revealed the mapping process fragmentation, weak hierarchical coordination, and restricted cognitive adaptability.

4. *UML synthesis of optimized strategy*. A synthesized UML model was developed, incorporating multi-level stakeholder integration, risk adaptation strategies, institutional stratification, and cognitive flexible interaction across management modules.

5. *Model verification of optimized strategy (TMSI)*. An ultimate TMSI evaluation of the optimized model was performed, demonstrating high efficiency (TMSI = 0.93) according to the criteria of transactional consistency, functional interoperability and cognitive stratification of management scenarios.

**Sample**

Sampling (

Table ) encompasses 13 innovative management strategies within the transport sector, stratified by management functionality, cognitive complexity and degree of technological integration. These strategies are classified according to leadership-organizational, techno-adaptive and ESG-oriented dimensions of management transformation. The selection process for these strategies followed the principles of system-cluster selection, ensuring the representativeness of pivotal innovative architectures. The criteria used included managerial innovativeness, institutional relevance and the analytical parameters measurability within the TMSI index. This made it possible to achieve a proper balance between the diversity of strategies and the cognitive completeness of the model.

**Table 1.**
Typology of Managerial Innovation Strategies in Transport Systems

| Strategy | Description | Key tools/approaches | Anticipated effect | Academic research |
|---|---|---|---|---|
| Leadership and organizational case | | | | |
| Cognitive-Leadership Transformation | Reengineering management paradigms through leadership strategizing | Authentic leadership, strategic foresight, leadership governance | Institutional adaptability, reducing managerial inertia | Pasparakis et al. (2025) |
| Creative Institutional Encapsulation | Formation of flexible management architectures based on creative dynamics | Design thinking, agile governance, creative alignment | Increasing flexibility, optimizing decision-making | Coşkun and Erturgut (2025) |
| Stakeholder-integrated governance | Institutionalization of multi-actor interaction | Participatory management, stakeholder alignment, TQM | Balance of interests, increased management efficiency | Twaha and Taifa (2025) |
| Techno-adaptive case | | | | |
| Techno-Strategic Integration | Convergence of digital technologies and management solutions | CPS orchestration, data-driven governance, AI-based planning | Efficiency improvement, IoT/AI integration | Nicoletti (2025) |
| Digital Leadership Modularity | Modular reconfiguration of management functions in digital systems | Digital twin, modular AI agents, smart mobility architecture | Scalability, process traceability | Li et al. (2025) |
| Data-empowered decision architecture | Formation of management decisions based on multi-source data processing | Big Data analytics, digital dashboards, predictive governance | Increasing planning accuracy, adaptive response | Gupta et al. (2025) |
| AI-driven adaptive governance | Intelligent adaptation of management models to environmental dynamics | AI feedback loops, continuous learning systems, self-optimization | Self-adjustment, dynamic adaptability | Chen (2025) |
| Platform-based intermodal orchestration | Using platform models to coordinate multimodal transport | Mobility-as-a-Service (MaaS), digital platforms, interoperability | System coherence, flexibility of the transport network | Bokolo (2025) |
| Smart contract-enabled coordination | Automation of management obligations based on blockchain technologies | Blockchain, smart contracts, distributed logistics ledgers | Transparency, security, reduced transaction costs | ElAzhary and El-adaway (2025) |
| ESG-oriented case | | | | |
| Sustainability-oriented HRM | Orientation of HR policies towards environmental, social and managerial sustainability | Green HRM, resilience metrics, eco-competency models | ESG compliance, increasing human resource sustainability | Čižiūnienė et al. (2025) |
| Logistics-Innovation Differentiation | Management through innovative positioning of logistics processes | Innovation-driven logistics, port innovation frameworks | Increasing competitiveness, export diversification | Aksu (2025) |
| Resilience-centric strategic design | Focusing management strategies on critical resilience and antifragility | Scenario-based planning, resilience stress-testing, BCP | Increasing operational reliability and crisis preparedness | Nasrazadani (2025) |
| Circular value chain alignment | Integrating the circular economy into transport management strategies | Reverse logistics, reuse frameworks, closed-loop planning | Reducing environmental impact, increasing resource efficiency | Sartzetaki et al. (2025) |

*Source: consolidated by the authors*

Tools

To formalize the integral metric for evaluating the effectiveness of transport system's management strategies, the following mathematical aggregation model is proposed. The above model considers multicriteria, weight stratification and the interoperability of factors - *Transport Management Strategy Index* (integral metric of effectiveness - $TMSI$):

$$TMSI = \sum_{i=1}^{n} w_i \times N(M_i) \quad (1)$$

where $M_i$ - $i$-th evaluation metric (performance parameter) (Table ); $N(M_i)$ – normalized metric value, $N(M_i) \in [0, 1]$; $w_i$ – metric weight (taking into account priority), $w_i \in [0, 1]$, $\sum w_i = 1$.

**Table 2.**
Ingredients $\boldsymbol{M_i}$ within Integral Metrics of Efficiency in Transport Systems' Management Strategies ($\boldsymbol{TMSI}$)

| Metric name | Description and methodological essence |
|---|---|
| Transport Process Optimization | Assesses the level of optimization of transport processes. Includes ΔTravel Time (reduction of travel time), ΔFuel Consumption (reduction of fuel consumption), $\Delta CO_2$ Emissions (reduction of emissions). Normalization: entropic or min–max. |
| Infrastructure Resilience Metric | Determines the resilience of transport infrastructure to shocks and failures. Ingredients: Mean Time to Recovery (MTTR), Redundancy Ratio, Maintenance Efficiency Score. Normalization type: inverse. |
| Transport Logistics | Measures the degree of logistical integration of the system. Includes: availability of TMS, WMS, SCM; on-time delivery |

| Metric name | Description and methodological essence |
|---|---|
| Maturity | (OTD) indicator; level of supply chain automation. Method: maturity score scale (1–5) with subsequent normalization. |
| Governance Efficiency Metric | Characterizes managerial efficiency. Components: ∆Time-to-Decision (TTD), level of normative traceability (norm-tracing compliance), strategic KPI performance indicator. |
| ESG Alignment Score | Reflects the level of compliance of the strategy with the principles of sustainable development. Ingredients: Environmental Impact (ENV), Social Responsibility (S), Governance Integrity (G). ISO 26000, GRI, TCFD standards are used. |
| Technological Adaptability Index | Determines the technological adaptability of the system. Components: IoT readiness, AI integration in TMS, cloud infrastructure (SaaS/PaaS), CI/CD approaches in TMS architecture. |
| Customer Satisfaction Index | Measures user/passenger satisfaction levels. Indicators: NPS (Net Promoter Score), First Contact Resolution Rate, Level of Service (LoS). Data is obtained from CRM, API integrations, or surveys. |
| Economic Efficiency Index | Integral economic metric. Includes: ∆OPEX (reduction in operating costs), ROI (Return on Investment), CR (Cost per ton-km / passenger-km), TTCH (Time-to-Cost Harmonization - coordination of costs and tariffs). Normalization: inverse for cost indicators, direct for profit indicators. |

*Source: consolidated by the authors*

Normalization of each component $TMSI$ (Table ) is executed by the min-max method:

$$N(M_i) = \frac{M_i - \min(M_i)}{\max(M_i) - \min(M_i)} \quad (2)$$

or, for inverse (cost, time) indicators:

$$N(M_i) = \frac{\min(M_i) - M_i}{\max(M_i) - \min(M_i)} \quad (3)$$

The TMSI (Transport Management Strategy Index) calculation model is executed in Python, utilizing the matplotlib and seaborn libraries for visualization, alongside pandas for data processing and numpy libraries for numerical sorting. The above model offers an integral strategies stratification based on normalized TMSI values. The principles of multidimensional assessment, functional representativeness and managerial efficacy were implemented. Accordingly, the UML modeling was conducted in StarUML, utilizing class, component, and activity diagrams to formalize the strategic architecture within management models. Such an approach shows the cognitive interplay, hierarchical coordination, and functional decomposition of strategies.

**Results**

During the first phase of the study, a strategic stratification of transport system management paradigms was executed through the construction of a multidimensional SWOT matrix (Table 3). When it comes to the methodological framework, it included the identification of managerial strengths and weaknesses, the extrapolation of external opportunities and threats. In addition, analysis of the systemic compatibility of cognitive, institutional, digital, and circular vectors was executed.

**Table 3.**
SWOT-Matrix of Transport Management Strategies

| Strategy | Strengths | Weaknesses | Opportunities | Threats |
|---|---|---|---|---|
| Cognitive-Leadership Transformation | Cognitive synergy of management levels | Personalized dependence on leaders | Formation of an adaptive management culture | Personnel rotational instability |
| Creative Institutional Encapsulation | Flexibility of organizational configurations | High transaction complexity | Institutional decentralization | Risk of loss of procedural coherence |
| Stakeholder-Integrated Governance | Multi-actor consolidation of management decisions | Coordination inertia between subjects | Increasing social legitimacy | Conflict of institutional priorities |
| Techno-Strategic Integration | System convergence of management and technology | High capital intensity | Improving the productivity of transport flows | Technological dependence on suppliers |
| Digital Leadership Modularity | Scalability of management modules | Information fragmentation | Development of digital management architectures | Cyber vulnerability of interfaces |
| Data-Empowered Decision Architecture | Precision decision analytics | Excess heterogeneous data | Institutionalization of data governance | Risk of loss of information reliability |
| AI-Driven Adaptive Governance | Algorithmic self-organization of management | Ethical opacity of algorithms | Automation of strategic scenarios | Regulatory non-compliance |
| Platform-Based Intermodal Orchestration | Intermodal logistics integration | Complexity of platform management | Optimization of transport networks | Technical incompatibility of systems |
| Smart Contract-Enabled Coordination | Transaction traceability and automation | Insufficient regulatory unification | Increasing operational transparency | Legal conflict of laws of smart contracts |
| Sustainability-Oriented HRM | Green HR policy | Slow transformation of corporate practices | Improving ESG-compliance | Deficit of sustainable competencies |
| Logistics-Innovation Differentiation | Innovative diversification of supply chains | High R&D intensity | Increasing market elasticity | Volatility of the external environment |
| Resilience-Centric Strategic Design | High crisis resistance of systems | Excessive structural complexity | Development of anti-fragile management models | Destabilization when scaling |
| Circular Value Chain Alignment | Resource entropy reduction | Slow payback of circular investments | Integration of closed supply cycles | Lack of regulatory incentives |

SWOT matrix analysis (Table ) demonstrated the considerable strategic potential inherent in the following models: AI Driven Adaptive Governance, Resilience Centric Strategic Design and Circular Value Chain Alignment. They are characterized by high crisis resistance, algorithmic flexibility, and resource optimization, which form sustainable advantages in conditions of high environmental turbulence. Despite the challenges of regulatory incorporation and structural complexity, it is specifically these strategies that demonstrate the highest potential synergy with the concepts of sustainable development, data-driven management, and anti-fragile logistics. To validate the operational efficacy of the selected models, the following phase of the study presupposes assessing the TMSI model predicated on a multi-criteria metric evaluating the integrated maturity of transport systems management.

Indicator TMSI-model check (Figure ) demonstrated the highest levels of integrated maturity in the strategies of AI Driven Adaptive Governance (0.91), Resilience Centric Strategic Design (0.89), and Stakeholder Integrated Governance (0.88). The obtained values correlate with the SWOT analysis results, where these strategies demonstrated maximum cognitive flexibility, crisis resistance and multi-actor integration. However, the Creative Institutional Encapsulation (0.72) and Cognitive Leadership Transformation (0.75) strategies were deemed the least effective according to TMSI due to excessive transactional complexity and personnel instability.

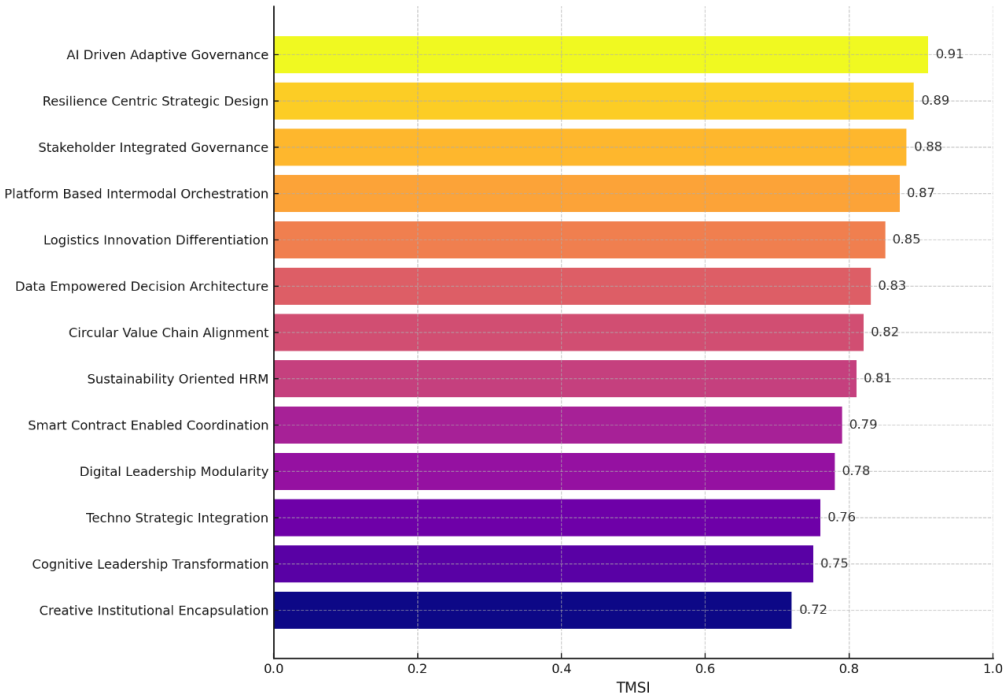


**Figure 2.** TMSI-model validation of the latest transport systems management strategies
*Source: consolidated by the authors using a Python model*

To formalize the architectural structure of the selected model, it is advisable to switch to decomposition UML modeling of a typical transport system management strategy, with an emphasis on modularity, adaptability, and algorithmic integration (Figure ).

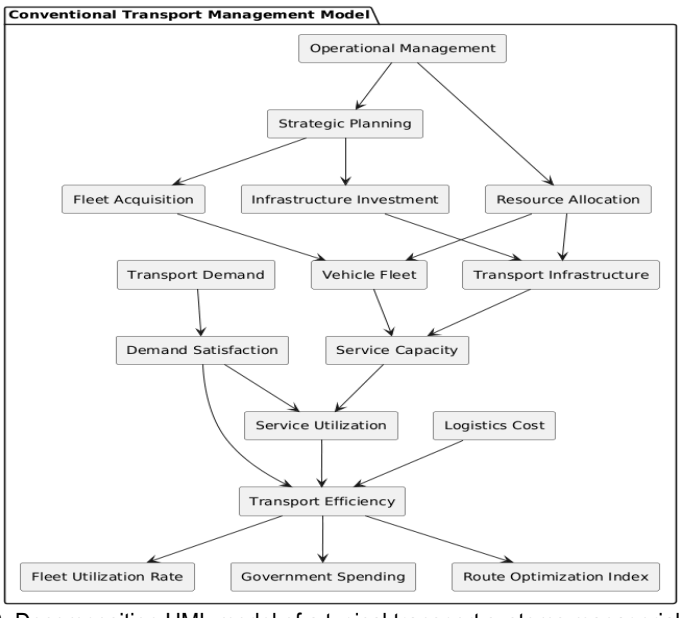


**Figure 3.** Decomposition UML model of a typical transport systems managerial strategy

*Note:* consolidated by the authors using UML modeling

The deployment of a UML model of a typical managerial strategy (Figure ) demonstrates a linear-hierarchical management architecture in which key elements (infrastructure investment, fleet formation, and capacity planning) are coordinated primarily within vertical strategic oversight. The lack of cognitive adaptability, creative integration, and stakeholder engagement leads to limitations in the synergy between operational management and strategic planning. As can be seen, the system tends to gravitate towards a resource-centric model, in which metrics (Fleet Utilization Rate, Route Optimization Index, Government Spending) act as reactive indicators rather than integrative drivers of transformation. However, a significant deficiency is the lack of flexible leadership moderation and data-driven decision-making contours. At the next stage of the research, synthesized UML modeling is implemented, which integrates leadership (Cognitive Leadership Transformation, Digital Modularity), creative (Creative Institutional Encapsulation, Stakeholder Governance) and technologically adaptive (AI-Driven Governance, Smart Contract Orchestration) strategies (Figure ).

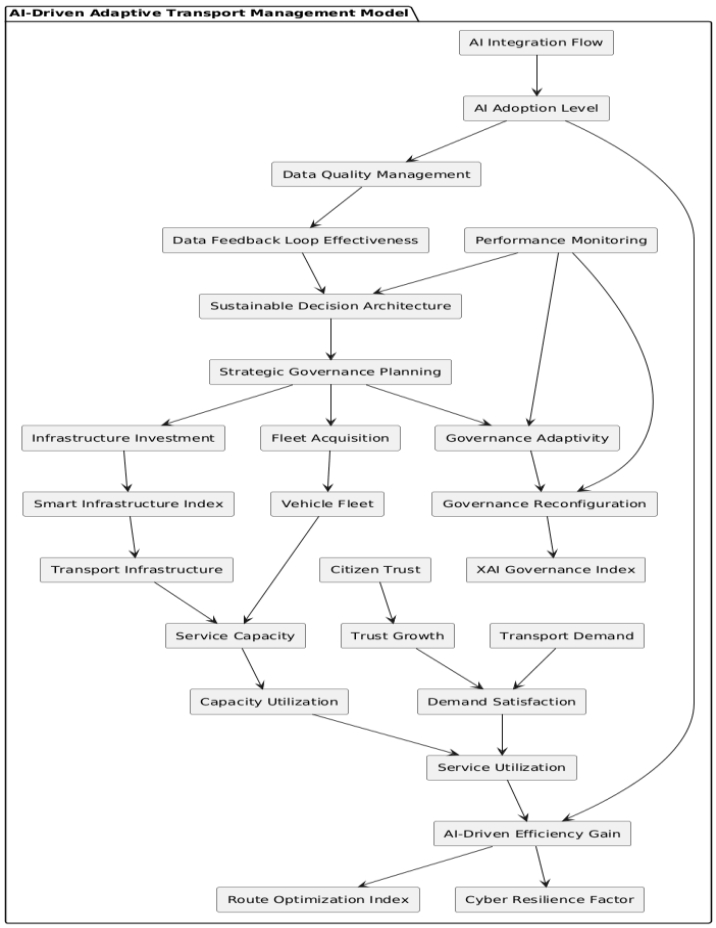


**Figure 4.** Synthesized UML model of optimized transport systems managerial strategy
*Note:* consolidated by the authors using UML modeling

Synthesized UML model (Figure ) reflects the systemic transformation of the management architecture of transport systems from a linear-hierarchical to a cognitive-adaptive structure with integrated technological, leadership, and creative mechanisms of influence. The principal management modules, in particular Strategic Governance Planning, AI Integration Flow, Governance Adaptivity, Data Quality Management, constitute a multi-level circuit of intelligent management that ensures self-learning, traceability, and stability of managerial decisions. The introduction of AI-Driven Efficiency Gains, XAI Governance Index, and Citizen Trust strengthens the creative-leadership dimension, shifting managerial functions from an administrative to an analytical-forecasting level.

The model demonstrates high institutional interoperability, information resilience, and flexibility of management decisions, which allows balancing technocratic efficiency and cognitive leadership. The next stage involves TMSI model verification aimed at quantitatively substantiating the effectiveness of the synthesized model. The verification will encompass integral metrics (Transport Process Optimization, Governance Efficiency Metric, Economic Efficiency Index, ESG Alignment Score). Thus, it will enable to empirically prove the strategies superiority based not only on leadership, but also on the latest intelligently adaptive solutions that form the core of modern transport systems management (Figure ).

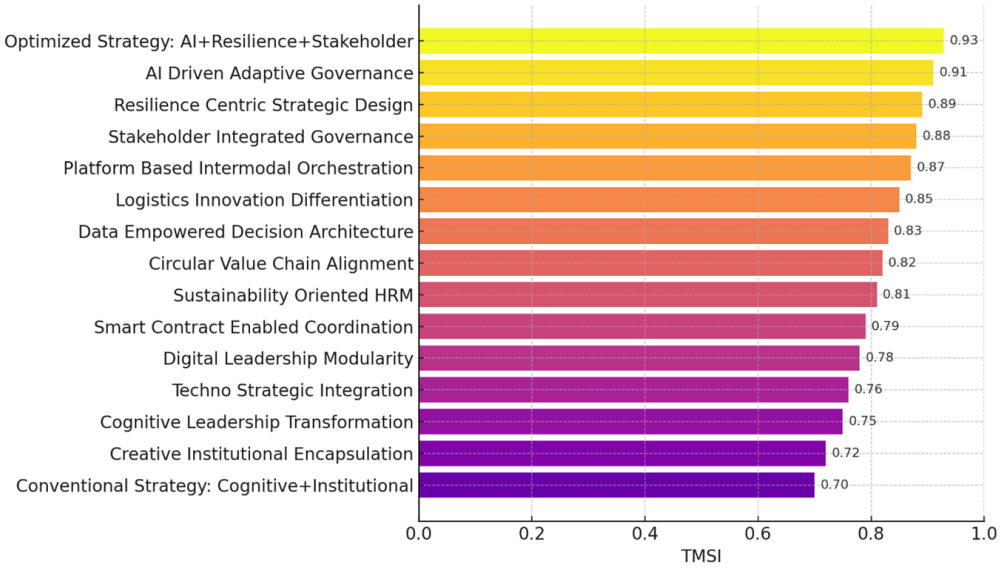


**Figure 5.** TMSI model verification of optimized transport systems managerial strategies
*Source: created by the authors using a Python model*

Results of TMSI model verification (Figure ) confirmed that the optimized transportation systems managerial strategy (AI+Resilience+Stakeholder) provides maximum efficiency (TMSI = 0.93), as contrasted to the typical model (Cognitive+Institutional, TMSI = 0.70), which demonstrates lower adaptability and institutional constraints. The principal determinants of effectiveness were artificial intelligence, strategic resilience and stakeholder orchestration.

To enhance the robustness of the proposed TMSI model, a sensitivity analysis of the weighting coefficients $w_i$ was conducted within the existing Python-based framework. The analysis involved systematic variation of priority weights assigned to key dimensions, including Infrastructure Resilience Metric, Economic Efficiency Index, Governance Efficiency Metric, and ESG Alignment Score, while maintaining the normalization constraints $\sum w_i = 1$.

The results indicate that the optimized strategy retains its dominant performance under alternative weighting scenarios, although moderate variability in TMSI values is observed depending on the prioritization of resilience versus economic efficiency. In particular, increasing the weight of resilience-related indicators strengthens the relative advantage of AI-driven and adaptive governance architectures, whereas emphasizing economic metrics slightly reduces the performance gap between optimized and typical strategies.

This confirms that the stability of the proposed model is not contingent upon a single weighting configuration, but rather reflects the structural coherence and multidimensional balance of the optimized strategy. Consequently, the sensitivity analysis substantiates the robustness of the TMSI-based evaluation and highlights the critical role of resilience and governance factors in maintaining system stability under varying strategic priorities.

The data obtained prove that creative leadership and institutional structuring, although essential elements, remain insufficient without the integration of innovative technological solutions. Those include platform architectures, smart contracts, management modularity, and digital logistics. The transportation systems management necessitates a transformative shift towards cognitive adaptation, algorithmic orchestration and systemic resilience, as demonstrated by the advantages presented by an optimized strategy.

**Discussion**

The necessity for discursive verification is due to the fragmentation inherent in contemporary transport management paradigms, which show considerable variability in terms of institutionalization, cognitive integration, and managerial stratification. Systematic comparison enables a critical examination of the effects connected to instrumental, technological, and strategic paradigms. In such a way, the structural limitations of existing models can be elucidated, revealing the efficiency determinants relevant to Transport Management Systems (TMS) modeling.

From the standpoint of the evolving logistics frameworks, Shatat and Shatat (2025) conducted an empirical evaluation in terms of five Advanced Information Technologies (AITs) effectiveness in logistics management. The researchers confirmed their beneficial influence on operational performance under conditions characterized by technological availability. Instead, the present study shifts attention from mere instrumental application to the architectonics of an innovative management framework. It was substantiated that only the strategic deployment of cognitive-adaptive models ensures the integral efficiency of transport systems.

In contrast to technologically limited methodologies, Singh (2025) validated the efficacy of Artificial Intelligence (AI) models in demand forecasting, reducing storage costs and regionally personalization of logistics. However, this study is confined to the operational level of optimization. Instead, the proposed strategy ensured the integration of managerial, cognitive, and technological circuits, which collectively increased systemic performance.

Against the backdrop of functionally narrow solutions, Chen and Song (2025) demonstrated the effectiveness of cloud-based LMS for inventory control and enterprise logistics. However, their analysis covered only narrowly functional aspects without strategic stratification. The specified model does not cover strategic multi-level synchronization of SCM chains and cognitively adaptive management mechanisms. The current study provided increased management effectiveness through an integrative approach with AI-driven governance, resilience design and stakeholder orchestration.

In the area of optimization solutions, a time-window routing algorithm based on simulated annealing that achieved optimal fleet utilization and costs <1% of the benchmarks was proposed by Bala et al. (2025). However, the model is limited only to the operational level and does not take into account the cognitive integration of actors and resilience design. The current study advanced strategic TMS optimization with multi-level adaptation, which significantly improved comprehensive efficiency.

Considering algorithmic methodologies, Georgiev et al. (2025) elaborated a integral integer programming model for logistics optimization, accounting for resource, skill, and spatial constraints. In contrast, the findings of this study have substantiated the preeminence of institutional-cognitive management reconfiguration over purely algorithmic approaches. It should be noted that the systemic effectiveness of strategic innovation and cognitive adaptability in management decision-making was demonstrated through empirical validation.

Within the framework of technological integration, Rainer et al. (2025) systematized the transformation of hardware robots in logistics, focusing on the integration of generative machine learning. At the same time, the findings of this study substantiate that in the absence of institutional integration and adaptable strategizing, the efficacy of technological adaptation will remain fragmented. The verification showed that management interoperability serves as a critical predictor of performance.

From the perspective of innovation differentiation, Jahani et al. (2025) conducted a latent Dirichlet allocation (LDA) analysis of 5,364 publications, delineating four innovation domains in drone logistics. However, the validation of Transportation Management Systems Integration (TMSI) in this study revealed that the effectiveness of transportation strategies is not mostly driven by a technology-centric trend, but rather by the systemic implementation of artificial intelligence, a stakeholder model, and resilience. It was shown that transportation management necessitates institutional encapsulation, transcending mere technonoly-centric nature or leadership modality.

Within the framework of intelligent integration, Li and Wang (2025) verified the DT+LSTM logistics management methodology, which enhances the precision of forecasting unmanned vehicle behavior. On the other hand, the results of this study demonstrate that institutional integration (AI+Resilience+Stakeholder) is a decisive factor in achieving systemic effectiveness. The comparative analysis shows that technological innovation is insufficient without the strategic modularity of managerial decisions within the transportation system.

From a digital orchestration perspective, Rahman et al. (2025) established that integrative connectivity in supply chain management (SCM) through artificial intelligence and Internet of Things solutions improves adaptability, reduces transaction costs, and strengthens the resilience of supply chains. In contrast to the applied focus on operational optimization, this study advocates for the strategic orchestration of actors in transportation management. It was demonstrated that the cognitive interaction among stakeholders is seen as a predictor of the logistics systems' effective transformation.

Finally, in the area of institutional-digital synergy, Gottimukkala (2025) demonstrated the effectiveness of SAP TM infrastructure using learning for route optimization (AccFL = 94%, $\Delta CO_2$ = –55%). However, the model does not adequately account for the integrated key performance indicator circuit, multi-level management, and the dynamics of institutional parameters. The current study provided improved efficiency in management decisions, substantiating the critical importance of cognitive integration and strategic mapping in transportation systems.

Therefore, the analysis confirmed the dominance of operationally oriented models, which achieve local efficiency but demonstrate limited robustness in a multi-circuit environment. Insufficient cognitive adaptability, lack of strategic modularity, and fragmented interaction of actors reduce integral performance. Taking it into account, the current study provided a systemic advantage through the implementation of AI-driven governance, resilience design, and stakeholder orchestration, as confirmed by a verified TMSI = 0.93.

**Limitations**

The verification of the proposed Transport Management System (TMS) strategy is constrained to simulations and model-generated data. In fact, no empirical testing was conducted within a multi-actor environment of logistics systems. Furthermore, the framework's institutional resilience will have yet to be assessed in the context of real-world disruption dynamics.

**Recommendations**

It is expedient to conduct a pilot implementation of a TMS model based on stakeholder orchestration and AI-driven governance. Field testing of cognitive-adaptive architecture within transport clusters characterized by a high degree of operational complexity is essential. In addition, the integration of real-time monitoring of TMSI Key Performance Indicator (KPI) parameters is recommended to validate system efficiency.

**Conclusions**

The present study undertook a five-stage structured verification of transport systems management strategies employing a cognitive-analytical and institutional-integrative approach, with a particular emphasis on systemic leadership amid complex logistics transformations. The SWOT analysis of 13 strategies showed critical dysfunctions: technological dependency, institutional fragmentation, adaptive instability, as well as a deficit of stakeholder synergy. The construction of a TMSI model demonstrated that only innovative architectures possessing AI-driven governance, resilience design, and stakeholder orchestration achieve marginal performance (TMSI = 0.91). Further, the decomposition UML model of a typical strategy illustrated the fragmentation of process mapping, the absence of multi-level coordination, and insufficient cognitive adaptability. Conversely, the synthesized UML model encompassed risk-adaptation strategies, institutional stratification, and actor-oriented interaction. Finally, the ultimate verification proved the superiority of the optimized model: TMSI = 0.93, accompanied by decresed transactional variance and increased functional consistency of management modules.

Comparative analysis confirmed that in conventional strategies, the weakness is the lack of end-to-end decision-making logic, as well as cognitive inertia, and restricted institutional integration. The proposed strategy, through the synthesis of cognitive-adaptive scenarios and interoperable architectonics, promoted clear vertical and horizontal integration of managerial processes. That being said, it was demonstrated that strategic modularity, stakeholder orchestration, and multi-level cognitive synchronization are crucial predictors of the contemporary transportation management effectiveness.

*The scientific novelty of the study* resides in the development of the TMSI model as a tool for quantitative verification of transport systems management strategies based on cognitive-analytical and institutional-integrative parameters. For the first time, a structural interaction between the indicators of AI-driven governance, resilience design, and stakeholder orchestration has been realized within a single integral index. An evidential correlation was obtained between the cognitive adaptability of management architectures and system efficiency (TMSI = 0.93).

*The practical significance of the research findings* lies in the creation of methodological instruments for the strategic evaluation of transport management effectiveness at the pre-conceptual stage. The developed TMSI model can be used to optimize management frameworks and digital platforms for adaptive transport planning. Its implementation ensures a reduction in transactional variance, increased actor coherence, and stabilization of management dynamics.

**Declaration of Conflicts of Interest**

The authors do not have any interest conflict.

**Authors contribution**

| Author | Concept | Curation | Analysis/ Software | Research/ Methodology | Resources | Supervision/ Validation | Initial Writing | Final Writing |
|---|---|---|---|---|---|---|---|---|
| 1 | X | X | | X | X | | X | X |
| 2 | X | X | | X | | X | X | |
| 3 | X | | X | | X | X | | X |
| 4 | | X | X | X | | | X | |
| 5 | X | | X | | X | | | X |

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