International Journal of Innovative Research and Scientific Studies, 8(6) 2025, pages: 2241-2251

IJIRSS
International Journal of Innovative Research & Scientific Studies

ISSN: 2617-6548

URL: www.ijirss.com

Bridging the gap between intelligent transportation systems development and state decision-making

Justina Hudenko[1*], Liga Millere-Kruma[2], Inguna Jurgelane-Kaldava[3]

[1,2,3]*Governance and Security Institute, Riga Technical University, Riga, Latvia.*

Corresponding author: Justina Hudenko (*Email: justina.hudenko@gmail.com*)

Abstract

This study addresses the ongoing disconnect between the rapid advancement of Intelligent Transportation Systems (ITS) and their limited integration into transport policy and decision-making in Latvia. Despite global ITS progress, adoption at national levels remains inconsistent, often due to structural, institutional, and educational barriers. A mixed-methods approach was used, comprising (1) a systematic literature review of 57 open-access sources to identify global ITS trends, (2) a comparative case study of Latvia's ITS ecosystem against European and international best practices, and (3) participatory action research with public authorities, industry associations, and academic institutions to co-develop practical insights. Findings informed the redesign of the International Transport Management course at Riga Technical University (RTU), addressing gaps that limit ITS adoption in governance. In the next phase, the revised curriculum was piloted alongside stakeholder interviews, and a data-driven Transport Intervention Modelling (TIM) system was developed on RTU's High-Performance Computing platform. The TIM system supports both education and ITS development for policy and industry. The study concludes that aligning ITS with governance requires both technical and institutional coordination. Education reform, when embedded in a multi-stakeholder environment, can bridge the gap between innovation and policy. The framework and interventions piloted in Latvia offer a scalable model for integrating ITS into strategic transport governance elsewhere.

Keywords: Decision-Making in Transport, Digitalisation in Transport Education, Intelligent Transportation Systems (ITS).

DOI: 10.53894/ijirss.v8i6.10101
Funding: The development of the curriculum and the Transport Intervention Modelling (TIM) system was financially supported by the project “Highly Specialized Digital Skills in High-Performance Computing” (Grant Number: Nr. 2.3.1.1.i.0/1/22/I/CFLA/003), funded under the EU Structural Funds.
History: Received: 3 July 2025 / **Revised:** 8 August 2025 / **Accepted:** 11 August 2025 / **Published:** 19 September 2025

Competing Interests: The authors declares no conflict of interest. This study was conducted in accordance with the ethical standards of Riga Technical University.
Authors’ Contributions: All authors contributed equally to the conception and design of the study. All authors have read and agreed to the published version of the manuscript.
Transparency: The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.
Institutional Review Board Statement: The data supporting the findings of this study are available from the corresponding author upon reasonable request. Survey data and analysis outputs have been anonymised in accordance with ethical research standards and institutional policies.
Publisher: Innovative Research Publishing

1. Introduction

The transportation sector is experiencing a significant transformation driven by technological advancements, sustainability goals, and the need for improved efficiency. The integration of ITS with technologies such as connected vehicles, cloud computing, and the Internet of Things (IoT) has been crucial for optimising traffic flow and infrastructure planning, emerging as a key focus over the past decade. These technologies aim to address issues such as traffic congestion, high fuel prices, and CO_2 emissions, thereby improving road safety and efficiency. However, the sector faces challenges in system modelling, data integration, and collaboration across institutions, industries, and international partners [1].

ITS is becoming more popular to address decision-making problems, but it requires overcoming computational complexity and ensuring high reliability in large networks [2]. The digital transformation in the transport sector is hindered by a lack of standards and cooperation among stakeholders, which affects data availability and integration with real-world operations. Many case studies, including those in Latvia, demonstrated the importance of institutional, sectoral, and international collaboration in developing multimodal ITS for optimising energy use and guiding efficient investments [3-6]. However, existing research rarely addresses the institutional and educational barriers that limit ITS adoption in national policy-making, particularly in smaller or transitioning economies such as Latvia.

This study investigates these underexplored gaps and proposes solutions through the development of a cohesive ecosystem that connects public authorities, industry stakeholders, and academia, with the education system as a foundational platform. Specifically, this study aims to (1) identify institutional barriers to ITS adoption, (2) design educational strategies to strengthen ITS governance, and (3) enhance academic–industry collaboration in Latvia. We hypothesised that establishing and teaching a unified standard for data collection, processing, and exchange will enhance ITS integration and improve decision-making processes.

This study is guided by the following research questions:

1. What are the primary barriers preventing the integration of ITS developments into the transport sector’s decision-making processes?
2. How can educational initiatives, particularly through transport management curriculum enhancements with digital competencies, contribute to bridging the gap between ITS innovations and policy implementation?
3. What role does academic-industry collaboration play in enhancing the implementation of ITS in Latvia?

To address these questions, the study adopted a mixed-methods approach, comprising (1) a systematic literature review to identify global ITS trends and barriers, (2) a comparative case study of Latvia’s ITS ecosystem in relation to European and international best practices, and (3) participatory action research, conducted in collaboration with public authorities, academic institutions, and industry associations. These phases informed the development of targeted curriculum enhancements and a data-driven Transport Intervention Modelling (TIM) system to support both ITS governance and education. Additionally, ex-post surveys were conducted to assess perceptions of ITS development among students and industry professionals.

The remainder of the paper presents the methodology, followed by the results and a discussion of their implications for transport governance and education policy.

2. Data and Methodology

2.1. Research Design

This study adopted a mixed-methods research design to enable triangulation across different types of data and stakeholders. By combining theoretical insights with practical interventions, the study integrates three methodological components: systematic literature review, comparative case study, and participatory action research. These were strategically chosen to examine the problem from global, national, and stakeholder-specific perspectives.

2.2. Data Collection Methods

A review of 57 peer-reviewed, open-access sources was conducted using Scopus and IEEE Xplore databases. Inclusion criteria focused on:

- ITS integration challenges and governance models;
- Data interoperability and emerging technologies;
- Educational frameworks supporting ITS-based decision-making.

Latvia's ITS ecosystem was assessed against European and international best practices. Data sources included:

- European Commission policy documents;
- Grey literature on ITS deployment benchmarks;
- Thirteen stakeholder interviews, expert consultations, and workshops involving representatives from national authorities, academia, and transport industry associations.

Educational innovations and the Transport Intervention Modelling (TIM) system were co-developed with stakeholders and embedded into revised transport management curriculum modules. These revised modules were pilot-tested with

- 97 students (master level);
- 6 industry stakeholders, who participated in the educational program.

2.3. Data Analysis Techniques

Sources in the literature review were analysed using qualitative content analysis and thematic coding to identify cross-cutting issues, knowledge gaps, and recurring patterns related to ITS governance and education.

A document analysis technique was applied using a structured coding frame to evaluate Latvia's regulatory frameworks, institutional structures, and public–private collaboration. Interview and workshop data were analysed using thematic analysis. Triangulation across document data, expert input, and stakeholder perspectives ensured robustness and validity of findings.

Structured survey responses were analysed using descriptive statistics to measure perceptions of curriculum relevance, digital competence acquisition, and the applicability of ITS concepts to real-world decision-making.

2.4. Novelty and Contribution

The development of the TIM system, hosted on RTU's high-performance computing (HPC) infrastructure, enables data-driven simulations for educational and policy use. Unlike previous ITS studies that focus primarily on infrastructure and technological deployment, this research introduces a governance-education integrated approach. The participatory curriculum co-design and stakeholder engagement strategy are particularly novel in the context of post-transition EU member states, where institutional inertia and educational fragmentation often hinder ITS adoption.

3. Findings

3.1. Systematic Literature Review

To better understand the challenges and opportunities in the integration of ITS developments into the transport sector's decision-making processes, a systematic literature review was conducted. This review examines key factors influencing ITS ecosystems, including ITS integration challenges, data and technological interoperability, and educational frameworks supporting ITS-based decision-making.

ITS integration involves technological, legal, and governance issues. Alanazi and Alenezi [7] and Shukla, et al. [8] concluded there are challenges of integrating ITS, including the need for seamless interoperability between IoT platforms, cloud computing, and connected vehicles. These technologies must work together to enhance transportation network safety and efficiency while addressing issues like traffic congestion and CO_2 emissions. Furthermore, the deployment of ITS requires careful consideration of legal frameworks, which may not fully accommodate new technologies such as 5G and IoT. Identifying gaps in current regulations and adapting them to support ITS is crucial for successful integration [9, 10]. Central governing authorities play a pivotal role in traffic management policies for connected vehicles. The level of control exerted by these authorities can significantly impact network performance, requiring a balance between centralised control and stakeholder autonomy [11].

ITS is at the forefront of modernising how we manage and interact with transportation networks. A critical aspect of ITS is data interoperability and the technological advancements that facilitate cooperation among various components of these systems.

Distributed ledger technologies (DLTs), such as blockchain, are being explored to enhance data management in ITS with Zichichi, et al. [12] and ElAmine [13]. They suggest that DLTs offer required features like immutability, traceability, and verifiability of data, which are crucial for secure and efficient data sharing. Digital Twin (DT) technology is emerging as a powerful tool in ITS, providing a virtual model of physical systems to address complex traffic issues. Ge & Qin, based on the systematic review of the evidence, conclude that DT-ITS integrates data fusion, cooperative perception, and edge-cloud collaboration to enhance service delivery and stakeholder engagement [14][.

These findings emphasise the necessity of developing shared knowledge frameworks and standardised systems to facilitate effective communication and service delivery within cooperative, connected, and automated mobility environments. Given the continuous advancements in standardisation, security, and multi-vendor integration, achieving full-scale ITS implementation remains a complex challenge. Therefore, the establishment of a continuous knowledge exchange and harmonisation platform should be regarded as a fundamental cornerstone in this process.

The CAPITAL project, funded by the European Union Horizon 2020, has developed an online training platform to address the knowledge gap in ITS and C-ITS (Cooperative Intelligent Transportation Systems). This platform focuses on capacity building and offers massive open online courses to educate public authorities and other stakeholders about the operation and impacts of ITS and C-ITS [15]. While the platform effectively addresses requirements of standardisation, interoperability, and system integration, it does not sufficiently bridge the link between ITS and the decision-making process. A critical gap remains in supporting authorities, who often lack even basic knowledge of data engineering, in leveraging ITS data for informed policy and investment decisions. The concept of foundation intelligence is pivotal for the future of smart infrastructure services in Transportation 5.0 as well [16].

The literature review supports our hypothesis, showing that focusing on training, capacity building, and the use of modern technologies alongside stakeholder collaboration can improve cooperation and decision-making.

3.2. Examination of Existing ITS in Latvia

To evaluate Latvia's ITS ecosystem in comparison to the best practices in European and global transport systems, a comparative case study approach was utilised. The analysis focused on key dimensions, including open metadata, data interoperability, geographical connections, and data architecture.
Table 1 Compares Latvian state entities, public and private company harmonisation of ITS.

Table 1.
Harmonisation of ITS Provided in Latvia.

Entity	ITS	ITS features			
		Open Meta data	**Geo-graphical Links**	**Data inter-operability**	**Architecture**
Rigas Satiksme	e-talon	v	n/d	n/d	x
Latvian State Roads	lvceli.lv	v	v	v	v
Road Traffic Safety Directorate	e.csdd	n/d	n/d	n/d	n/d
Latvian Railways	OPVS, RNE	n/d	n/d	n/d	n/d
ViVi	trainmap	n/d	v	v	n/d
Riga International Airport	Airport Operations Management Systems	v	v	v	x
Riga Seaport	SKLOIS, VTMS, PCS		v	v	x
Latvian Ministry of Transport	No name (ArcGIS)	x	x	x	x

Source: v – ITS features are accessible; x - ITS features are not accessible; n/d - ITS features are not defined.

Table 1 identifies significant gaps evidenced from the previous studies that persist in the development and implementation of cooperation in Latvian ITS, particularly in data standardisation, interoperability, and intersectoral consistency:

- Most entities continue to rely on fragmented and incompatible data systems. The absence of standardised data formats inhibits seamless data exchange, creating inefficiencies in system coordination and integration [17].
- Disparities in geographical feature adoption across entities result in data inconsistencies, limiting the ability to provide accurate real-time monitoring and predictive analytics [18].
- Interoperability remains a major challenge, with many ITS operators lacking frameworks for cross-sectoral data exchange [19].
- Entities deploy ITS features without integrating them into broader transportation sector objectives, leading to inefficiencies and missed opportunities for strategic optimisation [20].

To address these gaps and enhance the integration of data-driven decision-making in ITS, we recognised the need to strengthen education and industry collaboration. Consequently, we upgraded the International Transportation Management course to bridge the disconnect between decision-making, data analysis, and data engineering, ensuring that both students and industry professionals develop the necessary competencies to navigate and optimise modern transportation ecosystems. The next section explores the implemented innovations in the educational process and presents the results of their testing.

3.3. Implementation and Evaluation of Educational Innovations in ITS

The International Transport Management course at RTU (Riga Technical University) aims to equip students with a comprehensive understanding of decision-making processes in the organisation of international transportation and develop their ability to make economically sound decisions. The previous version of the course focused on the following core learning outcomes:

- Analysis of international transport processes and the ability to assess associated challenges.
- Familiarity with international transport organisation methods and their practical applications.
- Evaluation of terminal locations in relation to transport time planning.

- In-depth knowledge of international transport processes and the ability to select appropriate solutions for improving business performance.

While these outcomes provided a solid theoretical foundation, they lacked a digital and data-driven approach, which is crucial for modern ITS integration. The course also did not adequately address data engineering, real-time analytics, or predictive modelling, all of which are essential for informed decision-making in the transport sector.

To bridge these gaps, the course was transformed into a modern, digitally enhanced learning program incorporating situational simulations and real-world case studies for both students and industry participants.

Figure 1 depicts a collaborative framework for future decision-making, emphasising the integration of diverse roles and methodologies to bridge the gap between data insights from and to ITS and actionable strategies.

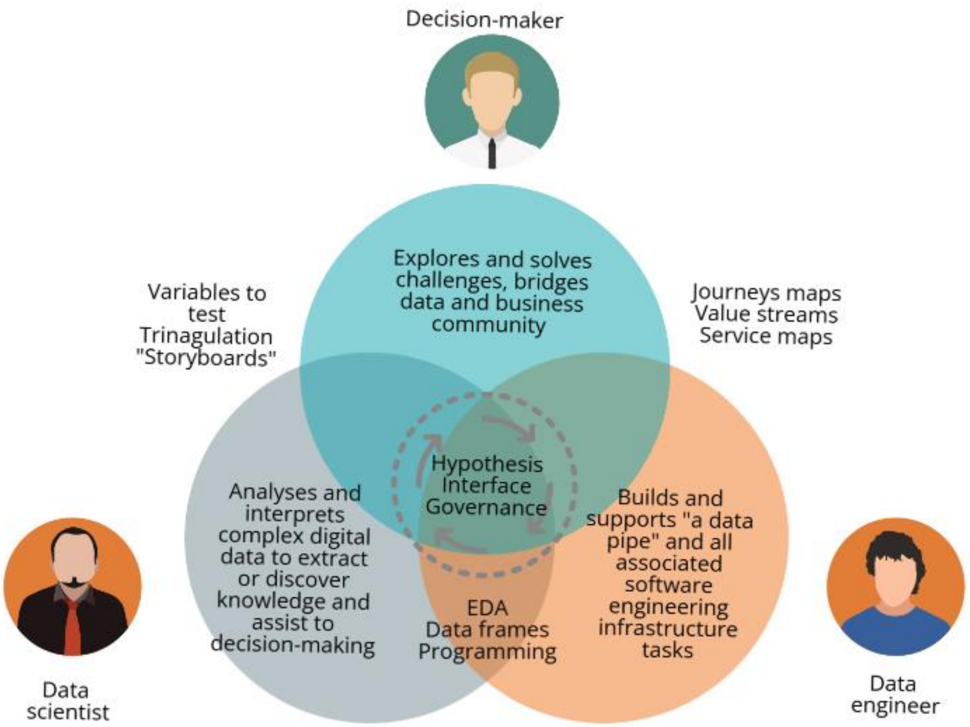

Figure 1.
A conceptual model of the professional standards in data-driven decision-making.

This visual represents a structured approach to decision-making in a future context for both business and governmental authorities. It highlights the importance of interdisciplinary collaboration, robust data infrastructure, and rigorous analytical methods in shaping the future of decision-making. It emphasises a shift towards a more data-centric and evidence-based approach, where insights derived from data are translated into actionable strategies through the combined expertise of business stakeholders, data scientists, and data engineers.

The following key improvements were made in the course:

1. Implementation of the Face-to-Face Driver Model (FFDM): A blended learning approach combining traditional lectures with digital simulation-based training was introduced. This implementation was driven by the need to address the highly diverse digital competencies observed both within the industry and among student groups, ensuring that all participants could effectively engage with the learning process regardless of their prior technical expertise.
2. Use of interactive textbooks and built-in assessments: These resources integrate theoretical knowledge with practical applications of digital tools for transport management.
3. Simulation of transport organisation scenarios in the contexts of already developed simulation models: Students engage with complex logistics scenarios to apply their knowledge in real-world decision-making environments.

The curriculum of the course was enhanced with advanced ITS methodologies, ensuring that students and industry stakeholders develop digital competencies relevant to the modern transport industry. Table 2 outlines the primary changes.

Table 2.
Course Content Enhancements.

Existing Content	Improved Content	Digital Tools and Technologies
Incoterms, conventions, regulations, licences, permits	International legal framework for transport; digital contract management	Open-source tools for contract analysis, document verification systems
International transport route planning	Economic geography, gravity models	GIS-based spatial analysis tools
Supply chains and logistics	Modern digital communication and electronic collaboration	Blockchain-based supply chain tracking systems
Transport mode selection	Intermodal and multimodal transport solutions	Digital freight platforms, AI-driven transport selection tools, HPC
Infrastructure development in Latvia and worldwide	Transport policy impact assessment and infrastructure planning	Simulation-based transport policy modelling
International transport operations	ESG in transport and logistics	Cybersecurity and other risk analysis and decision-support reporting

The curriculum of the course was developed in close collaboration with industry experts through semi-structured interviews. These discussions provided valuable insights into the industry's needs, allowing for necessary adjustments to ensure the course content aligns with real-world challenges and competencies required in the field.

The course was piloted during the 2023/2024 academic year with two participant groups: master students (103 participants) and industry professionals (7 participants). To ensure both groups developed a strong foundation in ITS decision-making, preparing them for roles in policymaking, logistics management, and smart mobility solutions, participants were interviewed, and their feedback was incorporated into the lecture materials. The course was continuously revised to incorporate ITS-based decision-making frameworks. Key enhancements include:

- *Integration of Transport Intervention Modelling*: A real-world simulation-based approach to decision-making on state interventions enabling students to assess the impact of transport policy interventions, based on existing open-access ITS data.
- *Focus on geodata-driven policymaking*: Students now gain expertise in geospatial analysis (GIS), big data analytics, and machine learning for transport applications.
- *Real-world case studies and collaborations*: Industry case studies and partnerships with state and private transport enterprises enhance practical learning.
- *Public-private policy workshops*: Direct engagement with state institutions allows students to contribute to ongoing national transport policy discussions.

While the course was piloted, it was observed that students with prior experience in the transport sector were better equipped to handle data gathering and make well-informed decisions. This situation highlights the need for RTU to develop additional courses for students who are lacking this knowledge.

3.4. Establishing a Cooperative ITS Ecosystem

To strengthen the real-world relevance of the course, partnerships were established with Latvian state authorities, RTU, and private sector associations. This collaboration is aimed at providing:

- *Preparation for real-world transport data utilisation.* Both new-entry students and industry professionals gained an understanding of existing transport databases, ITS capabilities, and potential developments, enabling them to apply real-world data imperfections in case studies and simulations.
- *Engagement in policy workshops.* These workshops facilitated knowledge exchange, allowing policymakers to grasp advancements in C-ITS from RTU data scientists while also considering practical constraints highlighted by industry professionals. This interaction is helpful in integrating up-to-date transport regulations into decision-making.
- *Practical training with digital infrastructure.* Participants of the ecosystem, including both students and industry professionals, acquired hands-on experience with industry-standard digital tools, ensuring they develop practical, sector-relevant skills for modern transport management and planning.

Further in this section we disclose our ongoing discussion on the organisation of the C-ITS ecosystem within these three areas of common interest.

Figure 2 presents the data flow in C-ITS, showcasing how data from various ITS sources are ingested, processed, and transformed into actionable insights for decision-makers.

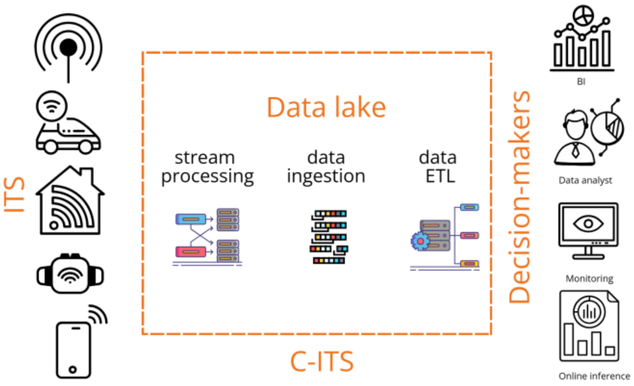

Figure 2.
A conceptual model framework of data integration in C-ITS.

Figure 2 highlights the integration of diverse ITS data sources, including e-ticketing, roadside sensors, mobile devices, and smart infrastructure. This data is aggregated into a data lake, where it undergoes stream processing, ingestion, and ETL (Extract, Transform, Load) processes. These steps ensure that raw transport data is standardised, structured, and made available for data analysts, business intelligence (BI) tools, monitoring systems, and real-time decision-making applications.

During *ex-ante* interviews and *ex-post* surveys, we observed significant differences between students' and industry professionals' perceptions of ideal transport data attributes and the actual characteristics of available data. Therefore, prior training in data mining, ingestion, and data fusion is essential before working with real-world data to improve the efficiency, safety, and sustainability of transportation systems while also preventing the overestimation of potential outcomes.

Our practical study supports previous research on the main challenges in C-ITS, including data fusion, real-time processing, interoperability, security, and adaptive learning. Some of these issues can be addressed through better education in transport management. For example, while most students and policymakers support using GPS and mobile device data, they do not always recognise the difficulties involved. Understanding these challenges can help develop a common framework to manage different types of data while ensuring accuracy and timely processing for filtering, decision-making, and evaluation—key steps in the data fusion process [21]. Similarly, there is a common belief that real-time data processing is straightforward, but our study confirms earlier findings by Naval, et al. [22] and Kunjir, et al. [23] which show that it requires strong infrastructure to handle large amounts of data with low delay. However, ensuring real-time insights remains a major challenge, especially in Latvia's transport systems.

Before this study, data management and security concerns were not widely discussed. Even though state-provided solutions exist for managing large datasets, most stakeholders still use their own data storage systems. Our research supports Zhu, et al. [24] findings, highlighting the importance of data quality, security, and privacy. Without proper management systems, risks like data breaches and incorrect insights could reduce the effectiveness of C-ITS.

Finally, C-ITS models must keep adapting to changes in transport systems. Our study supports earlier research by Laña, et al. [25] which emphasises the need for advanced learning algorithms. This requires including scientific approaches in new collaborations between academia, industry, and policymakers.

The introduction of a cooperative platform on ITS enhances decision-making by providing valuable insights into the datasets required for policy and operational planning. It helps address issues related to disproportionate and sometimes inefficient data collection while creating opportunities for digital twin development—establishing feedback loops between real-world transport systems and ITS-driven decision models. Additionally, C-ITS supports the development of predictive models to assess the effectiveness of state interventions in the transport sector. Figure 3 depicts these opportunities.

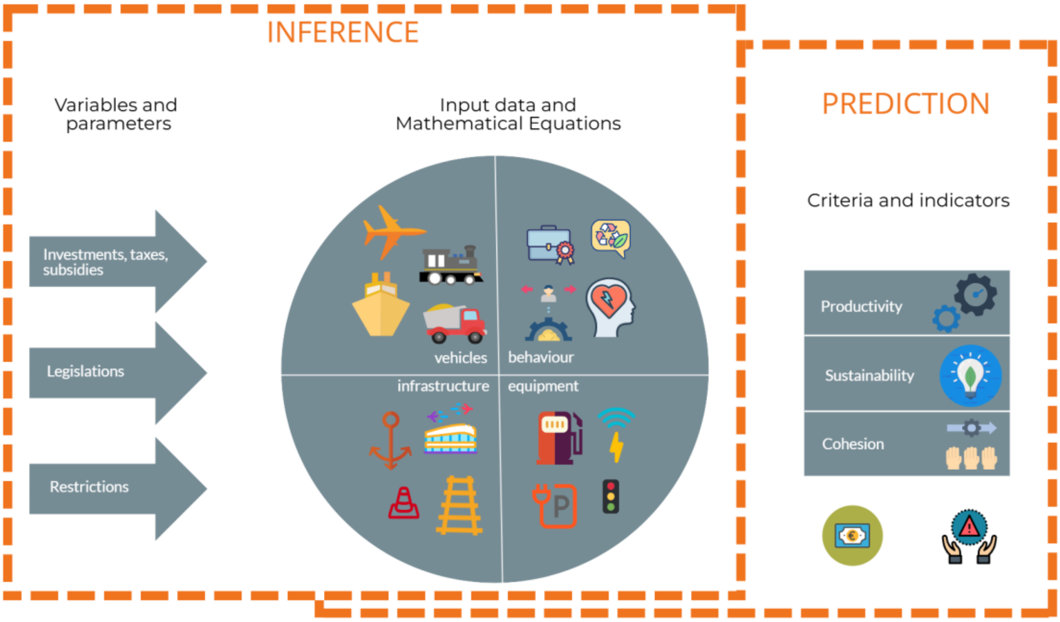

Figure 3.
Inference and Prediction in Cooperative ITS.

Therefore, our practical observations support that active communication and coordination among stakeholders are crucial for effective decision-making, ensuring a cohesive and efficient transport system [26]. Integrating policies can provide timely insights from government authorities to both current and future transport system participants, aligning them with long-term goals related to CO_2 emissions reduction, resource efficiency, and social equity [27].

Last but not least, the partnership between Latvian state authorities, RTU, and private sector associations provided an opportunity to test and develop the research infrastructure shown in Figure 4.

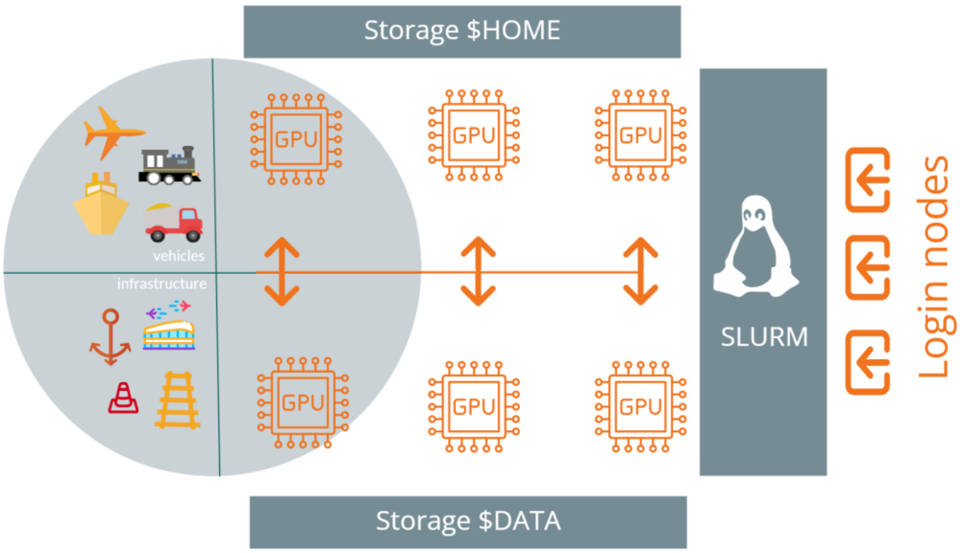

Figure 4.
Integration of Cooperative ITS with High-Performance Computing for enhanced data processing and management.

While C-ITS relies on advanced data analytics to improve traffic flow, safety, and system efficiency, the increasing complexity of mobility data requires robust computational power, which HPC provides through parallel processing and efficient resource management. Figure 4 illustrates the role of HPC in supporting C-ITS, highlighting key components such as GPU clusters, storage systems, and scheduling tools provided by RTU and promoted through educational processes and ecosystem development to the transport industry.

The integration of HPC potential enables further developments in the processing of large-scale transportation datasets, facilitating the development of predictive models and digital twins that improve decision-making and state intervention evaluation [28, 29]. However, the implementation of HPC in C-ITS during our examination remains challenging due to complex system integration and the need for specialised expertise in both transportation and high-performance computing domains.

4. Discussions

The systematic literature review highlighted critical gaps in the integration of ITS into decision-making processes, including challenges related to interoperability, standardisation, legal frameworks, and education. Our empirical examination of Latvia's ITS ecosystem and the educational innovations piloted at RTU offer concrete contributions toward addressing these issues. This discussion synthesises our findings with current literature and recent research to demonstrate how real-world educational and policy-driven interventions can contribute to bridging the disconnect between ITS capabilities and strategic decision-making.

Our case study revealed a fragmented system with inconsistent adoption of metadata standards, data architecture, and geographical tagging. These findings align with prior studies [7, 8] that emphasise the critical need for interoperable ITS ecosystems. As observed, many Latvian entities continue to function independently with limited interagency coordination, lacking the unified frameworks needed for effective data exchange. This is consistent with Kummetha, et al. [30] study, which highlights rapid progress through open standards such as Transport Operator Mobility-as-a-Service Provider, Mobility Data Specification, General On-Demand Feed Specification, and Transactional Data Specification, and exposes persistent barriers rooted in regulatory fragmentation, governance limitations, and uneven digital maturity. Thus we challenge earlier assumptions [12] that technological readiness alone can enable effective ITS deployment. Without robust human capital and cross-disciplinary knowledge, data infrastructure remains underutilised. The transformation of the International Transport Management course at RTU directly addressed previously identified gaps in multidisciplinary educational preparedness.

Coherent with previous literature [9, 11] our analysis confirms that ITS deployment in Latvia is hindered by unclear legal frameworks, especially concerning cross-modal data exchange. The Ministry of Transport, for example, lacks an active ITS framework for railways and low-emission transport, resulting in missed opportunities for combined transport integration and long-term infrastructure planning for sustainable transport. The implementation of simulation-based training and transport intervention modelling equips students and professionals with practical competencies for real-time and predictive decision-making in ITS contexts.

Our observations reinforce recent findings by Naval, et al. [22]] and Kunjir, et al. [23] which highlight the critical role of high-performance computing in supporting real-time analytics. This contrasts with studies [31, 32] promoting lightweight edge solutions, which argue that real-time processing can be achieved without large-scale HPC investment. The divergence suggests that while edge systems may suffice for local-level ITS functions, national-level predictive modelling and digital twin simulations still require centralised, high-capacity computing infrastructure.

Despite growing concerns in the literature about ITS-related cybersecurity and data privacy risks [24] these issues remain largely neglected in Latvia's transport data governance. Our findings show that most stakeholders continue to rely on internal databases and *ad hoc* security measures. The lack of centralised governance and standard practices mirrors issues raised by ElAmine [13] who stresses the necessity of blockchain and DLTs in ensuring data verifiability and traceability.

Interestingly, however, our fieldwork did not support claims that DLTs are easily applicable in current transport ecosystems. While they provide theoretical advantages, their implementation requires significant infrastructural and legal adaptation, which is currently beyond the scope of most Latvian entities.

One of the key innovations of this study is the creation of a cooperative ITS ecosystem that integrates students, industry professionals, state authorities, and researchers into a common decision-making framework. This model reflects best practices seen in projects such as TM2.0 and C-Roads, which promote collaborative governance models for ITS deployment.

However, we also noted resistance from some industry actors who questioned the practical relevance of academic approaches. This points to a remaining cultural gap between applied research and business practice, which can only be bridged through sustained engagement, co-creation of tools, and tangible policy outcomes.

5. Conclusions

This study investigated the persistent disconnect between the technical potential of ITS and their integration into strategic transport decision-making, with a specific focus on Latvia. Building on a systematic literature review and a mixed-methods case study, we identified core challenges, such as data interoperability gaps, inconsistent standards, fragmented governance, and insufficient cross-disciplinary education, that continue to limit the effectiveness of ITS in real-world contexts.

To address these barriers, we piloted a curricular reform of the International Transport Management course at Riga Technical University, incorporating digital tools, real-world case analysis, and collaborative projects. The developed cooperative ecosystem, which linked academia, state authorities, and the workforce, further reinforced the integration of data analysis, engineering knowledge, and policy considerations.

5.1. Implications

Our findings emphasise that ITS adoption is not merely a technical challenge but a socio-technical transformation requiring institutional alignment, policy support, and human capital development. The RTU educational model illustrates how university-led interventions can foster practical competencies in transport intervention modelling and real-time decision-making. Moreover, the Latvian case underscores the importance of localised, context-sensitive strategies alongside broader standardisation efforts to overcome uneven digital maturity and regulatory fragmentation.

These results contribute to growing evidence that industry–academia partnerships can accelerate ITS integration in public governance. The curriculum reform offers a scalable template for other regions navigating similar interoperability and governance bottlenecks.

5.2. Limitations

While the study provides valuable insights, it is limited by its national scope and early-stage implementation. The long-term effectiveness of the reforms, particularly regarding interoperability improvements and workforce outcomes, remains to be assessed. Additionally, perspectives from international stakeholders, end users, or multi-country comparisons were not within the scope of this phase but are important for generalisation.

5.3. Future Research

Future studies should evaluate the longitudinal impact of the RTU reforms by tracking graduate career trajectories, analysing institutional uptake of ITS tools, and monitoring progress in standard adoption. Further research is also needed to explore how similar education-policy collaborations can be scaled across the European ITS landscape, particularly in low- and middle-income countries or less digitally mature regions.

By strengthening the interface between education, governance, and data systems, we argue that ITS can fulfil its promise as a driver of smarter, more sustainable transport solutions.

References

[1] C. N. Tran, T. T. H. Tat, V. W. Tam, and D. H. Tran, "Factors affecting intelligent transport systems towards a smart city: A critical review," *International Journal of Construction Management,* vol. 23, no. 12, pp. 1982-1998, 2023. https://doi.org/10.1080/15623599.2022.2029680

[2] P. Conroy, S. Shladover, J. Dahlgren, P. Varaiya, W. Recker, and S. Ritchie, "Intelligent transportation systems: Research products for public works professionals," *Public Works Management & Policy,* vol. 5, no. 1, pp. 3-12, 2000. https://doi.org/10.1177/1087724X0051001

[3] J. Hudenko, I. Kukjans, and I. Jurgelāne-Kaldava, "Development of GIS-based simulations for evaluating interventions in Latvia's transport system," in *Proceedings of the 14th International Conference on Simulation and Modeling Methodologies, Technologies and Applications (Vol. 1, pp. 258–265). Dijon, France: SciTePress*, 2024, doi: https://doi.org/10.5220/0000178700003758.

[4] L. Gamidullaeva, T. Tolstykh, A. Bystrov, A. Radaykin, and N. Shmeleva, "Cross-sectoral digital platform as a tool for innovation ecosystem development," *Sustainability,* vol. 13, no. 21, p. 11686, 2021. https://doi.org/10.3390/su132111686

[5] C. Öberg and H. Lundberg, "Mechanisms of knowledge development in a knowledge ecosystem," *Journal of Knowledge Management,* vol. 26, no. 11, pp. 293-307, 2022. https://doi.org/10.1108/jkm-11-2021-0814

[6] L. Pilelienė and G. Jucevičius, "A decade of innovation ecosystem development: Bibliometric review of scopus database," *Sustainability,* vol. 15, no. 23, p. 16386, 2023. https://doi.org/10.3390/su152316386

[7] F. Alanazi and M. Alenezi, "A framework for integrating intelligent transportation systems with smart city infrastructure," *Journal of Infrastructure, Policy and Development,* vol. 8, no. 5, p. 3558, 2024. https://doi.org/10.24294/jipd.v8i5.3558

[8] R. Shukla *et al.*, "Original research article understanding integration issues in intelligent transportation systems with IoT platforms, cloud computing, and connected vehicles," *Journal of Autonomous Intelligence,* vol. 7, no. 4, pp. 1-13, 2024.

[9] D. Van Hiep, T. H. Nam, D. T. Kien, D. D. Dinh, T. M. Hung, and S. Lee, "A three-stage framework for efficient deployment of intelligent transportation systems in urban areas," *Journal of Science and Technology in Civil Engineering,* vol. 17, no. 2, pp. 47-61, 2023.

[10] L. Guevara and F. Auat Cheein, "The role of 5G technologies: Challenges in smart cities and intelligent transportation systems," *Sustainability,* vol. 12, no. 16, p. 6469, 2020. https://doi.org/10.3390/su12166469

[11] A. Kotsi, I. Politis, and E. Mitsakis, "The impacts of centralized control on mixed traffic network performance: A strategic games analysis," *Sustainability,* vol. 16, no. 15, p. 6343, 2024. https://doi.org/10.3390/su16156343

[12] M. Zichichi, S. Ferretti, and G. D'angelo, "A framework based on distributed ledger technologies for data management and services in intelligent transportation systems," *IEEE Access,* vol. 8, pp. 100384-100402, 2020. https://doi.org/10.1109/ACCESS.2020.2998012

[13] F. N. ElAmine, *Using distributed ledger technologies in VANETs to achieve trusted intelligent transportation systems*. West Virginia University, 2021. https://doi.org/10.33915/etd.10322

[14] C. Ge and S. Qin, "Digital twin intelligent transportation system (DT-ITS)—A systematic review," *IET Intelligent Transport Systems,* vol. 18, no. 12, pp. 2325-2358, 2024. https://doi.org/10.1049/itr2.12539

[15] C. Chalkiadakis, P. Iordanopoulos, and E. Mitsakis, "Training opportunities for intelligent transport systems and cooperative intelligent transport systems," *arXiv preprint arXiv:2010.12037,* 2020. https://doi.org/10.48550/arXiv.2010.12037

[16] X. Han *et al.*, "Foundation intelligence for smart infrastructure services in transportation 5.0," *IEEE Transactions on Intelligent Vehicles,* vol. 9, no. 1, pp. 39-47, 2024. https://doi.org/10.1109/TIV.2023.3349324

[17] A. Choosakun, Y. Chaiittipornwong, and C. Yeom, "Development of the cooperative intelligent transport system in Thailand: A prospective approach," *Infrastructures,* vol. 6, no. 3, p. 36, 2021. https://doi.org/10.3390/INFRASTRUCTURES6030036

[18] S. Kozhevnikov, M. Svitek, and S.-Y. Chou, "Smart services ecosystem concept for cooperative ITS," in *Proceedings of the 11th Euro American Conference on Telematics and Information Systems*, 2022, doi: https://doi.org/10.1145/3544538.3544654.

[19] J. Zhang, S. Li, and Y. Wang, "Shaping a smart transportation system for sustainable value co-creation," *Information Systems Frontiers,* vol. 25, no. 1, pp. 365-380, 2023. https://doi.org/10.1007/s10796-021-10139-3

[20] L. Tseng and L. Wong, "Towards a sustainable ecosystem of intelligent transportation systems," in *2019 IEEE International Conference on Pervasive Computing and Communications Workshops (PerCom Workshops)*, 2019, doi: https://doi.org/10.1109/PERCOMW.2019.8730669.

[21] S. A. Kashinath *et al.*, "Review of data fusion methods for real-time and multi-sensor traffic flow analysis," *IEEE Access,* vol. 9, pp. 51258-51276, 2021. https://doi.org/10.1109/ACCESS.2021.3069770

[22] P. Naval, S. K. Jain, and K. G. Krishna, "The integration of stream data models in modern transportation networks," presented at the 2023 IEEE International Conference on ICT in Business Industry & Government (ICTBIG), 2023.

[23] S. N. Kunjir, S. S. Patil, B. S. Hingane, J. A. Pagariya, and M. Rashid, "Managing Smart Urban Transportation with the integration of Big Data Analytic Platform," *2023 6th International Conference on Contemporary Computing and Informatics,* vol. 6, pp. 1807-1811, 2023. https://doi.org/10.1109/IC3I59117.2023.10397915

[24] L. Zhu, F. R. Yu, Y. Wang, B. Ning, and T. Tang, "Big data analytics in intelligent transportation systems: A survey," *IEEE Transactions on Intelligent Transportation Systems,* vol. 20, no. 1, pp. 383-398, 2018. https://doi.org/10.1109/TITS.2018.2815678

[25] I. Laña, J. J. Sanchez-Medina, E. I. Vlahogianni, and J. Del Ser, "From data to actions in intelligent transportation systems: A prescription of functional requirements for model actionability," *Sensors,* vol. 21, no. 4, p. 1121, 2021. https://doi.org/10.3390/s21041121

[26] S. ILCHENKO and Y. D. KOSTIUK, "Regulatory and legal ensuring the sustainable development of transport and logistics systems," *Economic Innovations,* vol. 25, no. 3, pp. 113-124, 2023. https://doi.org/10.31520/ei.2023.25.3(88).113-124

[27] A. Hull, "Policy integration: What will it take to achieve more sustainable transport solutions in cities?," *Transport Policy,* vol. 15, no. 2, pp. 94-103, 2008. https://doi.org/10.1016/J.TRANPOL.2007.10.004

[28] M. A. Javed, S. Zeadally, and E. B. Hamida, "Data analytics for cooperative intelligent transport systems," *Vehicular Communications,* vol. 15, pp. 63-72, 2019. https://doi.org/10.1016/J.VEHCOM.2018.10.004

[29] R. Merrill, D. Schanzenbach, S. B. Cleveland, and G. A. Jacobs, "Mana-bringing accessible HPC to Hawai'i," *Practice and Experience in Advanced Research Computing 2023: Computing for the Common Good,* pp. 86-93, 2023. https://doi.org/10.1145/3569951.3593611

[30] V. C. Kummetha, S. Concas, L. Staes, and J. Godfrey, "Mobility on demand in the United States–Current state of integration and policy considerations for improved interoperability," *Travel Behaviour and Society,* vol. 37, p. 100867, 2024. https://doi.org/10.1016/j.tbs.2024.100867

[31] T. Gong, L. Zhu, F. R. Yu, and T. Tang, "Edge intelligence in intelligent transportation systems: A survey," *IEEE Transactions on Intelligent Transportation Systems,* vol. 24, no. 9, pp. 8919-8944, 2023. https://doi.org/10.1109/TITS.2023.3275741

[32] Y. Jiang, X. Xu, H. Gao, A. D. Rajab, F. Xiao, and X. Wang, "LBlockchainE: A lightweight blockchain for edge IoT-enabled maritime transportation systems," *IEEE Transactions on Intelligent Transportation Systems,* vol. 24, no. 2, pp. 2307-2321, 2022. https://doi.org/10.1109/TITS.2022.3157447