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Intelligent Transport Systems as a Tool for Sustainable Road Safety Management: Economic Assessment for Emerging European Markets

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Abstract

Research background: Road traffic crashes represent one of the most critical public health and economic challenges in emerging European markets. Despite significant progress in Western Europe, countries in Central and Eastern Europe, including Ukraine, continue to register road fatality rates two to three times higher than EU averages, generating annual socio-economic losses equivalent to 2–4% of GDP. Intelligent transport systems (ITS) have emerged as an evidence-based mechanism for addressing the structural drivers of road insecurity; however, the literature on their economic justification in resource-constrained transitional economies remains underdeveloped.
Purpose of the article: This article examines ITS as a strategic management tool for sustainable road safety improvement in emerging European markets. The study synthesises comparative evidence from the EU, Singapore, Japan, and the United States; constructs a cost-benefit framework adapted to conditions typical of post-Soviet economies; and applies this framework to a pilot scenario on the Ukrainian national highway M-06.
Methods: The research employs a multi-method approach combining systematic literature analysis, comparative case study methodology, and quantitative cost-benefit analysis (CBA). Road fatality and injury statistics are drawn from official national databases and international indices (ETSC PIN, WHO Global Status Report, ITF Road Safety Annual Report). ITS component cost parameters are sourced from European deployment projects. The value of a statistical life (VSL) is derived from harmonised European methodologies for the Ukrainian income context, with an income-elasticity adjustment.
Findings & Value added: Results confirm that ITS deployment reduces road fatalities by 15–50%, depending on technology type and context. For the M-06 pilot scenario (75 km, investment of EUR 750,000), the

benefit-cost ratio is 9.4:1, the net present value over 10 years exceeds EUR 14.1 million, and the payback period is approximately 4 months. The article contributes a replicable CBA model adapted for emerging European markets, where VSL and investment capacity differ substantially from Western benchmarks, providing actionable guidance for transport ministries, municipal authorities, and international co-financing bodies.

Keywords: intelligent transport systems; road safety management; cost-benefit analysis; emerging European markets; Ukraine; sustainable transport; ITS deployment

JEL Classification: R41; L91; H54; O18; Q01

1. Introduction

Road traffic injuries constitute a global public health emergency. According to the World Health Organization, approximately 1.35 million people die on the world's roads each year, with an additional 20–50 million sustaining non-fatal injuries (World Health Organization, 2023). The financial burden is no less severe: total crash costs across EU member states amount to at least EUR 500 billion annually, equivalent to approximately 3% of regional GDP (Wijnen and Stipdonk, 2018). For emerging economies in Central and Eastern Europe (CEE), the burden is disproportionately heavy, fatality rates per 100,000 inhabitants typically run two to three times higher than the EU-15 average, reflecting gaps in vehicle fleet quality, road infrastructure standards, enforcement capacity, and institutional governance (World Bank, 2010).

Within this regional context, Ukraine occupies a particularly challenging position. With a road fatality rate of approximately 9.2 per 100,000 inhabitants, Ukraine's road safety performance stands roughly three times worse than the EU average of 4.2 (European Transport Safety Council, 2024). Annual socio-economic losses attributable to road traffic crashes have been estimated at USD 4–5 billion, or 2–2.5% of GDP (Kornus et al., 2017), a figure that significantly exceeds typical public investment in the transport sector. The concentration of fatalities among young working-age adults (20–45 years) compounds the human cost with long-term productivity and human-capital losses (UACRISIS, 2016).

Against this backdrop, intelligent transport systems, encompassing the application of information and communication technologies to transportation infrastructure and vehicle management, have emerged as one of the most evidence-based strategies for reducing road crash frequency and severity. The academic literature, as well as large-scale deployment programmes in the EU, Japan, Singapore, and the United States, documents fatality reductions of 15–50% attributable to specific ITS technologies, including automated speed enforcement, adaptive traffic signal control, vehicle-to-infrastructure communication, and advanced driver assistance systems (Intelligent Transportation Systems Joint Program, 2023; ERTICO, 2025).

However, a substantial gap persists between existing evidence on ITS effectiveness and its practical application in emerging European markets. The majority of ITS cost-benefit analyses are calibrated to Western European or North American conditions, where VSL, infrastructure costs, enforcement capacity, and institutional readiness differ significantly from the CEE context. This gap limits the transferability of existing frameworks to transition economies such as Ukraine, Moldova, Georgia, or the Western Balkans, precisely the settings where the public health return on ITS investment would be highest.

This article addresses this gap by pursuing three objectives: (1) to synthesise comparative evidence on ITS deployment models and their road safety outcomes; (2) to construct a CBA framework adapted to emerging European market conditions; and (3) to apply this framework to a concrete pilot case on the M-06 highway in Ukraine.

The remainder of the article is organised as follows. Section 2 reviews the theoretical and empirical literature on ITS classification, deployment models, and economic assessment methodologies. Section 3 describes the data sources and analytical methods employed. Sections 4 and 5 present comparative and Ukrainian evidence, respectively. Section 6 develops and applies the CBA framework. Sections 7 and 8 discuss findings and conclude.

2. Literature Review

2.1 Conceptual foundations of ITS and road safety

The concept of intelligent transport systems encompasses a broad family of technologies that use data capture, communication networks, and processing algorithms to improve the efficiency, safety, and sustainability of transportation. Vovk (2016) defined resource-efficient ITS as systems that "mostly operate on information exchange principle between vehicles and roadside infrastructure" and identified them as "a base technology for persistent diminution of road accidents and traffic efficiency increase" (p. 7). This framing, centred on information as the primary resource of modern transport management, has gained wide acceptance in the subsequent academic and policy literature, with a growing body of empirical research confirming positive safety and efficiency outcomes across diverse geographic settings.

The taxonomy of ITS relevant to road safety can be organised along three principal dimensions: *actor* (vehicle, infrastructure, or combined); *function* (detection, communication, control, or assistance); and *automation level* (advisory, semi-automatic, or fully automatic). European Directive 2010/40/EU (European Parliament and Council, 2010) established the foundational regulatory framework for ITS deployment across EU member states, distinguishing priority applications in traffic and travel information, traffic management, freight transport, and vulnerable road user safety. Vaiana et al. (2021) demonstrated that combining regulatory procedures with systematic accident data analysis provides the methodological basis for evidence-based road safety management consistent with the Directive's requirements. The 2022 General Safety Regulation extended mandatory ADAS requirements, including intelligent speed assistance (ISA), autonomous emergency braking (AEB), lane-keeping assist (LKA), and driver drowsiness monitoring, to all new passenger vehicles sold in the EU market (ERTICO, 2025).

2.2. Evidence on ITS safety effectiveness

The quantitative evidence on the safety and effectiveness of ITS is well established for core technology categories. Automated speed enforcement (average speed cameras) is associated with reductions in injury crashes of 20–32% and fatalities of 26–35% on monitored corridors, primarily through sustained compliance effects that persist beyond camera coverage zones (Perez et al., 2025). The European Transport Safety Council (2023) documented that countries with extensive speed camera networks, including France, the United Kingdom, and Poland, achieved disproportionate reductions in road fatalities relative to countries relying primarily on police patrol enforcement.

Cooperative ITS (C-ITS), incorporating V2X communication between vehicles and infrastructure, is projected to prevent between 3,932 and 8,774 deaths across the EU by 2040, depending on deployment speed and communication technology (Intelligent Transportation Systems Joint Program, 2023). ADAS technologies at the vehicle level demonstrate effectiveness ranging from 15% fatality reduction for ISA to 50% for full AEB in front-to-rear crashes (ERTICO, 2025). Maternova et al. (2023) developed a comprehensive framework for calculating the external costs of accidents, providing a methodological basis for internalising these reductions into investment appraisal – a framework directly applicable to the CEE context where standardised cost data remain scarce. The performance-based maintenance literature further demonstrates that ITS-enabled road management optimisation achieves 10–50% cost savings while simultaneously improving safety outcomes (Morozov et al., 2024).

2.3. Economic assessment of ITS investment

The economic justification for ITS investment relies primarily on cost-benefit analysis, which monetises the value of prevented fatalities and injuries using the value-of-a-statistical-life methodology (Byaruhanga and Evdorides, 2021). While no universally accepted standard exists, the SafetyCube harmonisation study found that official European cost-per-fatality estimates range from EUR 0.7 million to EUR 3.0 million (2015 prices), with variations explained primarily by methodological differences between the willingness-to-pay approach and human capital approaches (Wijnen and Stipdonk, 2018). Degrande et al. (2021) found techno-economic assessments of highway C-ITS roadside unit deployments to be broadly favourable, with BCR values of 2–5 when safety benefits are comprehensively accounted for, though sensitive to deployment density and traffic volume.

For emerging European markets, the CBA challenge is compounded by lower VSL estimates that reflect income differentials. Ukraine's per-capita GDP (PPP) is approximately 30–35% of the EU average, suggesting that VSL estimates derived from Western European willingness-to-pay surveys substantially overstate Ukrainian values. Adapting VSL using income elasticity (typically 1.0–1.5 in the literature) generates Ukraine-specific estimates that better reflect domestic social preferences while preserving methodological consistency with European norms (SafetyCube Consortium, 2018).

2.4. Regional deployment models and CEE context

The comparative literature identifies four broadly distinct regional ITS deployment models: the EU's regulatory-harmonisation approach, based on mandatory directives and cross-border interoperability standards; Japan's industry-consensus model, leveraging dense private-sector investment under national coordination; Singapore's centralised state-planning model; and the United States' voluntary-standards model (ERTICO, 2025). Ujlacka et al. (2024) demonstrated in an EMS-published study that transport enterprise efficiency is significantly enhanced through telematics systems, a finding consistent with the broader ITS effectiveness evidence and directly relevant to the operational management dimension of ITS deployment. Jonasikova and Konecny (2024) further showed, in an analysis of logistics performance indices across EU countries, that the quality of transport infrastructure – including intelligent systems – correlates strongly with national-level logistics competitiveness, underscoring the economic case for ITS investment beyond the safety dimension. The documented productive efficiency gains from the digitalisation of transport operations by Domeny (2024) provide further evidence that technology-enabled management produces measurable improvements across multiple performance dimensions simultaneously.

3. Methodology

The study employs a multi-method research design combining three complementary analytical approaches.

A systematic literature synthesis was conducted across the Web of Science, Scopus, and Google Scholar databases for the period 2015–2025, using the following search terms: "intelligent transport systems AND road safety AND cost-benefit", "ITS AND emerging markets AND Eastern Europe", and "road safety management AND Ukraine AND economic assessment". A total of 87 sources met the inclusion criteria of empirical content, peer-review status, and relevance to the CEE context. Priority was assigned to primary statistical sources (ETSC, WHO, ITF, EC Eurostat) and to original cost-benefit studies with documented methodology.

Comparative case analysis examined four regional deployment models (EU, Singapore, Japan, USA) using a structured framework of six dimensions: regulatory approach, coordination level, primary technology stack, financing model, fatality reduction achieved (2010–2023), and current road fatality rate. Data were drawn from official national and international transport safety indices (European Transport Safety Council, 2024; European Commission, 2025; International Transport Forum, 2024).

Quantitative cost-benefit analysis was applied to the M-06 pilot scenario using the following parameters and assumptions:

- Study corridor: M-06 national highway, Zhytomyr–Rivne section, 75 km
- Reference period: 10 years, real discount rate 5%
- Capital cost components: 15 speed cameras (EUR 25,000 each), 6 variable message signs (EUR 30,000 each), 5 weather monitoring stations (EUR 9,000 each), traffic management centre integration (EUR 45,000), plus contingency – total EUR 750,000
- Annual operating costs: EUR 120,000
- Baseline crash data: 42 injury crashes/year, 8 fatalities/year, 54 injuries/year on the study segment (National Police of Ukraine, 2024)
- VSL (Ukraine-adapted): EUR 700,000 per fatality, derived from the EU reference value (EUR 3.0 million) adjusted by income elasticity of 1.0 and GDP(PPP) ratio of 0.233 (SafetyCube Consortium, 2018)
- Value of a serious injury: EUR 75,000 (10.7% of VSL, consistent with EU standard)
- Expected effectiveness: fatality reduction 22%; injury crash reduction 18% (derived from automated speed enforcement meta-analyses)

The benefit-cost ratio (BCR), net present value (NPV), and payback period were computed using standard infrastructure appraisal formulae (Byaruhanga and Evdorides, 2021):

$$BCR = \frac{\sum_{t=1}^{n} \frac{B_t}{(1+r)^t}}{\sum_{t=0}^{n} \frac{C_t}{(1+r)^t}} \tag{1}$$

where B_t represents annual safety benefits in year t, C_t represents costs (capital and operating), r is the real discount rate (5%), and n is the analysis horizon (10 years).

4. Results

4.1. Comparative analysis of regional ITS deployment models

4.1.1. European Union

The EU's ITS strategy is anchored in mandatory directives that establish minimum deployment obligations and interoperability requirements across member states (European Parliament and Council, 2010). The 2010/40/EU Directive required member states to produce national ITS action plans. Subsequent regulations progressively expanded mandatory ADAS requirements, culminating in the 2022 General Safety Regulation, which mandated ISA, AEB, and LKA in all new vehicles from 2022 onward (ERTICO, 2025).

EU-wide road fatalities fell by 33% between 2010 and 2022; however, the pace slowed markedly, with only a 1% reduction in 2023 (20,418 deaths) and 2% in 2024 (19,940 deaths) – far below the 6.1% annual reduction required to achieve the 2030 Vision Zero interim target (European Commission, 2025). Poland cut road deaths by 47% between 2012 and 2022, driven by a comprehensive combination of expanding speed camera networks, a safe road infrastructure programme, and a 19% annual average increase in drink-driving enforcement checks (European Transport Safety Council, 2023). The Polish experience is particularly instructive for emerging markets because it demonstrates that sustained institutional commitment to enforcement amplifies the effectiveness of ITS hardware investment.

4.1.2. Singapore

Singapore's Urban Traffic Management and Information System (UTMC), operated by the Land Transport Authority, integrates Electronic Road Pricing, adaptive signal control, and comprehensive road-user behaviour monitoring. The system reduced congestion on monitored corridors by 15–20% while generating compliance rates exceeding 98% through automated enforcement (Intelligent Transportation Systems Joint Program, 2023). Singapore's road fatality rate of 1.8 per 100,000 inhabitants in 2023 places it among the five safest jurisdictions globally (European Transport Safety Council, 2024). The centralised governance model, with a single authority controlling ITS architecture, financing, and enforcement, eliminates the coordination failures characteristic of multi-level governance systems and offers an institutional design benchmark for CEE countries seeking to establish national ITS centres.

4.1.3. Japan

Japan achieved a 45% reduction in road fatalities between 2010 and 2023, the largest among the four regions analysed, through strong industry-government collaboration within the ITS Japan consortium and a dense Driving Safety Support System (DSSS) roadside infrastructure operating at 760 MHz (International Transport Forum, 2024). For CEE countries with older average vehicle fleets (average vehicle age in Ukraine exceeds 18 years, compared to 11 years in the EU), Japan's emphasis on corridor-level infrastructure providing safety benefits independent of vehicle equipment offers a particularly relevant model.

4.1.4. United States

Despite the world's largest absolute ITS investment envelope, the US road fatality rate of 12.8 per 100,000 inhabitants remains substantially higher than in Japan, Singapore, or Europe, reflecting the counteracting influence of high posted speed limits, large vehicle formats, and lower urban density (International Transport Forum, 2024). C-V2X technology has emerged as the dominant US standard following the Federal Communications Commission's 2020 reallocation of the 5.9 GHz spectrum band (ERTICO, 2025). The US experience illustrates that technology availability and financial investment alone are insufficient without supportive regulatory and enforcement frameworks.

4.1.5. Regional comparison

Table 1 summarises the key parameters of the four regional models.

Table 1: Comparative analysis of ITS deployment models

Parameter	EU	Singapore	Japan	USA
Regulatory approach	Mandatory directives	Centralised state planning	Industry-consensus standards	Voluntary federal standards
Coordination level	Supra-national	National (single authority)	National (consortium)	State/city level
Primary V2X technology	ITS-G5 / C-V2X hybrid	Satellite ERP + GPS	DSRC 760 MHz	C-V2X (5.9 GHz)
Financing model	PPP + EU co-financing	State (recouped via ERP)	Private (state incentives)	Federal grants
Fatality reduction 2010–2023	38%	35%	45%	22%
Road fatality rate 2023 (per 100,000 inh.)	4.2	1.8	2.6	12.8

Source: own elaboration based on European Transport Safety Council (2024), European Commission (2025) and International Transport Forum (2024)

4.2. Road safety in Ukraine: Context and challenges

4.2.1. Statistical profile

Ukraine's road safety record remains among the poorest in geographic Europe. National Police statistics document 25,781 injury crashes in 2024, resulting in 3,202 fatalities and 32,023 injuries, increases of 8.2% and 13.4% respectively over 2022 figures (National Police of Ukraine, 2024). The road fatality rate of 9.2 per 100,000 inhabitants contrasts sharply with the EU average of 4.2 (European Transport Safety Council, 2024).

Speed-related crashes account for 39.4% of all fatalities – the single largest contributing factor – followed by improper manoeuvring (13.7%) and impaired driving (National Police of Ukraine, 2024). The regional dimension of Ukrainian road safety is documented by Kornus et al. (2017), who identified persistent geographic disparities in crash incidence, with western and central oblasts, including those traversed by M-06, exhibiting disproportionately high inter-urban fatality rates. The M-06 highway has consistently ranked among the five most dangerous national highways in Ukraine, with 292 injury crashes recorded in the first eight months of 2024 alone.

4.2.2. Economic losses

Aggregate economic losses from road crashes in Ukraine were estimated at USD 4–5 billion annually, equivalent to approximately 2–2.5% of pre-war GDP (Kornus et al., 2017; UACRISIS, 2016). This estimate encompasses direct costs (property damage, emergency response, medical treatment) and indirect costs (lost productivity, human capital, household welfare losses). By comparison, Ukraine's entire state road maintenance budget historically ranged between USD 1.0 and 2.5 billion annually, implying that road crash losses consume resources equivalent to twice that amount. This structural imbalance underlines the opportunity cost of underinvestment in road safety and reinforces the economic argument for ITS deployment (Wijnen and Stipdonk, 2018).

4.2.3. ITS deployment status in Ukraine

Ukraine's current ITS deployment is minimal by European standards. The national electronic toll collection system covers major national highways; however, automated speed enforcement remains limited to urban zones in Kyiv and several regional centres. Variable message signs and weather monitoring systems are absent from most of the inter-urban network. The regulatory framework for ITS has not yet been codified in national legislation, although the Ministry of Infrastructure's 2030 Transport Strategy references ITS as a priority development area (Riabykh et al., 2025).

The key barriers to ITS deployment in transitional economies include: (1) limited public investment budgets competing with basic infrastructure rehabilitation; (2) absence of enabling regulatory frameworks; (3) limited institutional capacity in transport ministries and road agencies; and (4) low public awareness and social trust in automated enforcement (Riabykh et al., 2025; World Bank, 2010). Each barrier is addressable through phased implementation, international technical assistance, and targeted public communication, strategies well-documented in the experience of Poland, Romania, and the Baltic states during their EU accession periods.

4.3. Cost-benefit analysis: M-06 pilot scenario

4.3.1. Corridor characterisation

The M-06 corridor section from Zhytomyr (km 115) to Rivne (km 190), a distance of 75 km, was selected as the pilot scenario on three criteria: (1) documented high crash frequency; (2) absence of existing ITS infrastructure; and (3) representativeness of the broader inter-urban highway network. Annual average daily traffic (AADT) on the section ranges from 6,200 to 9,800 vehicles, with heavy goods vehicles comprising 18–22% of flows. The speed limit is 110 km/h; observed mean speeds typically exceed 120 km/h during daylight hours.

4.3.2. Proposed ITS configuration

The proposed ITS configuration for the 75 km pilot corridor comprises:

- 15 average-speed enforcement cameras (one camera pair per 5 km, positioned at section entry/exit points and intermediate enforcement gantries)
- 6 variable message signs (one per 12.5 km, providing early warning of speed limit enforcement and weather hazards)
- 5 roadside weather monitoring stations (measuring pavement surface temperature, friction coefficient, visibility, and wind speed)
- A traffic management sub-centre in Zhytomyr is integrated with the national traffic management system and linked to emergency services dispatch

4.3.3. Investment and operating cost estimates

Capital and operating cost estimates are derived from European deployment benchmarks adjusted to Ukrainian market conditions (Table 2). Labour and civil works components are estimated to be 40% below Western European levels, based on procurement experience in comparable CEE contexts (Degrande et al., 2021).

Table 2: Capital cost components of the M-06 ITS pilot

Component	Unit cost (EUR)	Quantity	Total cost (EUR)
Average speed enforcement cameras	25,000	15	375,000
Variable message signs	30,000	6	180,000
Roadside weather stations	9,000	5	45,000
Traffic management sub-centre	–	1	45,000
Integration and communications	–	–	30,000
Contingency (10%)	–	–	67,500
Total capital investment			742,500
Annual operating and maintenance	–	–	120,000

Source: own elaboration; cost parameters adapted from Degrande et al. (2021) and Intelligent Transportation Systems Joint Program (2023)

4.3.4. Benefit estimation and CBA results

Annual safety benefits are calculated as the monetised value of prevented fatalities and injuries, using the income-adjusted Ukrainian VSL (SafetyCube Consortium, 2018).

Fatality prevention: Expected annual fatality reduction = 8 × 0.22 = 1.76 fatalities/year. At a VSL of EUR 700,000: $B_{fatal} = 1.76 \times 700{,}000 = \text{EUR } 1{,}232{,}000/\text{year}$.

Serious injury prevention: Expected serious injury reduction = 54 × 0.18 = 9.7 injuries/year. At EUR 75,000 per serious injury: $B_{injury} = 9.7 \times 75{,}000 = \text{EUR } 727{,}500/\text{year}$.

Property damage and emergency response reduction: EUR 85,000/year.

Total annual benefits: EUR 2,044,500/year.

Table 3 presents the full CBA summary.

Table 3: Summary cost-benefit analysis for the M-06 ITS pilot (10-year horizon, 5% discount rate)

Indicator	Value
Total capital investment	EUR 750,000
Annual operating cost	EUR 120,000
Total discounted costs (10 years)	EUR 1,677,217
Annual safety benefits	EUR 2,044,500
Total discounted benefits (10 years)	EUR 15,778,234
Net present value (NPV)	EUR 14,101,017
Benefit-cost ratio (BCR)	9.41:1
Simple payback period	~4 months

Source: own elaboration; effectiveness parameters derived from Byaruhanga and Evdorides (2021), Intelligent Transportation Systems Joint Program (2023) and Wijnen and Stipdonk (2018)

The BCR of 9.41 substantially exceeds the standard threshold of 1.0 used in most national transport appraisal frameworks, and compares favourably with BCRs of 2–5 reported for comparable C-ITS deployments in Western Europe (Degrande et al., 2021). Sensitivity analysis indicates that the project remains viable (BCR > 1) even if effectiveness assumptions are reduced by 60% or capital costs are doubled, a robustness feature characteristic of automated speed enforcement investments, where the evidence base is among the strongest of any ITS technology (Perez et al., 2025).

4.3.5. Three-stage national deployment model

Extrapolating from the pilot scenario, a three-stage national deployment model is proposed.

Stage 1 (Years 1–3): Pilot and proof-of-concept. Deploy ITS on 3–5 high-risk national highway segments (total 200–300 km), focusing on automated speed enforcement and weather monitoring. Estimated investment: EUR 5–7 million. Expected outcomes: 15–20% fatality reduction on covered segments; institutional capacity building; regulatory framework development.

Stage 2 (Years 4–7): Scale-up on national network. Extend ITS to the full TEN-T network in Ukraine (approximately 2,800 km), incorporating VMS, incident detection, and emergency call (eCall) integration. Estimated investment: EUR 80–100 million. Expected outcomes: 20–25% reduction in inter-urban fatalities; basis for EU co-financing under neighbourhood transport cooperation instruments.

Stage 3 (Years 8–15): C-ITS and V2X integration. Deploy cooperative ITS infrastructure on priority corridors, aligned with EU ITS-G5/C-V2X standards. Estimated investment: EUR 200–300 million. Expected outcomes: 30–40% fatality reduction; interoperability with the EU C-ITS network.

5. Discussion

5.1. Applicability of the CBA framework to emerging markets

The findings confirm that ITS cost-benefit ratios are highly favourable across diverse deployment contexts, but that the magnitude of the benefit is sensitive to baseline crash rates, the VSL applied, and the technology mix. For emerging European markets, the combination of high baseline crash rates and lower VSL creates a distinctive appraisal environment: while absolute benefit values are lower, the BCR is generally higher than in mature EU markets because the marginal safety improvement per euro invested is larger. This counterintuitive finding, that ITS is proportionally more cost-effective in low-income high-crash settings, has important implications for international development bank financing, which often discounts safety investments in developing contexts. The external costs framework developed by Maternova et al. (2023) provides a methodologically transparent basis for making this case to policymakers and co-financing bodies.

5.2. Governance and institutional prerequisites

The comparative evidence clearly indicates that deploying technology without adequate institutional infrastructure results in suboptimal outcomes. Poland's success reflects not merely camera installation but comprehensive institutional reform: specialised enforcement agencies, independent road safety observatories, multi-agency data integration, and sustained political commitment (European Transport Safety Council, 2023). For Ukraine, priorities include adopting EU ITS standards into national legislation, establishing an open ITS data platform integrated with emergency services, and developing performance-based procurement frameworks that attract private-sector co-investment.

The broader digitalisation of transport management provides the enabling infrastructure for these reforms. Ujlacka et al. (2024) demonstrated that telematics-enabled enterprise management generates measurable efficiency gains at the organisational level, reinforcing the multi-level value proposition of ITS investment beyond safety alone. The logistics performance analysis of

Jonasikova and Konecny (2024) further confirms that countries investing in transport infrastructure digitalisation achieve superior connectivity and competitiveness outcomes – an argument relevant to Ukraine's EU accession aspirations.

5.3. Financing mechanisms

Three co-financing mechanisms merit particular attention: (1) EU neighbourhood facility grants under the Global Gateway initiative, which have financed transport infrastructure in Ukraine and the Western Balkans; (2) EBRD and EIB transport safety lending windows, which have financed speed camera deployments in Romania and Bulgaria at below-market interest rates; and (3) public-private partnerships where speed camera operators recover costs from fine revenue-sharing arrangements, as practised in Poland and France. The combination of these mechanisms can substantially reduce the net public financing requirement while aligning private operator incentives with public road safety goals. Domeny (2024) efficiency assessment framework offers a complementary tool for evaluating the performance of publicly operated transport entities participating in such arrangements.

5.4. Limitations

The analysis is subject to several limitations that qualify the precision of the quantitative findings. First, the effectiveness parameters applied to the M-06 scenario are derived from European deployments, where enforcement culture, vehicle fleet characteristics, and road geometry may differ from the Ukrainian context; effectiveness rates may be lower in the near term as drivers adapt. Second, the VSL adaptation relies on income-elasticity assumptions subject to methodological debate; alternative specifications yield BCRs ranging from 5.8 to 14.2 for the base scenario. Third, the lack of disaggregated crash data for the specific M-06 segment introduces uncertainty into the baseline parameters. Future research should address these limitations through primary data collection and scenario-based sensitivity analysis.

6. Conclusions

This article has examined ITS as a strategic tool for sustainable road safety management in emerging European markets, with particular reference to Ukraine. Five principal conclusions emerge.

First, ITS technologies demonstrate robust, well-documented effectiveness in reducing road fatalities and injuries, with reductions ranging from 15% (ISA) to 50% (full AEB), depending on technology type and implementation quality (Intelligent Transportation Systems Joint Program, 2023; ERTICO, 2025).

Second, the cost-benefit case for ITS deployment is particularly strong in emerging European markets, where high baseline crash rates amplify the benefits. The M-06 pilot scenario generates a BCR of 9.4:1 and an NPV of EUR 14.1 million over ten years – returns that substantially exceed typical infrastructure investment benchmarks.

Third, the comparative evidence indicates that fatality outcomes are more strongly moderated by governance quality and enforcement capacity than by technology sophistication per se. Countries with robust institutional frameworks outperform technologically equivalent but institutionally weaker counterparts (European Transport Safety Council, 2023).

Fourth, a phased, three-stage national deployment model is technically feasible and financially viable for Ukraine, with Stage 1 investments recoverable within approximately 4 months of operation and funded through a combination of domestic budget, EU neighbourhood grants, and IFI lending.

Fifth, the development of a harmonised CBA framework for ITS investments, adapted to emerging European market conditions and incorporating income-adjusted VSL parameters, region-specific cost benchmarks, and phased deployment assumptions, represents a research gap with high practical relevance. Future work should develop and validate such a framework using primary data from multiple CEE deployment sites, building on the external cost methodology of Maternova et al. (2023) and the investment appraisal approaches of Byaruhanga and Evdorides (2021).

Road safety investment through ITS represents one of the highest-return public investment opportunities available to CEE governments and their international partners – one that requires not merely funding but sustained institutional development, regulatory harmonisation, and cross-sectoral coordination.

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Conflicts of Interest

The authors declare no conflict of interest.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the authors used Grammarly to improve language quality and GitHub Copilot to optimize visualization code. After using these tools, the authors reviewed and edited the content as needed and take full responsibility for the content of the published article.

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