



# 12<sup>TH</sup> IEEE SMART CITIES SYMPOSIUM PRAGUE

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## Proceedings of Abstracts

Smart Cities Symposium Prague & European Transport Congress 2026 is organised under the auspices of the City of Prague.



Ministry of Regional  
Development  
of the Czech Republic

## **Smart Cities Symposium Prague 2026**

28-29 May 2026, Prague, Czech Republic

### **Proceedings of Abstracts**

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## Conference topics and objectives

SCSP2026 will be the twelfth annual symposium. The main themes of the SCSP2026 will be cooperative cities not only in terms of sustainable mobility, but also the way to climate-neutral cities.

**The Smart Cities Symposium Prague 2026 covers the following key areas:**

- Cooperative Cities
- Climate-Neutral Cities
- System approach to Smart and Climate-Neutral Cities transformation
- Livable cities
- Smart Cities Modeling
- City resiliency

Accepted papers will be submitted for inclusion into IEEE Xplore subject to meeting IEEE Xplore's scope.

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# Abstracts section



# A Neural Network–Based Framework for Identifying Hazardous Road Segments Using Geometrical Road Attributes

 **Igor Gavrilov, Pavel Hrubeš, Emil Pelikan**

Road accidents; LSTM; Hazardous road segments; Road geometry; Traffic safety prediction

"Accurate identification of hazardous road segments is essential for improving road safety and prioritising preventive interventions. This study proposes a neural network–based framework for predicting hazardous road segments by leveraging detailed geometrical properties of roads, including lane number, lane width, and curvature. The proposed framework was applied to the D1 highway in the Czech Republic, using geospatial data and reported road accidents from 2024. The road geometry was divided into 10 m sectors, from which sequences of 300 m were generated to form input for a Long Short-Term Memory (LSTM) network. The model was trained using a weighted binary cross-entropy loss function to address class imbalance, where hazardous segments represented only 29.2% of samples. The trained model demonstrated strong predictive performance, achieving a weighted F1 score of 0.895 and a macro F1 score of 0.906, which effectively distinguished between hazardous and non-hazardous highway segments. The results demonstrate that integrating detailed road attributes within an LSTM-based framework can effectively capture spatial dependencies and non-linear relationships associated with accident occurrence. The framework provides a scalable approach for identifying high-risk segments across various road types, offering valuable support for data-driven decision-making in transportation safety management."

# Research on the Integration of High-Speed Rail Mobility Hub Functions Based on an International Expert Survey

 **Vladimír Kremlík, Miroslav Svátek, Peter Vittek, Miroslav Haltuf**

Computer security, energy management, mobility hub, rail transportation, smart hub, traffic information systems, urban areas.

"High-speed rail (HSR) stations are increasingly expected to operate as mobility hubs that integrate multimodal transport, urban functions, digital services and low-carbon energy. This paper proposes a modular functional architecture for Mobility Hubs intended for future Czech HSR terminals. The approach combines a structured literature review with an international questionnaire survey (81 items) administered to infrastructure managers and station operators, complemented by a comparative assessment of ten operating hubs in Europe and Asia. Results indicate that multimodal integration and passenger services are widely implemented, whereas energy autonomy, alternative-fuel infrastructure aligned with the Alternative Fuels Infrastructure Regulation (AFIR), and cybersecurity governance remain uneven. Based on observed practices, we synthesize a reference set of functional modules covering rail operations and passenger flow management, multimodal interchange and parking, digital passenger services and Mobility as a Service (MaaS), safety and cyber protection, energy management and low-emission supply options (including fuel cells), universal accessibility for Passengers with Reduced Mobility (PRM), and mixed-use urban integration and governance. The architecture supports staged implementation and scalability and provides a basis for requirements definition and cross-case benchmarking of future HSR Mobility Hubs."

# Smart Vision for Clean Cities: Deep Learning-Based Graffiti Detection in Prague

 **Luuk Milo van Breugel, Segar Met, Vishay Ramcharan, Tomas Horak, Miroslav Svitek**

AI model, CNN, Deep learning, Graffiti Detection, Prague, Smart Vision

"The city of Prague, Czech Republic, has one of the most beautiful historic centers in the world. However, it is not immune to vandalism such as graffiti, which affects cultural heritage and contributes to a negative public perception of cleanliness and safety. Traditional methods of graffiti prevention remain labor-intensive and inefficient. This paper presents a smart vision approach for automated graffiti detection in Prague by the use of a Faster R-CNN model with a ResNet-50 backbone and data augmentation. The model is trained in the STORM dataset and achieves a precision of 79%, recall of 70%, and mIoU of 70% at an optimized threshold. Approximately 400 images were collected in a 500 x 500 meter area in the Old Town of Prague, including historical religious buildings and a dense network of narrow medieval streets. These images, analyzed by the model, were able to construct a spatial graffiti-intensity heatmap with hotspots concentrated in narrow streets with limited surveillance, while public squares and big streets showed fewer detections. Despite room for improvement in the model, the generated heatmap can already support more efficient graffiti prevention strategies, including optimized police patrol routes and targeted cleaning programs."

# 15-minute city analysis of new residential projects in Prague and Bergamo

 **David Kosik, Edoardo Zoppi, Tomas Horak, Miroslav Svitek**

smart city, 15-minute city, new development walkability, urban pedestrian facility accessibility

"This paper analyses facility accessibility of new residential projects in Prague, Czech Republic and Bergamo, Italy. New residential projects are important for the development of a city, the development of nearby amenities to new development is important for the quality of life of the new residents, poor placement of new development and lack of amenities can be difficult to remedy. A 15-minute walking radius approach is coupled with open-source geospatial data and time-distance matrix calculations. Amenities were divided into groups by urban functions. The paper finds that the selected new residential projects in Prague and Bergamo are within a 15-minute radius and the new residential projects benefit from good placement ensuring sufficient amenity accessibility by walking."

# From Zdiby to Prague: Designing Tram Logistics for Alza

 **Matej Harant, Matyas Sedivy, Tomas Horak, Miroslav Svitek**

Cargo Tram, City Logistics, Last-mile Delivery, Prague, Public Transport, Urban Logistics

"Urban logistics faces increasing pressure to reduce emissions and traffic congestion while maintaining high service levels for e-commerce. This paper develops a general framework for evaluating cargo-tram integration and applies it to a Prague case study linking the planned Zdiby extension with four major Alza branches. The routing problem is formulated on a directed tram graph and solved by a state-extended Dijkstra's algorithm with turn penalties and stop-visitation states. A second screening step evaluates night-time timetable compatibility on shared passenger infrastructure. For the Prague case, the feasible loop serves Vltavská, Dejvická, Anděl and Pankrác, departs at 03:10, and returns to Zdiby at 06:21. Under the assumed vehicle layout, one tram can transport up to 19 roll cages, corresponding to an upper bound of 4.75 t or approximately 1,710 parcels per trip. The results confirm technical feasibility for night operation, while also identifying noise, timetable coordination, infrastructure access, and demand uncertainty as key implementation limits."

# Improving public transport in the Calarasi and Olt Valley regions of Romania

 **Stefan Popa, Eduard - Antonio Surdoaia, Tomas Horak, Miroslav Svitek**

Corridor Transport Modelling, DRT, Elasticity-based demand estimation, Fleet sizing, Gravity model, ODPT, Rural mobility

"This paper evaluates the feasibility of On-Demand Public Transport (ODPT) in two contrasting Romanian regions: the Olt Valley, a congested, linear mobility corridor, and the Călărași–Lehliu Gară lowland region. A macroscopic modelling framework is developed using census-based trip generation, behavioral aggregation through an elasticity-based function, and a corrected gravity model to preserve long-distance socioeconomic interactions. The model estimates ODPT demand, accessibility, cycle structure, and fleet requirements for each hub. Results show that ODPT demand is highest in the Olt Valley due to strong regional attractors, tourism and congestion along DN7, while Călărași exhibits lower but more uniformly distributed demand. The combined use of  $\epsilon$  and  $\lambda$  captures the distinct spatial and behavioral dynamics of both regions, demonstrating ODPT's capacity to provide flexible, efficient mobility where fixed-route transport is unsuitable. The findings support ODPT as a viable solution for improving rural and peri-urban accessibility."

# Safety Analysis for the Perception System of Autonomous Train Operation

 **Lukáš Kacar, Michal Matowicki, Tomáš Tichý**

Automatic Train Operation, Autonomous Train, Cooperative Cities, ETCS, Grade of Automation, Perception, Rail Transport, Railway Safety, RAMS, Risk Analysis, SIL, Smart City, Urban Mobility

"The highly automated and autonomous operation of trains is becoming an integral part of future smart urban mobility systems. Although Grade of Automation (GoA) 3 and GoA4 are already deployed in closed metro networks, extending autonomous operation to open urban and suburban rail environments introduces new safety challenges due to interactions with pedestrians, road traffic, level crossings and heterogeneous city infrastructure. In this context, the perception system plays a critical role as a cooperative interface between the autonomous train, the surrounding urban environment, and other smart mobility subsystems. Replaces the situational awareness traditionally provided by a human driver and enables safe operation in complex, partially uncontrolled city environments. This article presents a safety analysis of a perception system for autonomous train operation in open rail networks, using a top-down risk assessment approach aligned with the Common Safety Methods (CSM) and the CENELEC EN 50126 standard. The failure modes of perception functions are identified, their impact on operational and public safety is evaluated, and their interaction with key railway systems such as ETCS and ATO is analyzed. The results support the safe integration of perception-based autonomy into smart city rail ecosystems, provided that clear responsibility boundaries, external safety barriers, and conservative safety integrity requirements are applied. The paper contributes to the concept of cooperative cities by demonstrating how autonomous rail systems can safely coexist and cooperate with urban infrastructure, road users, and citizens."

# Autonomous Public Transport as Part of Critical Infrastructure: Cybersecurity and System Resilience

○ **Tomáš Tichý, Tomáš Kohout, Miroslav Vaniš, Pavel Hájek, Karel Janečka, Lukáš Pícek, Jiří Brož, Jiří Růžička, Eva Hajčiarová, Kristýna Navrátilová, Lukáš Kacar, Martin Zajíček, Zuzana Bělinová, Pavol Kuchár, Júlia Kafková, Petr Procházka**

autonomous mobility, public transport, critical infrastructure, cybersecurity, system resilience, HD maps, traffic control, digital twin, ITS, C-ITS, tram traffic, Smart City

Autonomous public transport is becoming an integral component of the Smart City paradigm and, concurrently, a key element of critical urban infrastructure. Besides operational benefits, increasing automation, connectivity, and digitalization introduce updated requirements for security, reliability, and resilience against cyberattacks and unintended system behaviors. This article presents a methodological and technological framework for deploying autonomous public transport management in urban environments, with a special emphasis on rail-based modes and their safe integration into a city's critical infrastructure. The proposed approach combines dynamic HD maps, a digital twin of the urban environment, and cooperative intelligent transport systems (C-ITS) to achieve precise localization, enhanced situational awareness, and real-time data exchange among vehicles, infrastructure, and dispatch centers. Vehicle and infrastructure sensors feed a unified data platform that supports monitoring, diagnostics, and operational control. The architecture prioritizes secure data transmission, network segmentation, access control, and cyber-threat mitigation to ensure business continuity and high service availability.

# Evaluating Barriers to Pan-European Traffic Data Exchange: Metadata, Structural Quality, and Consumer Usability and Accessibility

 **Petr Bureš, Chrysostomos Mylonas, Maria Stavara, Jan Vičinský, Apostolos Vouitsis, Evangelos Mitsakis**

Intelligent Transport Systems, National Access Points, ITS Data Exchange, Safety-Related Traffic Information, Formal Quality of NAP Publications, Pan-European Road Status Visualization Tool

Making traffic information accessible on a pan-European scale presents significant challenges for data publishers and consumers. Our research evaluated the real-world experience of unprivileged data consumers accessing such information across Europe. We examined 31 National Access Points (NAPs), 39 catalogue records, and 42 distributions from 22 publishers, grading them on an A-F scale with a focus on Safety Related Traffic Information (SRTI). Results showed that while 21 records received B grades, half of distributions lacked proper DATEX II XML schemas, and many protocols exhibited implementation flaws in content encoding, authentication, and data validation. Location referencing frequently lacked crucial data for map visualization. Our findings confirm that while pan-European traffic information exchange functions at a basic level, it faces substantial quality and accessibility barriers. Improvements require better publisher education and formal evaluation processes. Though focused on SRTI, our approach could enhance data consumer experience across all mobility services, including public transportation.

# Wearable Metabolic Sensing for Thermal Comfort Control in Smart and Energy-Efficient Buildings

 **Pei Zhang, Huihe Qiu**

thermal comfort, energy-saving building, metabolic rate

"At the building and city scale, conventional HVAC systems typically follow fixed temperature setpoints, leading to comfort complaints and energy waste as occupants' thermal states vary over time. Human-centric HVAC control offers a promising solution to improve indoor well-being while reducing building energy use, but it requires accurate, real-time estimation of individuals' metabolic rates for thermal comfort prediction. This study presents a wearable-friendly approach for estimating metabolic rate and, based on this method, develops a wristworn measurement system tailored for next-generation smart buildings. The proposed system replaces bulky calorimetry with a compact, physics-based sensing framework that integrates heart rate, whole-body unit heat loss, skin resistance, and body muscle percentage. Whole-body heat-loss estimation is improved by incorporating a segment-based convective heat loss coefficient, enabling more consistent mapping from wrist measurements across varying environmental conditions. Overall, this work provides scalable, occupant-specific inputs to comfort models and supports the development of closed-loop, human-centric HVAC strategies that simultaneously enhance comfort and reduce energy consumption."

# Modelling Bicycle Rider Behavior in a Smart City

 **Leon J. M. Rothkrantz, Siska Fitrianie**

Bicycles, Global Positioning System, green transportation, modelling, questionnaire, smart cities

"Delft is a student city with many daily cyclists traveling between the train station and the university campus. As the city works toward becoming

an eco-city, it is important to understand how bicycle traffic works in order to design safer and better bike paths. Most current traffic models are based on cars and do not fit cyclist behavior, especially during busy hours.

The results show that bicycle traffic is highly dynamic, characterized by fluctuating densities and short but intense congestion waves during rush hours, often triggered by train arrivals and lecture schedules. A distinct behavioral category, termed the "hasty cyclist," was identified. These cyclists tend to prioritize speed over safety, frequently overtaking others, forming informal lanes, and occasionally ignoring traffic signals. Questionnaire analysis suggests that this behavior is influenced by both situational factors such as time pressure and individual traits, rather than personality alone. Overall, the study highlights fundamental differences between bicycle and car traffic, including flexible lane formation and highly variable speeds. It also introduces an initial behavioral framework for cyclist modeling. The findings underline the need for dedicated bicycle traffic models to support safer infrastructure design and sustainable urban mobility in the city."

# From Metrics to Decisions: Interpreting Route Deviation and Service Quality Indices in Public Transport Planning

 **Markéta Jirmanová, Patrik Horaždovský, Ondřej Příbyl**

Public transport; Route-quality index; Level of Service; Data-driven decision making; Route detours.

"Designing public transport services in suburban and peripheral areas requires balancing route efficiency, service quality, and social accessibility. While several indices exist to evaluate route directness and level of service, their interpretation under low and heterogeneous demand conditions often leads to ambiguous planning conclusions. This paper examines how operational performance indicators and route-quality measures behave under varying demand assumptions and how they can be translated into decision-relevant insights. Using a case study of selected radial bus routes, real-world operational data are combined with simulated demand scenarios to analyze the sensitivity of passenger-weighted route deviation measures and travel-time-based service indicators. The results show that identical route configurations may yield conflicting quality assessments depending on passenger exposure, highlighting a structural efficiency-equity dilemma.

To address this issue, a refined passenger-weighted route deviation indicator is introduced as a penalty-oriented, policy-aware diagnostic tool. Combined with operational reliability measures, the proposed approach supports transparent decisions on route restructuring, infrastructure investment, and the use of demand-responsive services."

# Beyond Normality: Regime-Aware, Multi-Modal Baselines for Public Transport Inter-Stop Travel Times

 **Markéta Jirmanová, Pavla Pecherková**

public transport, travel time, heterogeneity, multi-modality, mixture models, regime detection, smart city analytics

"Urban public transport (PT operations generate large volumes of inter-stop travel time observations from AVL/GNSS systems. These data underpin "typical" travel-time baselines used in monitoring, planning, anomaly detection, and KPI reporting. A common assumption in applied studies is that the empirical distributions of observed inter-stop travel times can be described by a single parametric distribution (typically normal, lognormal, or gamma, which implicitly treats variability as unimodal noise and leads to biased baselines and performance measures. This paper argues that for many inter-stop segments, this assumption is systematically violated because observations arise from regime mixing (e.g., uncongested vs. saturated signal cycles, varying dwell-time interactions, and recurrent congestion, producing multi-modal empirical distributions. We propose a regime-aware baseline framework centered on (i explicit multimodality diagnostics and (ii parsimonious finite-mixture / regime representations that separate recurrent operational states and demonstrate its advantages against single-distribution models (normal/lognormal/gamma using likelihood-based criteria and dedicated multi-modality tests. Using AVL-derived public transport data from three Czech cities — Pilsen, Brno, and the Prague metropolitan area (part of PID interurban bus services — we quantify the prevalence of statistically significant multimodality in inter-stop travel-time distributions. We demonstrate that conventional single-distribution baselines often systematically misrepresent typical conditions, distort segment rankings, and obscure recurrent operational regimes that are directly relevant for performance assessment and planning."

# Extending Transportation Digital Twins with Behavioral Dynamics: Linking Traffic Operations and Activity-Based Demand

 **Milad Ziya, Ondřej Příbyl**

Activity-based modeling, calibration, decision support systems, digital shadow, digital twin, inference, MATSim.

"Digital-twin (DT platforms are increasingly deployed in transport systems to support real-time monitoring and smart-city mobility decision support through a continuous alignment between observed data and simulation, forming a Digital Shadow. However, a critical gap exists in the evaluation of mobility policies: the inference step required to interpret discrepancies between the physical transport system and its virtual replica. This paper proposes a dual-loop DT architecture that decouples a fast operational loop (Digital Shadow for state estimation and dynamic traffic assignment (DTA from a slow learning loop (Travel Behavior DT for strategic demand adaptation. Central to this framework is an interpretation/inference layer that performs evidence-driven discrepancy diagnosis to disambiguate supply-side disruptions from demand-side behavioral shifts using state/LOS signatures. The behavioral loop integrates multi-source streams such as GPS traces, smartcard records, and app logs to update activity-based demand representations via accessibility/utility metrics (logsums and MATSim-compatible plan adaptation. Furthermore, the architecture incorporates a Decision Support System (DSS that accounts for traveler perception and response to information and incentives. This blueprint provides a defensible and socially responsive framework for smart-city mobility governance and the evaluation of complex mobility policies within digital-twin environments."

# Urban Traffic Detection Technologies: Limitations and a Data-Centric Architectural Perspective

 **Martin Zajčček, Zdeněk Lokaj, Tomáš Tichý, Miroslav Vaniš, Lukáš Kacar**

C-ITS, detection technology, urban traffic, traffic control

"Urban traffic management increasingly relies on accurate, timely and robust traffic detection to support safe, efficient and sustainable mobility in complex urban environments. While a wide range of traffic detection technologies is currently available, many limitations persist due to fragmented data utilization, limited interoperability and sensor-centric system architectures. This paper provides a structured review of commonly used urban traffic detection technologies and analyses their technical and system-level limitations. Based on this analysis, a data-centric reference architecture is proposed, which decouples traffic detection capabilities from individual sensing technologies and enables the integration of heterogeneous infrastructure-based sensors, mobile data and C-ITS sources through harmonization and AI-based multi-source fusion. Rather than presenting a concrete system implementation, the proposed architecture serves as a conceptual framework supporting resilient, scalable and future-ready traffic detection. Its relevance is illustrated using representative use cases focusing on vulnerable road user detection, predictive traffic management and incident handling. The paper argues that use case-driven, data-centric architectural design represents a key enabler for next-generation urban traffic management in smart city environments."

# Public Transport Integration of Regional Capitals in the Czech Republic

 **Lukáš Kacar, Milan Sliacky**

Integrated Public Transport; Regional Capitals; Fare Integration; Fare Collection and Information Systems; Tariff Integration; Urban Mobility

"The article deals with the issue of integrating public transport of regional capitals into integrated regional public transport systems. The aim of the work is to analyze the degree and forms of fare integration in thirteen regional cities, focusing on the conditions for short-term single fares, which best reflect the actual interconnection of urban and regional transport from the passenger's point of view. Based on four predefined criteria of the proposed methodology, individual cities are compared in terms of acceptance of state discounts, the existence of parallel public transport fares, the price differentiation between urban and regional zones, and differences between the use of urban and regional lines within the urban area. The results show considerable heterogeneity in the approaches of individual regions, which is conditioned by institutional arrangements, tariff policy, and the technical capabilities of ticketing systems. Plzen, Liberec, Jihlava, and Usti nad Labem show the highest degree of integration, while in Ostrava and Olomouc there are still significant tariff differences between urban and regional transport. Prague and Brno achieve a medium level of integration, with their extensive public transport systems posing a specific challenge in terms of financing social discounts. The study also confirms the tendency between the size of a regional capital and the level of integration of city public transport into integrated public transport systems (IPTs) and points to the influence of the fare model used. The article emphasizes that full fare and operational integration brings significant benefits to passengers but requires intensive coordination between cities, regions, and their transport organizers. The conclusions of the study can help in the integration process of public transport in the Czech Republic. If the initial assumptions are met, these conclusions may also be applied abroad."

# A framework for evaluating metro vehicle layouts to maximize satisfied passenger demand: A case study of Genoa metro

 **Summair Anis, Davide Giglio, Nicola Sacco**

Metro carriage layouts, Capacity utilization, Service efficiency, Resource utilization

"Metro systems of a region play an important role in the provision of high-speed and seamless connectivity between two stops. They also play an important role in addressing the issues related to congestion and environmental concerns while operating at underground levels. However, they often face problems related to the overcrowding of carriages and platforms which affects their efficiency and the comfort they offer to commuters. To this effect, the vehicle carriage layout plays an important role in handling the passenger demand. In this framework, this paper focuses on identifying the best layout of vehicle carriages that should be adopted during different operational periods of the metro to better serve passenger demands with the best achievable resource utilization. In doing so, a mathematical model is formulated with the aim of maximizing the average capacity utilization of metros while analyzing the resulting impacts over satisfied passenger demand. The efficiency of the proposed model is evaluated using the case study for the metro network of Genoa, Italy. In this context, a number of different scenarios of metro vehicle carriage layouts are tested to identify the best layout during two selected time periods, namely peak hour and off-peak hour periods. Overall, the results provide insights to stakeholders for making informed decisions by analyzing the average occupancy of metros in relation to the satisfied passenger demand, under different tested scenarios."

# Principles of Object–Process Methodology for System Architecture Modeling in Complex Transport Systems

 **Vladimír Kremlík, Miroslav Svátek, Vojtěch Merunka, Jiří Kofránek**

Mobility Hub, Object–Process Methodology (OPM), ČSN ISO 19450, High-speed rail (HSR), Large Language Models (LLMs), Modular functional architecture, Mobility as a Service (MaaS), Smart City, Smart Neighborhood, Industry 4.0, Mobility 4.0

"The paper introduces Object–Process Methodology (OPM; ISO 19450) as a unifying approach for designing a modular functional architecture of Mobility Hubs. OPM integrates the structural dimension (objects, assets, roles) and the behavioural dimension (processes, information and energy flows, control) into a single, coherent model. The paper outlines the core principles of OPM and its bimodal representation: graphical Object–Process Diagrams (OPDs) are paired with an equivalent textual specification in Object–Process Language (OPL). This duality supports intelligible communication with non-technical experts, facilitates requirements validation, and enables early detection of errors such as incompleteness, contradictions, or missing links between functions and resources. The practical value of OPM is demonstrated through a simplified case of passenger rail transport within the Czech Republic, where the end-to-end passenger journey is hierarchically decomposed. The example illustrates how OPM integrates processes with the required objects and resources (e.g., the app, ticket, travel plan, station, train, signaling) within a single coherent OPD/OPL model, enabling systematic checks of linkage completeness, decision conditions, and cross-level consistency."

# Accelerating Smart City Resiliency: AI-Agent Approach to Isotope Detection Development

 **Jan Zbirovsky, Kamil Stanek, Michal Jerabek, Lenka Kuklisova-Pavelkova**

multi-agent systems, radiation monitoring, smart city resilience, Monte Carlo simulation, isotope detection, IoT sensor networks

Urban resilience requires rapid deployment of monitoring systems capable of detecting radiological threats in transport networks without disrupting normal operations. This paper presents a multi-agent AI framework designed to accelerate the development and integration of isotope detection systems within smart city ecosystems. The proposed framework employs a hierarchical orchestrator-executor architecture in which specialized AI agents collaborate to generate synthetic training data via GEANT4 Monte Carlo simulations of NaI(Tl) scintillation spectra, automate the development workflow including script generation, test-driven development, and result aggregation, and prepare a data foundation for deploying classification models at urban transport checkpoints. The modular architecture with a TCP API interface enables seamless integration with existing smart city platforms and scales for metropolitan deployment. This work demonstrates that heterogeneous LLM-based multi-agent orchestration substantially accelerates radiological simulation pipelines and establishes the direction for autonomous radiological monitoring at smart city transport nodes.

# Parking in cities: Analysis of data from paid parking zones

 **Kristyna Navratilova, Tomas Tichy, Jiri Broz, Jiri Ruzicka, Eva Hajciarova**

[parking, public space, cities, parking zones, pricing](#)

"Most cities today use paid parking zones as the main tool for optimizing the use of parking spaces and public space. This paper describes the main research activities in the field of parking, including aspects where parking regulation has a major impact, and, above all, presents the outputs of the data analysis, which focused on the capacity of parking spaces, pricing, use, and compliance with defined rules. The analysis shows that price can be effectively used as a regulatory tool to reduce parking duration and increase the turnover of parked vehicles. In almost 30% of cases where parking time was monitored, a strong link to the price of a parking space was found. At the same time, the analysis shows that price increases do not have a major impact on compliance with parking rules. The application of appropriately set regulation proves that enduser behaviour can be influenced, including the optimal use of public space, in order to create cities that are accessible and habitable for different types of users."

# Smart Mobility in the Institutional Trap: Analysis of Non-technological Implementation Barriers in Czech Public Administration

 **Luke Bojčev, Radomíra Jordová**

Smart Mobility, Institutional Trap, Public Procurement, Vendor Lock-in, Multi-level Governance, Dynamic Capabilities

While the technological maturity of Smart Mobility solutions has accelerated rapidly, their effective deployment in the public sector remains quite stagnant. This paper challenges the prevailing technocratic narrative by arguing that the primary hurdles to Smart City development are not technological or financial but deeply institutional. Drawing on a unique qualitative dataset of semi structured interviews with city and regional representatives in the Czech Republic, we identify a systemic Institutional Trap. Our findings reveal that a culture of defensive procurement, political discontinuity, and organisational fragmentation (resortism) actively neutralises innovation. We demonstrate that current subsidy mechanisms, biased towards Capital Expenditure, create an Investment Trap that fosters unsustainable projects and deepens vendor lock-in. The study concludes that without a fundamental software upgrade of public administration specifically regarding human capacity and legislative agility the hardware of smart mobility will remain functionally unutilised.

# Cybersecurity Risk Analysis in Critical Transport Infrastructure: Potential of Probabilistic Models

 **Martin Zajčcek, Miroslav Vaniš, Zdeněk Lokaj, Martin Šrotýř**

Bayesian networks, critical transport infrastructure, cybersecurity risk assessment, influence diagrams, probabilistic risk modelling

"This paper reviews current approaches to cybersecurity risk analysis in critical transport infrastructure, with particular focus on their applicability to complex cyber-physical environments such as tunnel control systems. Modern transport infrastructures are characterised by strong interdependencies between digital control technologies and physical operational processes, which increase cybersecurity risks and the potential for cascading failures. The review shows that existing methodologies are based on standards-driven and governance-oriented frameworks. While these approaches provide structured procedures for risk identification and regulatory compliance, they remain largely qualitative, static, and limited in their ability to represent uncertainty, system interdependencies, and dynamic cyber-physical interactions. To address these limitations, the paper discusses the potential of probabilistic modelling approaches capable of supporting decision-making under uncertainty. Probabilistic graphical models offer mechanisms for modelling complex dependencies, integrating expert knowledge with available data, and improving analytical support for cybersecurity risk management. The findings highlight the need to complement compliance-oriented methodologies with probabilistic and decision-oriented approaches to enhance cybersecurity resilience in critical transport infrastructure."

# Assessment of Rider Visual Behaviour – Pilot Study During Training Track Riding

 **Vojtěch Thums, Přemysl Toman, Josef Svoboda**

powered two-wheelers (PTW), eye-tracking (ET), rider visual behaviour, motorcycle training, human-machine interface (HMI), smart urban mobility, pilot study

Powered two-wheelers (PTWs) are a vulnerable yet increasingly relevant component of smart urban mobility systems. Enhancing rider safety within intelligent and sustainable transport frameworks requires objective assessment of rider perception and visuomotor behaviour, particularly during skill acquisition. This study evaluates rider visual behaviour during structured motorcycle training tasks conducted in a real riding environment. Eye-tracking glasses were used to record gaze data from novice, intermediate, and instructor-level riders performing low-speed maneuvers. Quantitative metrics, including fixation frequency and gaze distribution within predefined Areas of Interest, were combined with qualitative scene-video analysis. The results indicate that visual strategies vary depending on the rider's level of experience with PTW riding. The findings indicate that eye-tracking-based evaluation can provide objective input for rider training assessment and may support the development of human-centred assistance systems and simulator-based training tools for safer integration of PTWs into smart and sustainable urban mobility ecosystems.

# Optimizing Municipal Teams: Personalized Learning for T-Shaped Profile Development

 **Klára Kubíčková, Janka Marschalková, Zuzana Hruška, Leonard Wallezky**

T-shape, Multidisciplinarity, Smart Cities, Cooperative City, Collaboration

"As Smart Cities mature from technological pilots to complex Cooperative Cities, the primary barrier to success is often not technical, but organizational. Traditional municipal structures rely on vertical silos that inhibit the crossdepartmental collaboration required for climate neutrality and system-level resilience. This paper argues that the Cooperative City requires a fundamental shift in human capital development toward T-shaped professionals—experts who combine deep vertical specialization with broad horizontal skills in boundary spanning and strategic collaboration. We present findings from a qualitative study of Czech municipalities identifying a critical gap in these horizontal competencies and a reactive approach to upskilling. In response, we introduce a Proof of Concept for an AI-driven system and explore the potential of Large Language Models (LLMs) to transform municipal education. We specifically identify the challenges of moving beyond static recommendations toward automated, individualized content generation. By synthesizing practical best practice examples into personalized learning paths, we demonstrate a vision for a "human infrastructure" that fosters true inter-institutional cooperation."

# Synergy of Semantic Modeling and Multi-Agent Systems for Resilient Smart City Utility Networks

 **Leonard Wallezky, Miroslav Svítek, Sergei Kozhevnikov, Zuzana Hruška**

4DocMod, Multiagent approach, Service thinking, Service dominant logic

"Bridging the gap between conceptual service design and technical execution remains a critical challenge for Smart City resilience. This research presents a novel integration of the 4DocMod semantic framework with Multi-Agent Technology (MAT) for autonomous utility network management. Using the "Diamond See" methodology, we deconstruct technical ontologies into dynamic semantic maps. The proposed framework enables "paradigmatic resilience," allowing AI agents to switch operational logics—from economic optimization to crisis survival—via a "Context Bridge." This approach ensures systemic stability in complex urban ecosystems without requiring modifications to the agents' core programming."

# Cybersecurity Risk Analysis in Critical Transport Infrastructure: Potential of Probabilistic Models

 **Benjamin Gabber, Jiří Růžička, Eva Hajčiarová, Felix Rudolph, Tomáš Tichý, Jiří Brož**

traffic control, C-ITS, energy consumption, TLS, TransUrban project

"Traffic lights are a key tool to ensure safe and smooth traffic control in smart cities. Due to the complexity of the urban traffic situations, including different needs for different road users, dense development, and special constraints, the traffic light design process is not trivial. Modern trends in the field of traffic light control systems (TLS) primarily aim at greater adaptability, the use of predictive algorithms and the integration of Cooperative Intelligent Transport Systems (C-ITS) communication, while maintaining comprehensibility and user-friendliness for all traffic participants. One of the key issues in European R&D is sustainable transport, as efforts to reduce emissions and energy consumption are becoming increasingly important. As part of the first phase of the international TransUrban project, a research and analysis of current TLS in Germany and the Czech Republic was carried out. Through qualitative interviews with leading experts in the fields of traffic engineering and C-ITS, the key current and future challenges of these systems were examined and assessed, with an emphasis on sustainability aspects. The research questions focused on the development of new control systems and on the increasing importance of prioritizing certain road users at traffic lights. Experts suggest that, whilst the current TLS is functioning well, further improvements are needed in managing complex networks and in data-driven control. Differences emerge in evaluation approaches and preferred applications, whereas both countries share common views on key development directions and the relevance of cooperative and data-based solutions."

# Uncovering Urban Mobility Signatures: A Multi-Facility Analysis of Parking Behavior

 **Ondrej Pribyl, Roman Dostal**

Urban Mobility, Parking Behavior, Watershed Transform, Multinomial Logit, Smart Cities, Big Data Analytics, Policy Sensitivity

"This paper presents a novel data-driven framework for identifying and quantifying urban mobility signatures using long-term parking transaction data. Leveraging a longitudinal dataset spanning 97 months and over 221,000 observations across 222 parking installations, we move beyond aggregate occupancy metrics to uncover latent behavioral archetypes. We employ an unsupervised watershed transform to segment the arrival-duration density space, successfully isolating seven distinct mobility signatures ranging from high-turnover utility visits to multi-day vehicle storage. These discovered behaviors serve as dependent variables in a Multinomial Logit (MNL model designed to evaluate policy sensitivity. Our results demonstrate that pricing acts as a significant structural filter, with a strong negative coefficient ( $\beta = -1.1215$ ,  $p < 0.001$ ) for workday commuting, effectively shifting facility composition toward high-velocity urban utility. Furthermore, the model reveals a critical dependency on infrastructure, where proximity to the public transport backbone significantly suppresses long-term vehicle idling ( $\beta = 1.0526$  for transit distance). This research provides a robust, GDPR-compliant methodology for urban planners to transition from reactive monitoring to proactive, signature-based policy design, enabling more efficient utilization of existing urban infrastructure without intrusive tracking technologies."

# Forecasting Accuracy Assessment of Average Vehicle Speeds Derived from Floating Car Data on the D11 Motorway: From ARIMA to ARIMAX

 **František Kekula, Pavel Hruběš**

reliability, floating car data, time series forecasting, time series stationarity, autocorrelation, cross-correlation, ARIMA, ARIMAX.

Monitoring traffic flow conditions is crucial for quantifying transportation performance and making transportation decisions. Vehicle speed appears to be an essential traffic parameter that can be used to evaluate the performance of different road segments. This study investigates the reliability of the vehicle speed model derived from Floating Car Data (FCD) on the sample from the D11 motorway in the Czech Republic through ARIMA and ARIMAX time series forecasting. For the forecasting accuracy assessment, the average speeds from automatic traffic counters (ATCs) were used as ground truth data. First, the augmented Dickey-Fuller test was conducted to test the time series stationarity. After the testing, the autocorrelation functions were calculated to check whether the series are highly autocorrelated. Since the calculated autocorrelation functions proved highly autocorrelated time series, the pre-whitening method was applied in order to make a more reliable subsequent cross-correlations. Finally, the ARIMA and ARIMAX models were fitted. The residual diagnostic indicates that the ARIMAX model outperforms the ARIMA model and therefore improves prediction capabilities with the use of the vehicle speed model. The prediction performance varies between the different lanes of the motorway.

# Human–Machine Interface Design Implications for Fuel Cell Range-Extended Motorcycles

 **Josef Svoboda, Přemysl Toman, Petr Bouchner,  
Ulrike Michel-Schneider, Dušan Poliaček, Pavel Horák**

Fuel Cell, Human Machine Interface, Motorcycle Simulator, Powered Two-Wheelers

The decarbonisation of urban mobility is accelerating the development of alternative propulsion technologies for light vehicles, including hydrogen fuel cell systems. In powered two-wheelers, hybrid battery–hydrogen architectures can extend operational range while preserving the advantages of battery-electric mobility. However, such multi-source energy systems introduce additional complexity that must be effectively communicated through the vehicle’s human–machine interface (HMI). This study investigates rider perception, trust, and visual attention when interacting with an HMI designed for a hydrogen fuel cell range-extended motorcycle. The evaluation was conducted using a high-fidelity motorcycle riding simulator combined with eye-tracking measurements and user experience questionnaires. Results show that riders predominantly prioritize battery-derived range information, while hydrogen indicators attract attention mainly during propulsion transitions. Participants reported high trust in the displayed information and positive usability ratings. The study provides experimental eye-tracking evidence on how riders interpret multi-source energy information and highlights the importance of clear visual hierarchy and transition signalling in HMI design for hybrid electric–hydrogen motorcycles.

# Evaluation of a Cabin Design Using Virtual Reality

 **Michal Cenkner, Naďa Tylová, Ulrike Michel-Schneider, Illia Melnyk, Petr Bouchner**

crane cabin, design evaluation, gaze mapping, headset motion tracking, virtual reality

Traditionally, operator cabin design is evaluated using physical mock-ups and subjective feedback based on user impressions and preferences. However, this approach is time-consuming, costly, and lacks objective metrics for systematic comparison. Virtual reality (VR), combined with physical simulator hardware, enables immersive real-time testing of cabin layouts during simulated crane operation. Modern VR headsets track head position and orientation within the virtual scene, allowing estimation of the operator's viewing direction. Using this approach, we conducted a pilot study to analyze the distribution of operator gaze and map the operator's field of view for two different crane cabin layouts. The results introduce gaze-based metrics that enable the identification of operator visual behavior patterns and provide a basis for systematic comparison of cabin layouts.



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