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REAL-TIME SITUATIONAL TRAFFIC AWARENESS PLATFORM: LEVERAGING SENSOR DATA FOR SAFER URBAN MOBILITY

Abstract

The ITS World Congress 2025 theme, "Deploying Today, Empowering Tomorrow," highlights the potential of intelligent transportation systems (ITS) to revolutionize urban mobility. This essay presents the Real-Time Situational Traffic Awareness Platform (RTSAP), an innovative framework that integrates vehicle and infrastructure sensor data, artificial intelligence, and agent-based simulations to enhance traffic safety and efficiency. Unlike traditional ITS, RTSAP seeks to leverage vehicle and traffic infrastructure sensors combined with cloud-edge computing to provide real-time insights into complex traffic scenarios—such as intersections and temporary bus stops—supporting safer autonomous vehicle operations and better urban mobility. Simulation studies conducted by [1] demonstrate that real-time situational awareness can reduce traffic accident severity by up to 40%, cut reaction times by 50%, and decrease accident rates during adverse weather by 30% [2]. By deploying RTSAP in diverse urban contexts like Oldenburg, Germany, and Kampala, Uganda, cities can significantly reduce traffic incidents while ensuring compliance with data privacy regulations and promoting equitable mobility. This scalable solution aligns with the European Commission's Vision Zero goal of eliminating road fatalities by 2050, offering a practical pathway for cities to deploy today's technology and empower tomorrow's safer, more inclusive transportation systems [3–5].

1 Introduction

Rapid urbanization, rising vehicle ownership, and the need for safer, more sustainable transportation systems pose significant challenges for cities worldwide. The World Health Organization (WHO) reports nearly 1.2 million annual deaths from road traffic crashes, with congestion and limited mobility access disproportionately affecting low-income communities [6]. The ITS World Congress 2025 theme, "Deploying Today, Empowering Tomorrow," urges the use of innovative technologies to build safer, more connected cities [7]. This essay proposes the Real-Time Situational Traffic Awareness Platform (RTSAP), a system that would use sensors on vehicles and infrastructure (e.g., traffic lights), AI, and simulations to deliver real-time traffic insights. Envisioned for diverse cities like Oldenburg, Germany, with advanced infrastructure, and Kampala, Uganda, with emerging systems, RTSAP would aim to improve safety through improved autonomous vehicle operations to reduce incidents, enhance mobility systems resilience, and ensure equitable mobility, such as accessible transport for people in developing cities [8]. By supporting the European Commission's goal of zero road deaths by 2050 and addressing global urban mobility needs, RTSAP offers a forward-looking framework to deploy today and empower safer transportation for tomorrow.

2 Context

By 2050, 68% of the world's population will reside in urban areas, increasing pressure on transportation systems with heightened traffic and safety risks [9] Road crashes disproportionately impact low- and middle-income countries, accounting for 93% of global road deaths despite fewer vehicles [10] While advanced driver-assistance systems (ADAS) enhance individual vehicle safety, they lack visibility into broader traffic dynamics, such as pedestrian movements at busy intersections [11]. In cities like Kampala, with mixed-traffic zones involving pedestrians, cyclists, and motorcycle taxis, and Oldenburg, with structured but congested intersections, this gap limits proactive safety measures. Current ITS, such as traffic cameras, provide partial data but are often fragmented or delayed, hindering effectiveness [2]. The proposed RTSAP would address this by integrating data from vehicle and infrastructure sensors (e.g., cameras, radar) with AI to create a shared, real-time traffic view. However, challenges like system interoperability, data integration and privacy under regulations like GDPR [12], and infrastructure gaps in developing cities must be addressed to make RTSAP viable [13]. By proposing a cost-effective, scalable platform, this essay envisions a solution to enhance road safety, support autonomous vehicle development, and promote equitable urban mobility.

3 Solution Description

3.1 Real-Time Situational Traffic Awareness Platform

The proposed Real-Time Situational Traffic Awareness Platform (RTSAP) would be a modular system integrating data from vehicle and infrastructure sensors—such as cameras, radar, and GPS—with AI and cloud-edge computing to monitor and analyze traffic in real time. Unlike centralized ITS, which often face latency issues, RTSAP would utilize edge computing to process data locally, reducing costs and delays [14]. It would enable vehicles, pedestrians (as traffic agents), and infrastructure to share insights, improving safety at high-risk areas like intersections or temporary bus stops (e.g., flexible stops created based on public transport demand) [15, 16] By leveraging AI to predict behaviors and supporting simulations to test scenarios, RTSAP would enhance autonomous vehicle safety and enhancing urban mobility. Its open-standard design would ensure compatibility with existing systems, while GDPR-compliant data handling would build public trust [12]. If piloted in cities like Kampala and Oldenburg, RTSAP could reduce intersection collisions by 15%, based on studies of related systems like [2], offering a scalable solution for safer, smarter mobility.

3.2 Platform Capabilities

Sensor Fusion; involves combining sensor data or data from different sources so that the resulting information has less uncertainty than would be possible if these sources were used individually. Sensor fusion techniques therefore create holistic perception systems for complex environments [17]. The RTSAP would integrate data from multiple sensors on vehicles (e.g., e-buses, delivery vans) and infrastructure (e.g., traffic lights, CCTV), minimizing the need for costly new installations. For instance, combining data from cameras, lidar and radar sensors on autonomous vehicles or passenger buses provides more context to predict actions of nearby pedestrians, enhancing safety in pedestrian zones [18, 19].

Scene Abstraction; Sensor data abstraction serves as an interface between sensor data and machine learning applications, improving transferability across different sensor setups [20] by representing complex scenes with minimal representations. RTSAP shall deploy Artificial Intelligence Models coupled with scene abstraction to transform raw sensor data into knowledge about traffic behavior and geographical zones [21] thereby creating holistic perception systems for complex environments [17] and providing actionable insights such as identifying road layouts or risky behaviors like sudden pedestrian crossings, making complex data usable for cities and autonomous vehicles to prevent incidents. Fusing AI and sensor technologies therefore contributes to more accurate perception, decision-making, and safety in autonomous vehicles, while also providing insights for cities towards safer, smarter mobility.

Interoperability; is a critical challenge for intelligent transportation systems (ITS) in smart cities, affecting various aspects including vehicle communication, and data exchange [22, 23]. This stems from deployment of diverse protocols and independently developed networked domains [23]. Addressing these challenges is crucial for realizing the full potential of ITS, which encompasses applications like traffic control, autonomous vehicles, and mobility prediction [24]. RSTAP shall employ standards like SAE J3216 for driving behavior signals and IEEE 2846 for behavior specification, middleware integration, and collaborative efforts among stakeholders, and a comprehensive framework combining various approaches proposed by [25] to tackle interoperability issues in smart cities [22, 25].

Interaction Interfaces: Human and machine interfaces play a crucial role in autonomous vehicles, facilitating communication between the vehicle and other road users or systems to enhance safety, trust, and situational awareness by incorporating explainable AI to convey complex decisions and potential hazards [26]. RTSAP is envisioned to provide real-time status updates, alerts, and feedback through visual, auditory, and haptic channels as recommended by [27] For remote operation scenarios, a design space approach can support the development of advanced visual interfaces, addressing challenges such as sensor data ambiguity and unexpected road user interventions [28]. Well-designed interfaces enable effective data exchange and decision-making in autonomous vehicles and smart city ecosystems.

Agent-Based Traffic Simulations: model traffic agents (vehicles, pedestrians, cyclists) as independent entities to predict outcomes in complex traffic scenarios. The integration of real-time data and agent-based modeling can greatly enhance traffic simulations and autonomous vehicle development. RTSAP can therefore build on [29] proposed framework for combining live-sensor data with agent-based simulation for real-time traffic modeling, support learning-based methods to improve prediction accuracy, enhance scenario generation, and create more realistic agent behaviors thereby improving work by [30]. These contribute to the development of safer and more efficient autonomous vehicles and thus safer city systems.

Open APIs: RTSAP should provide open APIs and curated data access for developers through secure data warehouses and standardized interfaces highlighted by [31]. These will enable third-party developers to create intelligent mobility solutions and apps [31, 32]. Challenges of balancing data openness with necessary access [32] can be addressed by leveraging edge-level processing architectures and cloud-based quality monitoring. By addressing the concerns, the platform can therefore support dynamic safety requirements, forecasts, and scenario-based decision support, while offering modular API designs for integration with existing traffic management systems and enabling scalable implementation and local innovation to address issues in different cities.

This proposed platform would transform vehicles into cooperative sensing agents, enabling cities to anticipate and prevent incidents while optimizing infrastructure use.

3.3 Legal and Ethical Standards

The Real-Time Situational Traffic Awareness Platform (RTSAP) prioritizes legal and ethical compliance to foster public trust and enable scalable deployment. In Europe, RTSAP adheres to the General Data Protection Regulation (GDPR) by anonymizing sensor data and implementing secure cloud-edge protocols to safeguard user privacy [12]. To address algorithmic bias, RTSAP shall employ transparent, explainable AI models, subject to regular independent audits to prevent disparities, such as prioritizing service in wealthier neighborhoods [33]**.** In developing cities like Kampala, where regulatory frameworks may be less established, RTSAP should align with World Bank guidelines to ensure equitable access, delivering benefits to underserved communities [34]. By embedding these standards into its design, RTSAP ensures ethical integrity, promotes inclusivity, and builds confidence for widespread adoption of digital solutions for mobility across diverse urban contexts.

3.4 Use Cases: Mixed-Traffic Zones in Uganda and Oldenburg

3.4.1 Market Zones along Roads in Kampala

In Kampala, Uganda, the Real-Time Situational Traffic Awareness Platform (RTSAP) would enhance safety in mixed-traffic environments by leveraging existing sensors on passenger EV buses, equipped with cameras and radar. These sensors stream real-time data to detect pedestrians, cyclists, or motorcycle taxis near dynamic bus stops, such as those in busy market zones along highways. For example, if a pedestrian crosses unexpectedly, RTSAP processes the data via edge computing to issue immediate alerts to nearby drivers and an abstract representation of the scene incident is stored on the cloud/ traffic management centers. This rapid response reduces collision risks in areas with high pedestrian activity. By utilizing existing bus sensors and prioritizing edge computing to address Kampala's limited connectivity, RTSAP ensures cost-effective, scalable deployment tailored to the city's informal transport networks.

3.4.2 Congested Intersections in Oldenburg

In Oldenburg, Germany, RTSAP integrates with the city's advanced infrastructure to improve safety at congested intersections. Delivery vehicles equipped with radar and cameras detect approaching cyclists, such as those navigating busy urban junctions. RTSAP processes this data to send real-time warnings to the cyclists and to nearby vehicles mitigating collision risks [2]. These interactions are logged to refine autonomous driving algorithms through agent-based simulations, enhancing their accuracy in complex scenarios. By leveraging Oldenburg's existing traffic light sensors and open-standard protocols like SAE J3216, RTSAP minimizes deployment costs while seamlessly integrating with the city's traffic management systems, ensuring adaptability and scalability [2, 23]

4 Summary

The proposed Real-Time Situational Traffic Awareness Platform (RTSAP) is a novel digital solution that fuses vehicle sensor data, artificial intelligence, and agent-based simulations to transform raw traffic inputs into real-time, semantically rich scene representations. Inclusively designed for both developed cities like Oldenburg, Germany, and rapidly growing urban centers like Kampala, Uganda, RTSAP extends beyond traditional Intelligent Transportation Systems (ITS) by using open standards, cloud-edge computing, and a modular approach to enable scalable, cost-effective solutions. Aligned with global safety and equity goals—including the EU's Vision Zero and the World Bank's inclusive infrastructure agenda [4] [34] —the platform helps developers and city authorities enhance situational awareness, particularly at high-risk intersections and in mixed traffic environments. To realize this vision, cities should launch pilot programs in mixed traffic zones with high traffic complexity, collaborating with mobility players that deploy sensor equipped vehicles and digital infrastructure. Initial deployments could be supported by funding mechanisms such as the EU's Horizon Europe [35], fostering cross-sector innovation and long-term scalability. By enabling pathways for data and AI-driven autonomous vehicle operation and development to reduce road traffic incidents, RTSAP lays the groundwork for resilient, equitable mobility systems. Deploying it today equips future generations with smarter, safer and more connected transportation ecosystems—truly embodying the spirit of "Deploying Today, Empowering Tomorrow."

5 References

[1] T. Blinova, R. Kumar, L. Kansal, P. Bhandari, U. Guven, and Y. L. Prasanna, "Data-Intensive Traffic Management: Real-Time Insights from the Traffic Management Simulation Test," *BIO Web Conf.*, vol. 86, p. 1089, 2024, doi: 10.1051/bioconf/20248601089.

[2] A. Nourbakhshrezaei, M. Jadidi, and G. Sohn, "Improving Cyclists' Safety Using Intelligent Situational Awareness System," *Sustainability*, vol. 15, no. 4, p. 2866, 2023, doi: 10.3390/su15042866.

[3] K. Gkoumas, F. L. Marques dos Santos, M. Stepniak, and F. Pekár, "Research and Innovation Supporting the European Sustainable and Smart Mobility Strategy: A Technology Perspective from Recent European Union Projects," *Applied Sciences*, vol. 11, no. 24, p. 11981, 2021, doi: 10.3390/app112411981.

[4] G. Neamțu, A. M. Țîțu, A. B. Pop, and A. Bogorin – Predescu, "Road Safety in The European Road Transport System and the Correlation with Sustainable Development," *IOP Conf. Ser.: Mater. Sci. Eng.*, vol. 1311, no. 1, p. 12047, 2024, doi: 10.1088/1757-899X/1311/1/012047.

[5] A. Tsakalidis, K. Gkoumas, and F. Pekár, "Digital Transformation Supporting Transport Decarbonisation: Technological Developments in EU-Funded Research and Innovation," *Sustainability*, vol. 12, no. 9, p. 3762, 2020, doi: 10.3390/su12093762.

[6] World Health Organization, *Global status report on road safety 2023.* [Online]. Available: https://www.who.int/teams/social-determinants-of-health/safety-and-mobility/global-status-report-on-road-safety-2023 (accessed: Jun. 22 2025).

[7] Paul, "Home - ITS World Congress 2024," *ITS World Congress*, 24 Aug., 2022. https://itsworldcongress.com/ (accessed: Jun. 5 2025).

[8] United Nations Department of Economic and Social Affairs, *World Urbanization Prospects: The 2018 Revision*: UN, 2019.

[9] United Nations, *2018 Revision of World Urbanization Prospects | United Nations.* [Online]. Available: https://www.un.org/en/desa/2018-revision-world-urbanization-prospects (accessed: Jun. 22 2025).

[10] World Health Organization, *Global Status Report on Road Safety*, 1st ed. Geneva: World Health Organization, 2023. [Online]. Available: https://ebookcentral.proquest.com/lib/kxp/detail.action?docID=31521197

[11] J. Antony and S. Manikandan, "Expanding vision-based ADAS for non-structured environments," *IET Intelligent Trans Sys*, vol. 14, no. 6, pp. 620–627, 2020, doi: 10.1049/iet-its.2019.0530.

[12] J. L. Hernandez-Ramos *et al.*, "Security and Privacy in Internet of Things-Enabled Smart Cities: Challenges and Future Directions," *IEEE Secur. Privacy*, vol. 19, no. 1, pp. 12–23, 2021, doi: 10.1109/MSEC.2020.3012353.

[13] S. Vivaswath and P. Blessed Prince, "A Comprehensive Review on Real-Time Traffic Signal Coordination Using Machine Learning: Optimizing Urban Traffic Flow for Efficiency and Sustainability," *IJRASET*, vol. 12, no. 1, pp. 1311–1315, 2024, doi: 10.22214/ijraset.2024.58160.

[14] K. Jain and S. Mohapatra, "Taxonomy of Edge Computing: Challenges, Opportunities, and Data Reduction Methods," in *EAI/Springer Innovations in Communication and Computing, Edge Computing*, F. Al-Turjman, Ed., Cham: Springer International Publishing, 2019, pp. 51–69.

[15] Y. Fu, M. K. Turkcan, V. Anantha, Z. Kostic, G. Zussman, and X. Di, "Digital Twin for Pedestrian Safety Warning at a Single Urban Traffic Intersection," in *2024 IEEE Intelligent Vehicles Symposium (IV)*, Jeju Island, Korea, Republic of, 2024, pp. 2640–2645.
[16] H. Veeraraghavan, O. Masoud, and N. Papanikolopoulos, "Managing Suburban Intersections through Sensing," 2002. [Online]. Available: https://www.semanticscholar.org/paper/Managing-Suburban-Intersections-through-Sensing-Veeraraghavan-Masoud/d419d7789aeb0c0340d7202f684aeb016842a951#citing-papers
[17] William Jack and Butler Jon, "Navigating Tomorrow: Advancements and Road Ahead in AI for Autonomous Vehicles," [Online]. Available: https://www.semanticscholar.org/paper/Navigating-Tomorrow%3A-Advancements-and-Road-Ahead-in-Jack-Jon/c3458a23afcc336440784c24ad816b5a7a67462a
[18] A. Kumar, K. Stephen, and A. S. Sabitha, "A Systematic Review on Sensor Fusion Technology in Autonomous Vehicles," in *2023 4th International Conference on Electronics and Sustainable Communication Systems (ICESC)*, Coimbatore, India, 2023, pp. 42–48.
[19] S. Thornton and S. Dey, "Multi-Modal Data and Model Reduction for Enabling Edge Fusion in Connected Vehicle Environments," *IEEE Trans. Veh. Technol.*, vol. 73, no. 8, pp. 11979–11994, 2024, doi: 10.1109/TVT.2024.3378182.
[20] H. Reichert *et al.*, "Towards Sensor Data Abstraction of Autonomous Vehicle Perception Systems," in *2021 IEEE International Smart Cities Conference (ISC2)*, Manchester, United Kingdom, 2021, pp. 1–4.
[21] E. Prezioso, F. Giampaolo, C. Mazzocca, A. Bujari, V. Mele, and F. Amato, "Machine Learning Insights for Behavioral Data Analysis Supporting the Autonomous Vehicles Scenario," *IEEE Internet Things J.*, vol. 10, no. 4, pp. 3107–3117, 2023, doi: 10.1109/JIOT.2021.3118834.
[22] F. Alanazi and M. Alenezi, "Interoperability for intelligent traffic management systems in smart cities," *IJECE*, vol. 14, no. 2, p. 1864, 2024, doi: 10.11591/ijece.v14i2.pp1864-1874.
[23] P. Agbaje, A. Anjum, A. Mitra, E. Oseghale, G. Bloom, and H. Olufowobi, "Survey of Interoperability Challenges in the Internet of Vehicles," *IEEE Trans. Intell. Transport. Syst.*, vol. 23, no. 12, pp. 22838–22861, 2022, doi: 10.1109/TITS.2022.3194413.
[24] M. Elassy, M. Al-Hattab, M. Takruri, and S. Badawi, "Intelligent transportation systems for sustainable smart cities," *Transportation Engineering*, vol. 16, p. 100252, 2024, doi: 10.1016/j.treng.2024.100252.
[25] S. S. Albouq, A. A. A. Sen, N. Almashf, M. Yamin, A. Alshanqiti, and N. M. Bahbouh, "A Survey of Interoperability Challenges and Solutions for Dealing With Them in IoT Environment," *IEEE Access*, vol. 10, pp. 36416–36428, 2022, doi: 10.1109/ACCESS.2022.3162219.
[26] S. Atakishiyev, M. Salameh, and R. Goebel, "Incorporating Explanations into Human-Machine Interfaces for Trust and Situation Awareness in Autonomous Vehicles," in *2024 IEEE Intelligent Vehicles Symposium (IV)*, Jeju Island, Korea, Republic of, 2024, pp. 2948–2955.
[27] J. A. Mandujano-Granillo *et al.*, "Human–Machine Interfaces: A Review for Autonomous Electric Vehicles," *IEEE Access*, vol. 12, pp. 121635–121658, 2024, doi: 10.1109/ACCESS.2024.3450439.
[28] G. Graf, H. Palleis, and H. Hussmann, "A Design Space for Advanced Visual Interfaces for Teleoperated Autonomous Vehicles," in *Proceedings of the International Conference on Advanced Visual Interfaces*, Salerno Italy, 2020, pp. 1–3.
[29] Y. Qian, J. Barthelemy, and P. Perez, "Towards Agent-Based Traffic Simulation Using Live Data from Sensors for Smart Cities," in *Lecture Notes in Computer Science, Multi-Agent-Based Simulation XXI*, S. Swarup and B. T. R. Savarimuthu, Eds., Cham: Springer International Publishing, 2021, pp. 28–40.
[30] M. Zhu, D. Chen, X. Yuan, Z. Shang, and C. Liu, "Learning Realistic and Reactive Traffic Agents," in *2024 IEEE Intelligent Vehicles Symposium (IV)*, Jeju Island, Korea, Republic of, 2024, pp. 2491–2496.
[31] S. R. S. Chan, D. A. G. Dilangalen, and W. M. Tan, "Real-time and Secure Geospatial Data Warehouse for Intelligent Transportation Systems," in *2020 International Conference on*

Information and Communication Technology Convergence (ICTC), Jeju, Korea (South), 2020, pp. 741–746.
[32] T. Scassa and A. Diebel, "Open or Closed? Open Licensing of Real-time Public Sector Transit Data," *JeDEM*, vol. 8, no. 2, pp. 1–20, 2016, doi: 10.29379/JEDEM.V8I2.414.
[33] C. O'Neil, *Weapons of math destruction: How big data increases inequality and threatens democracy*. New York: Crown, 2016.
[34] M. Khosrow-Pour, Ed., *Encyclopedia of organizational knowledge, administration, and technology*. Hershey PA: IGI Global an imprint of IGI Global, 2021.
[35] European Commission, *Horizon Europe the EU's funding programme for research and innovation.* [Online]. Available: https://commission.europa.eu/funding-tenders/find-funding/eu-funding-programmes/horizon-europe_en (accessed: Jul. 6 2025).