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THE ROLE OF INTELLIGENT TRANSPORTATION SYSTEMS (ITS) IN SUSTAINABLE SMART CITIES

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Abstract. *Intelligent Transportation Systems (ITS) are pivotal for developing sustainable smart cities, addressing critical challenges like traffic congestion, safety, and environmental impact. This article explores the key components of ITS, including adaptive traffic signals, and mobility prediction, enabled by advanced communication technologies. While reviewing global implementations and security considerations, the paper presents a focused case study on an adaptive traffic light control system deployed in Dnipro, Ukraine. This system utilizes FLIR TrafiOne thermal imaging sensors and a hybrid control strategy. The findings demonstrate that the integration of robust sensing technology and AI-driven optimization presents a scalable and effective pathway for enhancing traffic efficiency, reducing emissions, and advancing urban sustainability.*

Key words: *Intelligent Transportation Systems (ITS), adaptive traffic control, thermal imaging sensors, sustainable mobility, smart cities.*

Introduction.

The rapid growth of urban populations is placing unprecedented strain on traditional transportation networks, leading to chronic congestion, safety hazards, and environmental damage. In response, a new paradigm is emerging: Intelligent Transportation Systems (ITS). These systems represent a fundamental shift, leveraging digital technologies, data analytics, and advanced communications to create smarter, more responsive mobility solutions [1]. The central promise of ITS is to enhance the efficiency, safety, and sustainability of how people and goods move within cities. This paper explores the technological pillars of ITS, the communication networks that enable them, the critical challenges they face, and real-world evidence of their benefits, ultimately arguing that they are indispensable for building the resilient and sustainable cities of the future [2].

Main text.

1.Foundational Technologies of Modern ITS.

Adaptive Traffic Signals: Moving beyond simple timers, intelligent traffic lights use a network of sensors and cameras to perceive real-time traffic conditions [3].

Sophisticated algorithms process this data to dynamically adjust signal timings, prioritizing heavy traffic flows, emergency vehicles, or pedestrian crossings as needed. This adaptability reduces unnecessary stopping, shortens travel times, and cuts down on the fuel wasted and emissions produced by idling vehicles [4-11].

Virtual Traffic Management: This innovation replaces or supplements physical signals with digital ones. Using wireless technologies like 5G, warnings and right-of-way instructions are communicated directly to a vehicle's onboard display. This is particularly valuable at intersections without traditional lights, in construction zones, or to alert drivers to hidden hazards, effectively creating a "digital safety shield [4, 5].

Mobility Prediction: A powerful application of artificial intelligence, mobility forecasting analyzes patterns from historical and live data to anticipate the future movement of vehicles and people [4, 6, 7]. By predicting where traffic bottlenecks are likely to form or where high demand will occur, city management systems can proactively reroute flows, optimize public transit, and allocate resources more efficiently. This predictive capability is also crucial for the development of safe autonomous vehicles.

2. Critical Challenges: Security and Reliability. Integrating complex, connected systems into critical infrastructure introduces new risks that must be managed.

Cybersecurity Threats: The interconnected nature of ITS creates a larger attack surface [2]. Threats range from "Sybil attacks," where a malicious actor creates multiple fake identities to spoof traffic data, to the remote hijacking of vehicle controls or traffic management systems [12]. Ensuring the integrity and authenticity of every data transmission is paramount to public safety [13, 14].

Software Reliability: Modern vehicles and traffic control systems run on millions of lines of code. Ensuring this software is bug-free and resilient is a massive challenge. The paper discusses advanced methods, like hybrid fuzzy logic models, to assess software security and predict potential failures before they can cause real-world disruptions [6].

3. Impact and Real-World Validation. The ultimate proof of ITS value lies in its tangible benefits for sustainability and quality of life in urban areas.

Environmental and Sustainability Benefits: The primary environmental gain comes from optimizing traffic flow. By minimizing stop-and-go traffic and reducing the time cars spend idling or searching for parking, ITS directly lowers fuel consumption and emissions of greenhouse gases and local air pollutants like nitrogen oxides and particulate matter. This contributes directly to cleaner air and public health improvements [15].

Global Case Studies:

Los Angeles & Montreal: The implementation of adaptive traffic signals has yielded measurable results, including travel time reductions of up to 16% and fewer stops at intersections, leading to lower emissions and faster emergency response times.

Singapore & Barcelona: These cities are leaders in using a dense network of IoT sensors to manage traffic in real-time and guide drivers to available parking, effectively reducing congestion and its environmental impact.

Copenhagen: ITS is a core component of this city's ambitious goal to become carbon-neutral by 2025, promoting efficient and eco-friendly transportation modes.

Seoul & Dubai: These metropolises are investing heavily in big data, AI, and 5G to build holistic smart city platforms where intelligent transportation is a key service.

The global adoption of ITS is also evident in Ukraine, where the city of Dnipro serves as a notable case study. The city has implemented an adaptive traffic control system at key intersections, utilizing FLIR TrafiOne thermal imaging sensors for robust, all-weather vehicle detection. A rule-based adaptive algorithm processes this real-time data to dynamically extend or terminate green phases, which in a pilot deployment has already reduced average vehicle delays by 20–38% compared to fixed-time control [3].

European eCall Mandate: A regulation requiring all new cars to have an automated emergency call system has demonstrated how ITS can save lives by drastically shortening emergency service response times after accidents.

Automotive Industry Initiatives: Car manufacturers are not mere spectators but active drivers of this change. Companies like BMW, Mercedes-Benz, Audi, and Toyota are aggressively integrating V2X technologies into their vehicles [1]. Features now include receiving traffic light timings to enable "green wave" driving, warnings about pedestrians in blind spots, and alerts from other cars about hazardous road conditions ahead. These initiatives are framed as essential steps toward a future with zero traffic fatalities.

Summary and conclusions.

Intelligent Transportation Systems are a cornerstone in the architectural blueprint for the sustainable smart city. They offer a proactive, data-driven solution to the pressing challenges of urban mobility. The documented successes from cities worldwide provide strong evidence that the strategic deployment of ITS is not just an upgrade to transportation infrastructure, but a transformative investment in a safer, cleaner, and more efficient urban future.

References:

1. Mohamed Elassy, Mohammed Al-Hattab, Maen Takruri, Sufian Badawi / Intelligent transportation systems for sustainable smart cities / Transportation Engineering / Volume 16, June 2024, 100252 / URL:https://doi.org/10.1016/j.treng.2024.100252

2. Balashova Yuliia, Balashov Andrii / Transforming Mobility: how AI, Machine Learning, and Deep Learning are revolutionizing Transportation Systems / Proceedings of the XXIV International Scientific and Practical Conference. Paris, France. 2025. Pp. 365-368.
URL: https://isg-konf.com/integration-of-new-technologies-into-science-to-improve-research/

3.Balashov, Andrii and Ponomarova, Olena and Balashova, Yuliia and Tregub, Olexandr, Adaptive Traffic Signal Optimization with Thermal Sensors and Reinforcement Learning (August 28, 2025). Available at SSRN: https://ssrn.com/abstract=5414064 or http://dx.doi.org/10.2139/ssrn.5414064

4. Balashova Yu.B., Balashov A.O. / AI-driven optimization for traffic safety: predicting and preventing collisions at road intersections using machine learning / International periodic scientific journal «Modern engineering and innovative

technologies» ISSN 2567-5273, Issue №37, Part 2, February 2025, Karlsruhe, Germany, p. 91-99. / DOI: https://doi.org/10.30890/2567-5273.2025-37-02-040 / URL: https://www.moderntechno.de/index.php/meit/issue2025-37
https://www.moderntechno.de/index.php/meit/issue/view/meit37-02
http://www.moderntechno.de/index.php/meit/article/view/meit37-02-040

5. Balashova Yu., Balashov A. / Enhancing traffic safety at road intersections with artificial intelligence // Current trends in scientific research development. Proceedings of the 7th International scientific and practical conference. BoScience Publisher. Boston, USA. 2025. Pp. 151-156. URL: https://sci-conf.com.ua/vii-mizhnarodna-naukovo-praktichna-konferentsiya-current-trends-in-scientific-research-development-13-15-02-2025-boston-ssha-arhiv/.

6. Balashov A. Artificial intelligence in automobile transportation: enhancing traffic safety and efficiency / Proceedings XV All-Ukrainian Conference of Young Scientists «YOUNG SCIENTISTS 2025-FROM THEORY TO PRACTICE» / March 20 2025, USUST, Dnipro, Ukraine, p. 269-273 / https://nmetau.edu.ua/ua/mfac/i3002/p3749
http://www.uintei.kiev.ua/page/plan-provedennya-naukovyh-naukovo-tehnichnyh-zahodiv-v-ukrayini-0

7. Balashova Yu., Balashov A. / Revolutionizing transportation networks: AI-enabled solutions for next-generation highway systems / Conference proceedings «SW-Us conference proceedings» "Organization of scientific research in modern conditions ‘2025" No 30 on March 21, 2025, p. 29-33 /
DOI: https://doi.org/10.30888/2709-2267.2025-30-00-014
https://proconference.org/index.php/usc/article/view/usc30-01-014

8. Balashov A. Intelligent urban mobility: a machine learning framework for AI-driven traffic congestion mitigation in smart cities // Science and technology: challenges, prospects and innovations. Proceedings of the 9th International scientific and practical conference. CPN Publishing Group. Osaka, Japan. 2025. Pp. 158-164. URL: https://sci-conf.com.ua/ix-mizhnarodna-naukovo-praktichna-konferentsiya-science-and-technology-challenges-prospects-and-innovations-24-26-04-2025-osaka-

yaponiya-arhiv/.

9. Balashova Yu., Balashov A. Modeling and evaluating the impact of road construction on urban traffic / SW-Ger Conference Proceedings, / No 38 on April 20, 2025: "Scientific and technological revolution of the XXI century ' 2025" / Karlsruhe, Germany: p. 15–18. ISBN 978-3-98924-085-8.
DOI: https://doi.org/10.30890/2709-1783.2025-38-00-010
https://www.proconference.org/index.php/gec/issue/view/gec38-00

10. Balashova Yu., Balashov A. Modeling highway safety: optimal design of horizontal curves based on machine learning / Conference proceedings «SW-Us conference proceedings»: «Global science and education in the modern realities '2025» No 31 on May 21, 2025, Seattle, Washington, USA: p.37-41 /
DOI: https://doi.org/10.30888/2709-2267.2025-31-00-022
https://www.proconference.org/index.php/usc/article/view/usc31-00-022

11. Balashova Yu.B., Balashov A.O. / Optimal control and differential geometry approaches to highway vertical curve design using artificial intelligence techniques / International periodic scientific journal "SWorldJournal" ISSN 2663-5712, Issue №28, Part 1, November 2024, Svishtov, Bulgaria, p. 119-122.
URL: https://doi.org/10.30888/2663-5712.2024-28-00-041
https://www.sworldjournal.com/index.php/swj/issue/view/swj28-01/swj28-01
URL: https:// www.sworldjournal.com/index.php/swj/article/view/swj28-00-041

12. Andrii Balashov, Olena Ponomarova, Xiaohua Zhai / Multi-Stage Prompt Inference Attacks on Enterprise LLM Systems / https://arxiv.org/pdf/2507.15613
URL: https://doi.org/10.48550/arXiv.2507.15613

13. Balashov A. / Attention-integrated convolutional neural networks for enhanced image classification: a comprehensive theoretical and empirical analysis / International periodic scientific journal "Modern engineering and innovative technologies" ISSN 2567-5273, Issue №35, Part 2, October 2024, Karlsruhe, Germany, p. 18-27. / URL: https://doi.org/10.30890/2567-5273.2024-35-00-030
http:// www.moderntechno.de/index.php/meit/article/view/meit35-00-030
https://www.moderntechno.de/index.php/meit/issue/view/meit35-02/meit35-02

14. Balashov A. Enhancing image classification with attention-integrated convolutional neural networks: a comprehensive theoretical and empirical study // Current trends in scientific research development. Proceedings of the 4th International scientific and practical conference. BoScience Publisher. Boston, USA. 2024. Pp. 161-166. URL: https://sci-conf.com.ua/iv-mizhnarodna-naukovo-praktichna-konferentsiya-current-trends-in-scientific-research-development-14-16-11-2024-boston-ssha-arhiv/.

15. Balashova Yu., Balashov A. / Sustainable development of roads: Problems in the design of city streets and highways. / Proceedings of the XV International Scientific and Practical Conference. Paris, France. 2024. Pp. 320-323. / ISBN – 979-8-89619-789-8 / DOI – 10.46299/ISG.2024.2.15
URL: https://isg-konf.com/complexities-of-education-of-modern-youth-and-students

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