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APPLYING NEW TECHNOLOGIES INSIDE SMART CITIES FOR CLEAN MOBILITY OF PUBLIC PASSENGER TRANSPORT

Abstract: *The application of modern technologies in combination with logistics centres in the public passenger transport system can contribute to reducing fuel consumption, preserving the environment, and increasing driving comfort. The door-to-door passenger transport model has been researched in this study as one of the ways for smart traffic management but also for increased driving comfort, primarily for people with special needs or requiring constant medical care. Modern technologies include the use of artificial intelligence and machine learning, vehicles powered by alternative fuels in city transport, and minibuses. The study shows that implementing a door-to-door transportation system with eco-friendly minibuses could reduce the number of passenger vehicles by up to 50% over six years in medium-sized cities, leading to lower CO_2 emissions and improved accessibility. The use of natural gas and electric vehicles, combined with intelligent management systems, significantly enhances energy efficiency and supports sustainability goals.*

Keywords: emission, door-to-door transport model, smart cities, vehicles

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INTRODUCTION

Passenger transportation in smart cities is becoming an increasingly important topic as technology evolves and urbanization continues to grow. Smart cities use innovation and technology to improve the quality of life of their citizens, and passenger transportation is a key part of that process. Here are some key aspects (Miron, Hulea, & Rusu, 2024):

- Smart Transportation Systems: In smart cities, transportation systems use sensors, data analytics, and applications to optimize traffic. This can include smart traffic lights that adapt to current traffic conditions or apps that help passengers find the fastest route.
- Electric and Autonomous Vehicles: Many smart cities are introducing electric buses and autonomous vehicles, which reduce CO_2 emissions and improve transport efficiency.
- Ride-Sharing Services: Car, minibus, bicycle, and scooter sharing services are becoming popular, allowing citizens to use transportation without owning a personal vehicle. This reduces congestion and pollution.
- Integration of Different Modes of Transport: Smart cities enable the integration of various transportation modes (public transport, cycling, walking, door-to-door model) so that passengers can easily switch from one to another.
- Data and Analytics: By using data collected from various sources, cities can better plan infrastructure, improve transport services, and adapt to the needs of citizens.
- All these innovations contribute to the creation of more efficient, sustainable, and user-friendly transportation in urban areas, leading to improved quality of life and a reduced environmental impact.

The management of municipal vehicles, especially garbage trucks and street cleaning vehicles, is also crucial for the efficient functioning of urban environments (Bošković et al., 2024):

- Telematics: The use of GPS and sensors to monitor vehicle efficiency, fuel consumption, and preventive maintenance.
- Route Optimization: Software solutions that enable the most efficient routes for waste collection or other municipal services, reducing time and costs.
- Automation: The introduction of autonomous vehicles for specific municipal services, which can reduce human error and increase efficiency.
- Resource Management: Centralized systems for tracking and managing vehicles, enabling better coordination and resource allocation.

Smart cities use technology to improve the quality of life for their citizens, reduce congestion, and increase the efficiency of public services. Through innovation and the integration of smart solutions, cities can become more sustainable and more responsive to the needs of their residents.

In this way, technology contributes to the preservation of the environment by reducing the emission of harmful gases and noise from vehicles. Door-to-door transportation on demand using eco-friendly minibuses can significantly increase the comfort of passengers and persons with special needs (Milojević et al., 2024).

METHODOLOGICAL APPROACH

This paper is based on a qualitative and analytical approach, relying on the review and synthesis of relevant scientific literature, statistical data from the European Union vehicle fleet, and case examples from practice. The analysis includes a review of technological trends, environmental impact assessments, and transport system structures. A model-based evaluation of the door-to-door transport concept was conducted for a mid-sized city with 100,000 registered vehicles, assessing the potential for emission reduction and increased transport efficiency over a multi-year period. The aim is to identify effective strategies and technologies that can contribute to cleaner and more inclusive urban mobility in smart city environments.

MODERN TRANSPORT SYSTEMS IN SMART CITIES

Road transport emits one-fifth of the carbon dioxide (CO_2) emissions in the EU, which accounts for more than two-thirds of the total greenhouse gas emissions in the transport sector (Milojević et al., 2025).

Urban transport emits the largest share of emissions within the road transport sector. Moreover, by predominantly relying on fossil fuels in urban transport, we are responsible for air pollution in urban environments (Adikaram & Arambepola, 2025).

On the other hand, the mode of passenger transport (private and public, individual and mass) can significantly contribute to reducing the negative environmental impact. Priority is given to the use of alternative fuels alongside a parallel reduction in the use of fossil fuels. The main alternative fuels for propulsion and mobile systems are electric energy, hydrogen, and various types of biofuels. Synthetic fuels are still an option as a technology. Some of these technologies are very efficient, but their implementation cost remains high (Skrúcaný et al., 2018).

Another way to reduce emissions in the transport sector is the use of flexible passenger transport (such as door-to-door or on-demand systems), which enables a reduction in the number of cars and buses in urban areas, aiming to avoid traffic congestion and its negative environmental impact, as shown in Figure 1. Public urban transport and public transport in general, plays a special role in reducing dependency on fossil fuels. Along this path, the adoption of alternative propulsion technologies is necessary, as well as the development of a new public transport subsystem, along with the improvement of infrastructure and service quality (Milojević et al., 2025; Skrúcaný et al., 2018).

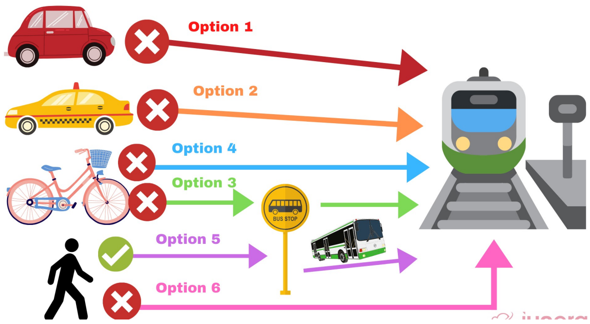

Figure 1. *Options for passenger transport over longer distances*

It is proposed that "on-demand" public transport be introduced, such as door-to-door services, primarily due to the comfort provided to passengers, which, in such cases, is comparable to the use of private cars (this especially applies to senior citizens, persons with disabilities, individuals undergoing regular medical treatments, etc.). The implementation of this transport system in cities reduces the excessive use of private vehicles, which in turn lowers traffic congestion and harmful gas emissions (Kluge et al., 2019).

The nature of mobility has changed over time, as has the way people travel; today, people travel long distances. Motor vehicles have gradually replaced non-motorized vehicles, giving preference to means of transport such as cars (Pooley & Pooley, 2022).

The use of motor vehicles (cars, motorcycles, buses, etc.) has simultaneously necessitated increasing amounts of energy, which mostly comes from burning fossil fuels. For this reason, fossil fuels remain the dominant energy resource in the transport sector today.

At the same time, due to the increasing energy demands in the transportation sector, there is a growing trend toward the application of alternative propulsion systems such as hydrogen-powered vehicles and electric vehicles (with electricity from renewable sources), which reduces the reliance on fossil fuels derived from oil (Milojević et al., 2024).

On the other hand, legal regulations set limits on the allowable emissions of toxic and harmful combustion products from motor vehicles and mandate the use of environmentally "cleaner" fuels.

Regarding the use of means of transport, people who live and work in rural areas, suburban settlements, and mountainous regions, as well as those working in isolated plants and inaccessible areas far from road networks, are forced to use their own cars, which contribute to congestion, the use of fossil fuels, and air pollution in urban environments.

In general, the reasons why the human population intensively uses cars for urban transport are numerous:

inconvenient public transport, residential areas not covered by public transit, inaccessibility (for people with children, the elderly, individuals with disabilities, etc.), inflexibility (breaking routine), the bad habit created by cheap fuel, and the increasing affordability of used (second-hand) vehicles, etc.

Urban traffic and traffic flow have the greatest impact on exhaust emissions and air pollution, especially in narrow streets, city centre zones, etc. The characteristics and types of roads also affect the cost of travel, safety, and passenger comfort. Furthermore, significant contributions to reducing exhaust emissions in urban traffic can be achieved through the application of various technologies and methods. Some of these can be very efficient and affordable and do not require additional costs, for instance (Milojević et al., 2024; Skrucany et al. 2019; Reji et al., 2025):

- The use of alternative fuels, biofuels, ethanol, natural gas, and hydrogen/electric energy, as well as other forms of "clean" propulsion energy, combined with the application of flexible transport, i.e. flexible transport systems that enable the reduction of the number of vehicles used in urban areas. This reduces congestion in city streets and downtown areas, thereby lowering fuel consumption and harmful exhaust emissions.
- Optimization and further improvement of the combustion process in internal combustion (IC) engines by using modern equipment and by reducing internal friction and mechanical losses, with the aim of reducing fuel consumption and exhaust emissions;
- Increasing vehicle reliability during operation and service life. An optimal approach to preventive maintenance of transport vehicles based on models that include planning processes, decision-making, logistics for supplying spare parts, skilled personnel for vehicle maintenance, etc.;
- Logistics for recycling vehicles at the end of their service life. Special attention should be paid to the logistics of dismantling and proper separation of rare materials from electric vehicles, such as neodymium or similar materials.

If the number of passenger cars in urban traffic were significantly reduced, significant results would be achieved in terms of lowering fuel consumption and environmental protection, which should contribute to a better-quality environment and social life. The following strategies, which are simultaneously real facts, can also serve as contributions to these trends:

- A significant increase in fuel prices on the market and limited supply;
- Penalties for exceeding permitted exhaust emissions.

Therefore, alternative ecological fuels, as well as modern propulsion systems for buses and other passenger transport vehicles, play an increasingly important role in the public transport system.

Essentially, it is necessary to implement transport systems that will enable higher-quality public transport services and comfort comparable to passenger cars while being accessible to potential users. Such optimal transport systems, which can complement conventional transport, can be applied in the following ways (Babić et al., 2022):

- Modern city buses or minibuses as suitable transport vehicles (introducing alternative fuels and technologies in public passenger transport);
- Introducing "door-to-door" transport models that will bring transport services closer to users, alongside appropriate information and communication systems as support, which should enable passenger information and "smart" and efficient management of the public transport system, as shown in Figure 2.

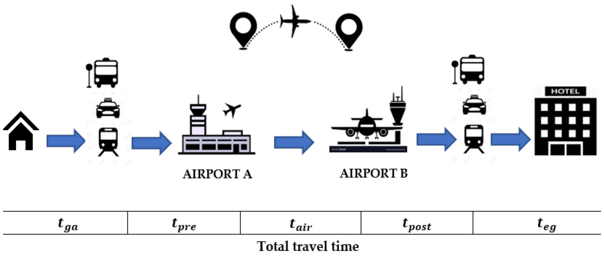

Figure 2. *Door-to-door passenger travel time*

A transport system for everyday fast public passenger transport over short distances, the so-called shuttle service, is one way to reduce the number of passenger cars on the roads. This type of transport has proven effective and inexpensive for users, easy to implement, and it contributes directly and indirectly to reducing fuel consumption and emissions.

Statistical data on the vehicle fleet in the EU

Concerning the number of vehicles and types of powertrains in the EU for the year 2023, the following characteristic data can be highlighted (Maniotis et al., 2023):

- A total of 96.4% of all trucks in the EU are diesel-powered, while gasoline vehicles account for 0.6% of the fleet. Only 0.1% of trucks on EU roads have a zero-emission powertrain;
- Diesel engine buses make up 89.2% of the EU fleet, with only 2.5% being electric and 2.2% hybrid-powered. However, a significant number of electric buses are found in the Netherlands (17.7%), Luxembourg (14.7%), and Ireland (13.5%);
- On average, there are 563 passenger cars and 83 commercial vehicles and buses per 1,000 inhabitants in the EU;
- Italy has the highest car density in the EU (694 per 1,000 inhabitants), while Cyprus has the highest density of commercial vehicles and buses (138 per 1,000 inhabitants). Conversely, Latvia has the lowest car density (381 per 1,000 inhabitants), as

well as the lowest density of commercial vehicles and buses (50 per 1,000 inhabitants).

- In Denmark, nearly 40% of households did not own a car, while 31% of French households had two passenger cars. The average annual distance travelled in the surveyed countries was 12,346 km.

Table 1 shows statistical data on the number of vehicles in the EU by vehicle type and powertrain.

Table 1. *Number of vehicles in the EU by vehicle type and powertrain*

Category of motor vehicles	M1	M2+M3	N1	N2+N3
Gasoline %	50	0.4	5.9	0.6
Diesel %	39.5	89.2	90.5	96.4
Electric vehicles, batteries %	1.8	2.5	1.1	0.1
Plug-in hybrid vehicles %	2.1	0.5	0.2	0.0
Hybrid powertrain %	3.2	2.2	0.2	0.1
Natural gas %	**0.6**	**4.2**	**0.5**	**0.8**
Liquefied petroleum gas (LPG) %	2.6	0.0	0.8	0.1
TOTAL	Passenger cars M1 (**248,824,542**)			
	Buses M2+M3 (**679,802**)			
	Vans N1 (**30,080,656**)			
	Heavy-duty vehicles N2+N3 (**5,998,915**)			

An analysis conducted in May 2025 showed an increase of 25% for battery electric vehicles and 16% for hybrid electric vehicles, while plug-in hybrid electric vehicles saw an increase of 46.9%.

By the end of May 2025, registrations of gasoline-powered cars had decreased by 20.2%, with the largest markets recording declines. France saw the biggest drop in registered vehicles at 34.3%, followed by Germany (-26.1%), Italy (-15.4%), and Spain (-13.3%).

With 1,305,525 newly registered cars, the market share of gasoline-powered vehicles dropped to 28.6%, down from 35.6%. The number of diesel-powered cars also declined by 26.6%, resulting in a market share of 9.5% in May 2025 since the beginning of the year. Year-on-year analyses compared to May 2025 indicate a decrease of 18.6% for gasoline and 27.6% for diesel vehicles.

Modern technologies aim to increase fuel efficiency and reduce harmful exhaust emissions, especially CO_2, whose emission is regulated by law, and any exceedance is penalized.

Alternative powertrain systems powered by natural gas

Natural gas as an engine fuel is gaining an increasing share in energy consumption, as evidenced by the fact that there are over 28 million natural gas vehicles (NGVs) worldwide.

Natural gas vehicles are powered by IC engines, and natural gas is stored on them under pressure either as compressed natural gas (CNG) or as liquefied natural gas (LNG). The main advantages of using natural gas as fuel for motor vehicles in traffic are as follows (Nylund et al., 2014; Spoof-Tuomi et al., 2022):

- Due to its low carbon (C) content compared to gasoline or diesel fuel, the combustion of natural gas produces lower amounts of CO_2, nitrogen oxides (NOx), and sulfur; emissions of particulate matter and smoke are also lower.
- Natural gas can be used in gasoline engines without major technical issues, while diesel engines require certain conversions.
- The production cost of natural gas is significantly lower compared to gasoline and diesel, and operating costs of NGV fuel are also lower, among other benefits.
- If biomethane is used, the amount of harmful substances in combustion products is further reduced.
- Natural gas has higher resistance to knocking (its octane number is about 105).

One example of a natural gas bus subsystem is the MAZ-BIK 203CNG-S bus, produced in Kragujevac (Figure 3). The use of such buses instead of conventional diesel-powered ones can significantly contribute to reducing noise emissions and harmful exhaust gases. From this perspective, the implementation of such buses has been initiated in larger cities (Milojević et al., 2025).

Figure 3. *Low-floor city bus powered by CNG MAZ-BIK 203CNG-S on bus route 74 in GSP Belgrade*

Such a propulsion system can also be applied to minibuses in the public passenger transport system, following the door-to-door model.

DOOR-TO-DOOR TRANSPORTATION MODEL IN SMART CITIES

The door-to-door transportation model for ecological and cleaner urban transport relies on modern information systems and may include several key components (Marinković et al., 2024):

- Integration of different modes of transport: Combining public transport, bicycles, walking, and electric vehicles to enable flexibility and easy access to various options;

- Travel planning applications: Developing mobile apps that allow users to plan their journeys using different modes of transport, with the option to choose more environmentally friendly alternatives;
- Bicycle and pedestrian paths: Building and improving infrastructure for cyclists and pedestrians to encourage citizens to use these modes of transport;
- Electric vehicles and car sharing: Promoting electric cars and vehicle-sharing services to reduce harmful gas emissions;
- Incentives for public transport use: Introducing subsidies or affordable fares for public transport users to encourage more people to choose it over private cars;
- Education and awareness: Organizing campaigns to raise awareness about the benefits of environmentally sustainable transport and its impact on the environment;
- Green corridors: Developing green corridors throughout the city exclusively for public transport, bicycles, and pedestrians, thus reducing congestion and pollution.

This model requires collaboration between local authorities, transport companies, and citizens in order to achieve sustainable urban transport solutions.

The essence of this transportation model includes main bus routes supported by auxiliary routes, where minibuses transport passengers to the main routes. The proposed system is flexible regarding the bus categories, as well as the number of secondary routes and passengers. The system can also be adapted for the use of electric-powered vehicles or autonomous vehicles, as shown in Figure 4 (Iclodean et al., 2020).

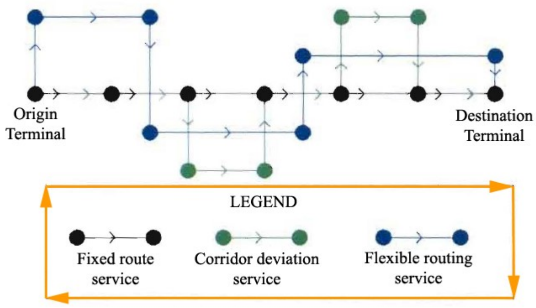

Figure 4. *Flexible routes in a door-to-door transportation system*

The goal of introducing such a transportation system is to reduce congestion on city streets, which should directly translate into lower fuel consumption and consequently reduce harmful gas emissions and noise pollution. Based on a medium-sized city with 100,000 vehicles, a 50% reduction in the use of passenger vehicles is expected by the sixth year of implementing the door-to-door transportation system.

CONCLUSION

In smart cities, the application of modern technologies is essential, as well as means of transportation whose management is based on artificial intelligence and machine learning methods.

The implementation of the door-to-door transportation model with eco-friendly buses should contribute to reducing the number of cars on the streets, thus lowering fuel consumption and exhaust gas emissions, as well as noise pollution.

The use of minibuses with alternative propulsion systems powered by natural gas and electricity also contributes to increased driving ergonomics and facilitates transportation for people with special needs.

REFERENCES

Adikaram, W. D. C. N., & Arambepola, C. (2025). Occupational hazard to on-road air pollution within passenger transport micro-environments: Evidence from traffic congested areas in Colombo, Sri Lanka. *BMC Public Health, 25*(1), 2253. https://doi.org/10.1186/s12889-025-23480-y

Babić, D., Kalić, M., Janić, M., Dožić, S., & Kukić, K. (2022). Integrated Door-to-Door Transport Services for Air Passengers: From Intermodality to Multimodality. *Sustainability*, *14*(11), 6503. https://doi.org/10.3390/su14116503

Bošković, G., Cvetanović, A. M., Jovičić, N., Jovanović, A., Jovičić, M., & Milojević, S. (2024). Digital Technologies for Advancing Future Municipal Solid Waste Collection Services. In F. Theofanidis, O. Abidi, A. Erturk, S. Colbran, & E. Coşkun (Eds.), *Digital Transformation and Sustainable Development in Cities and Organizations* (pp. 167-192). IGI Global Scientific Publishing. https://doi.org/10.4018/979-8-3693-3567-3.ch008

Iclodean, C., Cordos, N., & Varga, B. O. (2020). Autonomous Shuttle Bus for Public Transportation: A Review. *Energies*, *13*(11), 2917. https://doi.org/10.3390/en13112917

Kluge, U., Paul, A., Urban, M., & Ureta, H. (2019). Assessment of passenger requirements along the door-to-door travel chain. In B. Müller & G. Meyer (Eds.), *Towards user-centric transport in Europe* (Lecture Notes in Mobility (pp. 255-276) Springer, Cham. https://doi.org/10.1007/978-3-319-99756-8_17

Maniotis, G., Spyropoulos, G., & Christopoulos, K. (2023). The Footprint of Road Transport Emissions: Electric Vehicles and Their Impact on Air Pollution Reduction in Greece. *Environmental Sciences Proceedings*, *26*(1), 146. https://doi.org/10.3390/environsciproc2023026146

Marinković, D., Dezső, G., & Milojević, S. (2024). Application of Machine Learning During Maintenance and Exploitation of Electric Vehicles. *Advanced Engineering Letters*, *3*(3), 132-140. https://doi.org/10.46793/adeletters.2024.3.3.5

Milojević, S., Glišović, J., Savić, S., Bošković, G., Bukvić, M., & Stojanović, B. (2024). Particulate Matter Emission and Air Pollution Reduction by Applying Variable Systems in Tribologically Optimized Diesel Engines for Vehicles in Road Traffic. *Atmosphere*, *15*(2), 184. https://doi.org/10.3390/atmos15020184

Milojević, S., Stopka, O., Orynycz, O., Tucki, K., Šarkan, B., & Savić, S. (2025). Exploitation and Maintenance of

Biomethane-Powered Truck and Bus Fleets to Assure Safety and Mitigation of Greenhouse Gas Emissions. *Energies, 18*(9), 2218. https://doi.org/10.3390/en18092218

Miron, R., Hulea, M., & Rusu, A. (2024). Integrated services for passenger transportation in smart cities based on blockchain. In J. Machado et al. (Eds.), *Innovations in industrial engineering III. ICIENG 2024. Lecture Notes in Mechanical Engineering* (pp. 381-391). Springer, Cham. https://doi.org/10.1007/978-3-031-61582-5_32

Nylund, N., Karvonen, V., Kuutti, H., & Laurikko, J. (2014). *Comparison of diesel and natural gas bus performance* (SAE Technical Paper 2014-01-2432). https://doi.org/10.4271/2014-01-2432

Pooley, C. G., & Pooley, M. E. (2022). Mobility change over time. In *Everyday mobilities in nineteenth- and twentieth-century British diaries* (Studies in Mobilities, Literature, and Culture (pp. 55-80). Palgrave Macmillan. https://doi.org/10.1007/978-3-031-12684-0_3

Reji, A. K., Das, B., Ray, T. K., et al. (2025). Assessment of compressed natural gas as an alternative transportation fuel in reducing CO2 emission: A case of Agartala city. *Environmental Development and Sustainability*. https://doi.org/10.1007/s10668-024-05777-x

Skrúcaný, T., Milojević, S., Semanová, Š., Čechovič, T., Figlus, T. & Synák, F. (2018). The Energy Efficiency of Electric Energy as a Traction Used in Transport. *Transport technic and technology*, *14*(2), 2018. 9-14. https://doi.org/10.2478/ttt-2018-0005

Skrucany, T., Semanova, S., Milojević, S., & Ašonja, A. (2019). New Technologies Improving Aerodynamic Properties of Freight Vehicles. *Applied Engineering Letters, 4*(2), 48–54. https://doi.org/10.18485/aeletters.2019.4.2.2

Spoof-Tuomi, K., Arvidsson, H., Nilsson, O., & Niemi, S. (2022). Real-Driving Emissions of an Aging Biogas-Fueled City Bus. *Clean Technologies*, *4*(4), 954-971. https://doi.org/10.3390/cleantechnol4040059