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AI IN SMART MOBILITY - APPLICATION OF SOLUTIONS, DECISIONS, DETERMINANTS AND DEVELOPMENTS ON THE EXAMPLE OF SELECTED CITIES

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ABSTRACT

Purpose*: The aim of this article is to identify areas for the use of intelligent management in urban mobility, to identify factors determining further development in this area and to define a strategic decision-making framework for the integration of artificial intelligence in urban mobility.*

Need for the study*: Decisions to implement management based on modern intelligent mobility solutions can improve efficiency, reduce costs and increase passenger comfort. This article addresses the need to fill the research gap identified in the literature in the area of decision-making for the implementation and operation of AI-based smart mobility.*

Methodology*: The first part of this article presents a literature review of AI solutions used in smart urban mobility and the factors influencing the decision to implement them. This forms the basis for further practical research based on case studies showing examples of the application of these solutions in the intelligent management of selected cities and the conditions and further developments in this area. The final section of the article also provides a strategic view of the decision-making process in the development of smart urban mobility.*

Findings*: The research presented has identified the practical key elements of the AI-enhanced smart mobility concept and its framework conditions. In addition, the authors presented a model approach to strategic decision-making for the AI-enhanced smart mobility concept.*

Practical Implications*: The research carried out will identify good practices in the use of artificial intelligence (AI) in the management of sustainable urban mobility and will identify the main factors influencing decisions related to the use of AI in smart mobility.*

Keywords: smart mobility, decisions, intelligent management, sustainable development, artificial intelligence, public transport, smart city, decision-making process
JEL: O18, O33, R41

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1. INTRODUCTION

There are high expectations for the application of intelligent management in sustainable urban development, mainly including modern technologies used in decision-making, infrastructure management and urban services. The scope of application of AI in sustainable urban mobility goes far beyond the hitherto basic traffic control solutions. AI-based systems are expected to revolutionise traffic management, improve safety for drivers, pedestrians and cyclists, and provide equal access to mobility services for all residents. There is a gap in the literature related to a comprehensive presentation of the application of AI-based intelligent management in smart mobility, covering all the most important aspects of the concept, including in the context of inclusive mobility, as well as the factors determining the decision to implement such solutions. The aim of this article is to identify possible areas of application of AI technologies in smart urban mobility, as well as to create a decision-making model for the development of smart urban mobility.

2. LITERATURE REVIEW

The authors conducted an analysis of publications indexed by Scopus. Using the search engine, it can be determined that there are more than 520,000 articles indexed with the keyword ‘artificial intelligence’ and almost 4,000 articles with the keyword ‘smart mobility’ in this database (data as of 9 March 2025). The search results are shown in Table 1.

The authors performed the analysis on the basis of articles with topics covering both AI and smart mobility in terms of the intersection of these two concepts. In terms of the number of articles that are simultaneously described with the keywords ‘artificial intelligence’ or ‘AI’ and ‘smart mobility’, the search showed that 194 such articles were published.

Table 1. The search results

Keywords	Number of articles between 2022 and 2025 (all/open access)	Number of articles in Scopus database (all/open access)
artificial intelligence	159,399 / 69479	521 064 /139 187
smart mobility	1 423/ 535	3 969/1 276
artificial intelligence, smart mobility	67/ 29	153/ 49
AI, smart mobility	31/ 7	41/ 9

Source: own elaboration.

By choosing ‘artificial intelligence’ (AI) and ‘smart mobility’ as keywords to search for articles, the authors aimed to capture different perspectives on the field. By choosing these broad terms, they ensured that the review would cover the various applications of artificial intelligence in the context of mobility. This enabled the authors to provide a comprehensive overview of the current state of research and emerging trends. In addition, the focus on these keywords enabled the identification of literature that directly addresses the intersection of advanced technologies and the challenges and opportunities of sustainable mobility, which is closely aligned with the objectives of this review. The authors chose to review a selection of 194 articles.

Due to the large number of articles, it was decided to select them for further more detailed analysis. For this purpose, certain criteria were adopted for the selection of articles for the next stage of the research. These criteria are:

(1) connection to the topic of the article;
(2) articles that talk about current issues of smart mobility using AI;
(3) articles that have a practical dimension;
(4) open access articles.

Based on the aforementioned criteria, the authors made a selection by reviewing the abstracts of 58 articles and, as a result, 43 open access articles were left for the next stage. These articles were reviewed in full-text and described in this article.

In the next step, the papers were categorised into:
1. Areas of application of AI in smart mobility.
2. Determinants of smart mobility development based on AI.

Areas of application of artificial intelligence in smart mobility spotted in the literature are:
(a) autonomous vehicles,
b) intelligent traffic management, Intelligent Transport Systems (ITS) and support to public transport,
c) shared mobility,
d) support for micro-mobility,
e) inclusive mobility,
f) support for public services,
g) support for mass events,
h) mobility-as-a-Service (MaaS),
i) intelligent mobility in tourism,
j) smart parking.

The results of the study are presented in Table 2.

Table 2. Areas of application of artificial intelligence in smart mobility

Area of application	**Description**	**Articles**
Autonomous vehicles (AV, CAV, PAV, UAV)	identification of cyber threats and their link to CAV	Khan S.K., Shiwakoti N., Stasinopoulos P., Chen Y., Warren M. (2024)
	management of autonomous vehicles in the context of ITS	Louati A., Louati H., Kariri E., Neifar W., Hassan M.K., Khairi M.H.H., Farahat M.A., El-Hoseny H.M. (2024)
	relevance of the perception system in autonomous vehicles	Rolen L.R., Bhat S.J., Santhosh K.V. (2024)
	key initiatives (CAV), (PAV i UAV)	Nikitas A., Michalakopoulou K., Njoya E.T., Karampatzakis D. (2020)
	the use of autonomous vehicles (AVs) for „last-mile" mobile services	Bucchiarone A., Battisti S., Marconi A., Maldacea R., Ponce D.C. (2021)
	supporting autonomous mobility through optimised control systems	Mahrez Z., Sabir E., Badidi E., Saad W., Sadik M. (2022)
	a new challenge for automotive projects around the world,	Trovao J.P. (2021)
	applying artificial intelligence to the design of future cars	Martínez I. (2021)
	pointing to an overly optimistic timeline for CAV development and adoption	Nikitas A., Njoya E.T., Dani S. (2019)
	implementing AI algorithms in EV and TV to optimise travel costs, developing a realtime ecological traffic map.	Jendoubi F., Pradeep V., Khemmar R., Berradia T., Rossi R., Sibbille B., Fourre J., Ohayon A., Jouni M. (2024)
Shared mobility	improving the management of shared mobility systems	Kubik A. (2023)
	automated ride-sharing platforms	Ong Y.C., Protopapas N., Yazdanpanah V., Gerding E.H., Stein S. (2024)
Support for micromobility	support of cycling transport	Costa D.G., Silva I., Medeiros M., Bittencourt J.C.N., Andrade M. (2024) Fontes T., Arantes M., Figueiredo P.V., Novais P. (2022)
	supporting the transport of electric scooters	Al-Habaibeh A., Watkins M., Shakmak B., Javareshk M.B., Allison S. (2024)
Inclusive mobility	real-time data collection to improve the livability of the city and the amenities of its residents	Anedda M., Fadda M., Girau R., Pau G., Giusto D. (2023)
	advanced wheelchair technology for wheelchair users	Li L., Chen W., Chen K. (2024)

	social inclusion and secure mobility to improve mobility services outside the home for seniors	Bokolo A.J. (2023)
	conceptualising transport as one of the main domains of age-friendly cities	Loos E., Sourbati M., Behrendt F. (2020)
	smart home model for safe and robust mobility for blind people..	Tayyaba S., Ashraf M.W., Alquthami T., Ahmad Z., Manzoor S. (2020)
Intelligent traffic management Intelligent Transport Systems (ITS) Support for public transport including AI in rail transport (metro)	real-time traffic flow measurement, tackling traffic jams	Badidi E. (2022) Tayeb F., Chihaoui H., Filali F. (2023)
	traffic management in the city in the event of traffic incidents	Lenatti M., Narteni S., Paglialonga A., Rampa V., Mongelli M. (2023) Jadhav B., Kulkarni A., Khang A., Kulkarni P., Kulkarni S. (2025) Cirianni F.M.M., Comi A., Quattrone A. (2023) Albuquerque V., Oliveira A., Barbosa J.L., Rodrigues R.S., Andrade F., Dias M.S., Ferreira J.C. (2021)
	advanced surveillance and algorithms to regulate pedestrian signalling	Sepehr P. (2024)
	technologies to ensure the safety of road users when driving	Mahrez Z., Sabir E., Badidi E., Saad W., Sadik M. (2022)
	research areas for different ITS systems	Gamboa-Rosales N.K., Celaya-Padilla J.M., Hernandez-Gutierrez A.L., Moreno-Baez A., Galván-Tejada C.E., Galván-Tejada J.I., González-Fernández E., Gamboa-Rosales H., López-Robles J.R. (2020)
	support for train (metro) infrastructure in the fight against congestion, accidents, overloading of wagons and maintenance	Asad S.M., Ahmad J., Hussain S., Zoha A., Abbasi Q.H., Imran M.A. (2020)
Support for mass events	Anticipate high crowd density in specific areas that could lead to disasters. Reducing the risks associated with increased mobility in a specific area..	Bellodi E., Zese R., Petrovich C., Frascella A., Bertasi F. (2024)
Support for public services	implementation of a pathfinder service for paramedics in emergency situations	Charef A., Jarir Z., Quafafou M. (2022)
MaaS	exploration of IoV-based vehicle-mounted media scenarios and proposals for an IVI solution for MaaS.	Yu Z., Jin D., Song X., Zhai C., Wang D. (2020)
	mobility as a service (MaaS), but also transport-enabled technologies such as the Internet of Things (IoT) and the Physical Internet (PI)	Nikitas A., Michalakopoulou K., Njoya E.T., Karampatzakis D. (2020)
	sustainable mobility behavior	Schwinger F., Krempels K.-H. (2019)
Intelligent mobility in tourism	development of an intelligent mobility system combined with the presentation of video information to tourists about local attractions	Smirnov A., Kashevnik A., Shilov N., Mikhailov S., Gusikhin O., Martinez H. (2019)
Intelligent parking system	automating the parking process using the Internet of Things, artificial intelligence and multi-functional systems	Belkhala S., Benhadou S., Boukhdir K., Medromi H. (2019)
	use of multiple visual sources to monitor the wider parking area from different perspectives	Ciampi L., Gennaro C., Carrara F., Falchi F., Vairo C., Amato G. (2022)
	developing intelligent parking systems that provide real-time information on parking space availability	Belkhala S., Benhadou S., Medromi H. (2019)

Source: own elaboration.

Based on the literature survey, it can be concluded that AI technologies in relation to mobility most often refer to intelligent transport systems (ITS) and autonomous vehicles.

ITS integrate information and communication technologies (ICT) with transport infrastructure and, in a broader context, also with autonomous cars (Alanazi F., 2023). The data collected by the systems from sensors and devices implanted in vehicles and infrastructure provide relevant information about the state of the transport system at a given time and place. They can improve the efficiency of traffic management and the convenience of people in urban areas, by reducing congestion or journey times and thus reducing fuel consumption and air pollution (Meneguette R.I., De Grande R., Loureiro A.A., 2018). The integration of ITS into the transport system infrastructure and vehicles, can benefit the safety of road users. ITS has many other applications in intelligent mobility among others maintenance management, traffic signal management and public transport control systems (Maldonado Silveira Alonso Munhoz, P.A., da Costa Dias F., Kowal Chinelli C., Azevedo Guedes A.L., Neves dos Santos J.A., da Silveira e Silva W., Pereira Soares C.A., 2020).

The use of AI in vehicles allows them to move autonomously and participate in city traffic (Meneguette R.I., De Grande R., Loureiro A.A., 2018). Modern vehicles are often equipped with global positioning systems (GPS) and wireless communication devices. These can detect events in their environment and draw conclusions about route and navigation decisions without human intervention. However, there are concerns about their use, as even small faults in an intelligent vehicle system can lead to a serious safety problem (Rolen L.R., Bhat S.J., Santhosh K.V., 2024). These concerns necessitate large investments in automotive electronic systems for safety, comfort and also efficiency. There are also concerns about the possibility of cyber-attack, fully connected and automated CAVs (Khan S.K., Shiwakoti N., Stasinopoulos P., Chen Y., Warren M., 2024). Intelligent or autonomous vehicles (AVs) are already on the roads in many countries, and these vehicles already communicate with each other to ensure the safety of road users. One application of AVs is the use of autonomous vehicles (AVs) for 'last mile' mobility services. Autonomous shuttle transport as a service, various applications targeting last-mile delivery of goods, travel experiences and shared and integrated mobility (Bucchiarone A., Battisti S., Marconi A., Maldacea R., Ponce D.C., 2021).

Another application area for AI is a service that supports mobility planning and the use of different forms of transport within a single Mobility-as-a-Service (MaaS) platform. It provides users with a seamless integration of different modes of transport and customised mobility options to meet individual requirements. In addition, it allows users to pay for these services as well as obtain the necessary information for the traveller. With the help of MaaS and appropriate incentives, it is possible to move users towards a more sustainable mobility behaviour. This reduces congestion and relieves congestion in urban mobility networks (Schwinger F., Krempels K.H., 2019).

The solutions being introduced that make use of AI also relate to inclusive mobility projects. An inclusive transport system enables easy movement and provides unrestricted access to jobs and services for all potential passengers and people, regardless of their situation. Regardless of age, gender, economic or social status or disability, every citizen should be able to move efficiently (EC, 2023). Important solutions that can make use of AI are also micromobility systems related to cycling, or scooters, which as forms of sustainable transport are promoted in cities. Related to this form of transport are shared mobility systems, where a resident can use different modes of transport including cars without owning them. Smart mobility and in particular automated ride-sharing platforms promise efficient, safe and sustainable modes of transport in urban environments (Ong Y.C., Protopapas N., Yazdanpanah V., Gerding E.H., Stein S., 2024).

The problem in cities is often the problem of parking cars and the lack of information about parking availability. AI supports parking management by providing real-time updates of availability information, automated payment systems and predictive parking analysis, thus reducing traffic congestion and increasing parking efficiency (Belkhala S., Benhadou S., Medromi H., 2019).

The introduction of the solutions described, the way they function and their level of advancement in individual cases (cities) depends on a number of factors. Among these we can distinguish:

- ICT availability, interoperability, ability of systems and infrastructure to work together (Bokolo A. Jnr, 2024; Arora A., Jain A., Yadav D., Hassija V., Chamola V., Sikdar B., 2023; Fontes T., Arantes M., Figueiredo P.V., Novais P., 2022; Nikitas A., Michalakopoulou K., Njoya E.T., Karampatzakis D., 2020);

- the feasibility of ensuring system performance (Munhoz P.A.M.S.A., Dias F.D.C., Chinelli C.K., Guedes A.L.A., Dos Santos J.A.N., E Silva W.D.S., Soares C.A.P., 2020);
- the costs of using new solutions for users and also the savings that can be achieved through these solutions (Jendoubi F., Pradeep V., Khemmar R., Berradia T., Rossi R., Sibbille B., Fourre J., Ohayon A., Jouni M., 2024);
- regulations including sustainability and inclusive mobility (Sawhney N., 2023; Anedda M., Fadda M., Girau R., Pau G., Giusto D., 2023; Li L., Chen W., Chen K., 2024; Bokolo A.J., 2023; Loos E., Sourbati M., Behrendt F., 2020);
- urban development and urban mobility plans including the creation of car parks (Costa D.G., Silva I., Medeiros M., Bittencourt J.C.N., Andrade M., 2024);
- opportunities and willingness of the private and public sectors to cooperate (Schwinger F., Krempels K.-H., 2019; Bjørgen, A., & Ryghaug, M., 2022);
- privacy and data security concerns and opportunities to ensure security (Papyshev G., Yarime M., 2021; Wolniak, R.,Stecuła, K., 2024; Khan S.K., Shiwakoti N., Stasinopoulos P., Chen Y., Warren M., 2024; Rolen L.R., Bhat S.J., Santhosh K.V., 2024);
- residents' attitudes, competences, needs and social acceptance of the solutions offered (Costa D.G., Silva I., Medeiros M., Bittencourt J.C.N., Andrade M., 2024; Anedda M., Fadda M., Girau R., Pau G., Giusto D., 2023);
- the need to develop shared mobility (Kubik A., 2023; Ong Y.C., Protopapas N., Yazdanpanah V., Gerding E.H., Stein S., 2024);
- the need to enhance safety in transport (Al-Habaibeh A., Watkins M., Shakmak B., Javareshk M.B., Allison S., 2024; Albuquerque V., Oliveira A., Barbosa J.L., Rodrigues R.S., Andrade F., Dias M.S., Ferreira J.C., 2021).

3. METHODOLOGY

This article uses a literature review as the primary research method. In addition, the next part of the discussion analyses the practical dimension of the issues raised based on selected cities, namely: Singapore and Copenhagen. These cities were chosen because of the high level of sophistication of AI solutions implemented in smart mobility and the possibility to identify good practices for other cities. According to the Smart City Index ranking from IMD (IMD, 2024), which is one of three rankings assessing smart city development, Singapore and Copenhagen are among the most advanced smart cities in the world. In this ranking, Singapore is ranked fifth, closely followed by Copenhagen in sixth place. The authors deliberately chose cities in similar high positions and at the same time located on two different continents, which may show the different approaches to smart mobility development in these different environments. In addition, the main directions for the development of smart mobility in Central and Eastern European cities are presented. The final section of the paper presents a model approach to decision-making for implementing and developing AI in smart city transport. Figure 1 shows the subsequent research stages.

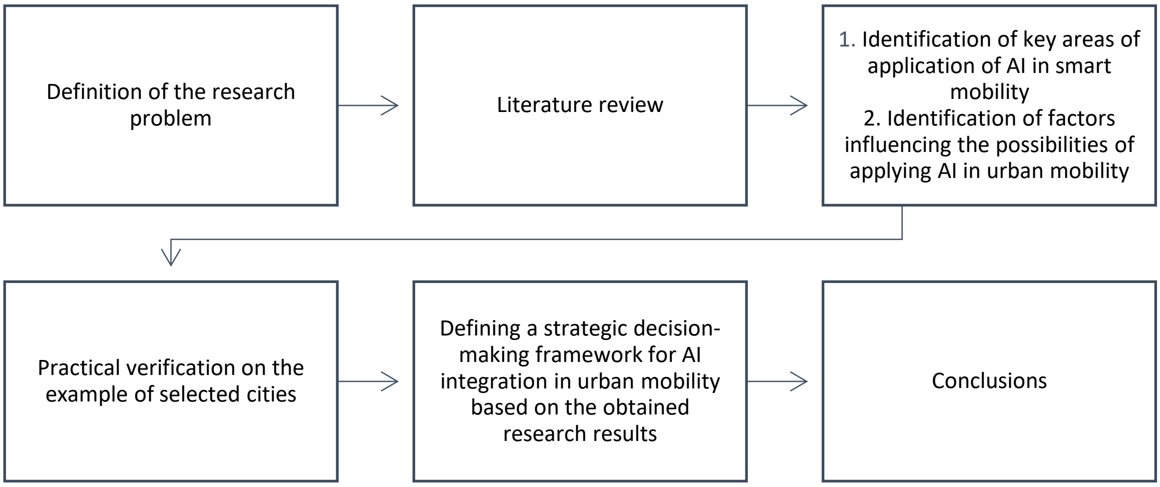

Figure 1. Stages of research
Source: own elaboration.

4. AI APPLICATION IN SMART MOBILITY IN SELECTED CITIES - RESEARCH FINDINGS

The literature research carried out provides a reference base for the practical implementation of AI in smart mobility in cities. Case studies were used to investigate the practical application areas and determinants of AI in smart mobility. Developed cities such as Singapore and Copenhagen, as well as cities in Central and Eastern Europe that are also taking steps towards AI-supported sustainable mobility and following the good practices of the aforementioned cities, were examined.

B. Singapore

One of the world leaders in smart mobility solutions is the city-state of Singapore. Within this city-state, a number of initiatives have been implemented to increase transport efficiency, reduce traffic problems and promote sustainable mobility. It is important to note that between 2017 and 2022, Singapore has seen an almost doubling of the intensity of people's movement - both residents and tourists. These dynamics have necessitated policymakers to trigger a decision-making process based on the use of an intelligent transport system, using innovative solutions and new technologies It should be noted that Singapore has been a forerunner of intelligent transport solutions. As early as 2005, a smart transport system was established there. This experience has given it a significant advantage over other cities that have not taken steps to digitise urban mobility. Among the measures implemented are:

- implementation of an electronic road pricing system to regulate access to the city centre;
- the development of a motorway monitoring system to inform drivers in real time of traffic accidents on major roads;
- mandatory priority rules on the road for buses. In Singapore, it is prohibited to restrict buses from joining traffic;
- a shift away from the use of private vehicles. Only 15% of Singaporeans own cars because obtaining a private vehicle involves acquiring an expensive certificate that is only valid for 10 years.

It should be pointed out that the development of Intelligent Transport System (ITS) has been ongoing for two decades. In Singapore, advanced ITS system has been introduced to maintain road safety and improve traffic flow. The ITS system provides many intelligent transport services to residents. The potential of ITS is the result of a holistic approach to traffic management. This includes a number of transport initiatives such as free public transport during peak hours, a vehicle limit system and the need to pay a fee to enter the city centre.

Singapore, using advanced ITS technologies, has the ability to manage traffic efficiently. These technologies allow for real-time traffic monitoring, dynamic message signs and intelligent traffic control systems that optimise signal times based on road conditions, reducing congestion and travel time. These technologies also improve journey planning and informed travel decisions. ITS helps optimise traffic flow, reduce congestion and increase overall transport efficiency in Singapore. By analysing data and using smart technologies, ITS contributes to safer and more convenient journeys for residents and visitors (Zhong et al., 2016). An example of a smart solution, is One Motoring, a comprehensive portal that serves all drivers and vehicle owners in Singapore. By installing GPS-equipped surveillance cameras on roads and taxis, up-to-date traffic data can be obtained. The information collected is available to residents on an online portal. In addition, pictures of the roads are taken at short intervals (about 5 minutes) and are available through One Motoring - Traffic Smart. However, while maintaining safety considerations, real-time close-ups and images from moving cameras are not made available online. The One Motoring portal collects information routes where roadworks are in progress, current ERP (Electrical Road Pricing) toll rates, as well as car parks. A travel time calculator is also available. As well as providing traffic information, it is a portal that offers residents tips on selling and buying vehicles, as well as vehicle maintenance. The portal is also available on mobile devices. It should be emphasised that a fast, smooth and safe response to traffic incidents is possible thanks to EMAS (Expressway Monitoring Advisory System). It provides intelligent incident management and is responsible for quickly restoring traffic flow when a traffic incident, accident or vehicle breakdown is detected. This intelligent tool allows drivers to make decisions regarding the choice of optimal travel routes. Located along expressways, electronic message signs display messages and graphics about the current traffic situation. The actual travel time is also taken into account. EMAS serves the main traffic routes, so that traffic flow is improved throughout the island. Another smart solution is the 'Your Speed Sign' (YSS), a smart sign that displays the speed of oncoming vehicles in real time. The sign is designed to warn drivers when a vehicle's speed is exceeded, but also to encourage more conscious driving that is within a certain limit. This solution contributes to improving road safety. The 'Parking Guidan-ce Service' has been in operation in Singapore since 2008. This is a tool designed to provide drivers with real-time access to information on available parking spaces. Efficient use of available parking spaces contributes to reducing traffic congestion. The information is displayed both on the electronic notice board and online in the One Motoring portal. Provision is also made for the use of the MyTransport app. SG app for mobile devices. This application informs commuters about the traffic situation, thus improving their travelling comfort. It should be emphasised that everything is done in real time. The information is regularly updated. Recently, the Land Transport Authority (LTA) worked with SBS Transit and SMRT to install and test a new centralised system that determines the location of a bus in real time, so that more accurate public bus arrival information can be provided. Seat availability information is colour-coded, with green indicating available seats, yellow indicating standing room, and red indicating that standing room is limited (Wolniak, Grebski, ,2023).

In addition to the development of the MyTransport.SG mobile app, Singapore has implemented a number of systems, integrating various solutions. These include:

- an automated track inspection system, using imaging sensors and scanners to monitor track condition in real time;
- a rail asset management system, gathering information from all trains and other supporting equipment to better assess and predict the condition of the entire network and its components;
- predictive analytics and data visualisation tools to analyse traveller behaviour and preferences;
- artificial intelligence used to improve pedestrian safety and facilitate urban planning.

Singapore has also introduced a number of instruments to prioritise buses on roads, including dedicated bus lanes, bus priority traffic lights and bus priority boxes at intersections. These instruments are aimed at improving bus speeds, increasing reliability and encouraging more people to use public transport. It should be pointed out that Singapore was also one of the first cities to introduce electronic road pricing as a way to manage congestion. The ERP (Electronic Road Pricing) system charges vehicles for road use during peak hours in congested areas, effectively controlling traffic congestion and encouraging the use of public transport (Chin, 2021).

Singapore has also embraced shared mobility options, including bike-sharing and e-scooters. In Singapore, bike-sharing services provide a convenient mode of transport for short trips. Users can easily locate available bikes using mobile apps, which show real-time bike availability at various docking stations across the city. Once located, users can unlock the bikes using the mobile app or their membership card. These bikes are designed for easy riding and are usually equipped with features such as adjustable seats, baskets and built-in GPS systems (Joo, 2023).

The decision to introduce bike sharing and electric scooter systems has had a positive impact on urban mobility in Singapore. These services are an easy and convenient solution, replacing private transport. As a result, the capacity of major arteries is increased while reducing the carbon footprint. The solution also encourages residents and tourists to enjoy an active lifestyle. Bike sharing and electric scooters offer connectivity to public transport hubs, making multimodal travel more accessible. In addition, the availability of shared mobility options supports the government's plan to create a car-free society in Singapore. It should be noted that by reducing reliance on private cars, these systems contribute to a more sustainable and efficient transport network (Ferro-Escobar et al., 2022).

A description of the implementation of the main factors of the smart mobility concept in Singapore is presented in Table 3.

Table 3. Key drivers of the smart mobility concept in Singapore

Pillars of smart mobility in Singapore	Method of implementation
Integration and connectivity	Singapore emphasises the integration of different modes of transport into a unified network. The city's rapid transit (MRT) system, buses, taxis and other mobility options are interconnected, allowing passengers to easily switch between different modes of transport.
Modern infrastructure	The city-state has invested heavily in building a comprehensive and advanced transport infrastructure. This includes a well developed road network, efficient public transport systems for public transport, dedicated bus lanes and pedestrian-friendly pavements. Intelligent Transport Systems (ITS) Singapore uses ITS technologies to improve traffic management and provide real-time information to commuters. This includes traffic monitoring, dynamic message signs and smartphone apps to help users make travel planning decisions
Planning and optimisation using data	The government uses data analytics to analyse travel patterns, traffic flow and passenger demand. This data-driven approach helps to optimise transport systems, identify bottlenecks and make informed decisions about infrastructure development and service improvements. infrastructure development and service improvements.
Smart payments and ticketing systems	Singapore has introduced contactless payment systems and smart ticketing options on various modes of transport. Commuters can use contactless smart cards or mobile cards to pay for their journeys, facilitating convenient and hassle-free travel.
Sustainable and green initiatives	Singapore is promoting sustainable mobility solutions such as electric vehicles and bike-sharing services and the use of a bike-sharing service. The government has implemented a system of incentives and infrastructure support to increase the use of electric vehicles and reduce carbon emissions.
Multimodal integration	Mobility-as-a-Service (MaaS) platforms are the underlying tool for Singapore's smart mobility. MaaS applications integrate various transport options, including public transport, ride-sharing services and micromobility solutions, allowing users to plan, book and pay for their entire journey.
Intelligent traffic management	Singapore uses technology such as the Electronic Road Toll (ERP) system to manage traffic. The ERP dynamically adjusts tolls based on demand, encouraging

	the use of public transport and reducing the use of private vehicles during peak periods.
Traffic management Autonomous vehicles	Singapore is at the forefront of testing and deploying autonomous vehicles. Autonomous vehicles are being tested in a variety of applications, such as autonomous shuttles for first and last mile connectivity and autonomous taxis for on-demand transport.

Source: own elaboration based on (Wolniak, Grebski2023).

In summary, the decisions made and the set of actions taken by Singapore on smart transport systems shows that their leadership is based on a coherent strategy, innovation and a willingness to implement modern solutions. Other cities are also introducing smart transport systems decision-making models that improve quality of life and sustainability.

The role of policy makers must be clearly emphasised. The Singapore government plays a proactive role in implementing smart mobility solutions. It sets policy, provides funding and incentives, works with industry stakeholders and actively engages the public to ensure the successful adoption of smart mobility initiatives.

C. Copenhagen

The City of Copenhagen is the first city to take the decision and introduce an innovative traffic control system that adapts in real time to changing traffic conditions and is the first in the world to introduce an all-electric freefloating car sharing system to be integrated into public transport in Copenhagen. Copenhagen has also introduced a range of smart mobility solutions to improve safety and accessibility. And inclusive mobility projects are particularly relevant here. Overwhelmingly, the decisions made are mainly about initiatives that affect pedestrians and cyclists, who are a priority. It is also extremely important for decision-makers to ensure adequate accessibility of mobility services including the provision of low-floor buses and tactile surfaces for visually impaired pedestrians (Bager, Mundaca, 2021). The key drivers of smart mobility in Copenhagen are presented in Table 4.

Table 4. Main drivers of the smart mobility concept in Copenhagen

Key drivers of smart mobility in Copenhagen	**Implementation of factors**
traffic control system	By analysing data from sensors and cameras, algorithms optimise traffic signal timings, reducing congestion and minimising the impact on pollution. The city also uses machine learning to predict traffic patterns, allowing it to proactively adapt to potential accidents. This method not only improves overall traffic flow, satisfying drivers of different types of vehicles, but also dovetails with the city's commitments to environmental sustainability.
Advanced infrastructure adapted to the needs of different residents	An extensive system of bicycle paths enables efficient movement around the city area Low-floor buses and tactile surfaces for visually impaired pedestrians
Urban bike sharing system	enables residents and tourists to rent bicycles for a small fee. It has been a great success and has contributed to an even greater development of the use of bicycles as the main means of transport in the city
Solutions that increase safety	detection systems for pedestrians and cyclists at key intersections, alerting drivers to the presence of pedestrians and cyclists and reducing the risk of accidents
Integration of public transport systems	a comprehensive network of buses, trains and metro lines that are integrated into a single ticketing system, making it easier and more enjoyable for residents and tourists to use public transport

Intelligent traffic management system for the city	an intelligent parking system that uses sensors to detect available parking spaces and directs drivers to the nearest available space, reducing the time spent looking for a parking space and minimising traffic jams
Collection and use of big data	Copenhagen Connecting aims to improve travel times for public transport and cycling by 10% (GPS on buses and intelligent control of lighting and traffic signals), more efficient water and waste management real-time air quality monitoring
Interaction between public and private actors	The City Data Exchange programme is a private-public project that aims to explore the buying, selling and sharing of a wide range of data between all users in the city - citizens, public institutions and private companies. The vision is to create a shared data centre to foster innovation, improve the quality of life in Copenhagen, stimulate economic activity and contribute to the success of the CO2 neutralisation programme.
Promoting sustainable mobility	The city prioritises buses and cyclists on the roads. Intelligent lighting at intersections, organised through the Copenhagen Intelligent Traffic Solutions platform, is part of this approach. A network of Wi-Fi-enabled devices on the roads provides data for officials to monitor and stimulate transport. Smart lights can vary in brightness, for example increasing light intensity when a nearby cyclist is detected, which improves traffic safety and has so far resulted in more than 70% savings on public lighting.
	Copenhagen residents' smartphones transmit anonymous information to wireless sensors along the city's streets, allowing traffic lights to adjust to the number of pedestrians, cyclists and drivers using the roads at any given time. Traffic lights can also communicate directly with city buses, giving them longer green lights when they are late or crowded with passengers. These systems will ensure better traffic flow so that as many people as possible save time in the most environmentally friendly way.
	The safety of cyclists is also served by the so-called "green wave" programme implemented in Copenhagen to synchronise traffic lights for cyclists. It means that cyclists riding on a road with a white-green sign at 20 km/h during rush hour will not encounter a red light on their way
Supporting traffic organisation during mass events	Buses have longer green lights, which can reduce journey times by up to 30 per cent, and traffic systems help to clear mass crowds, such as from concerts or sports meetings, much faster than at present
Car-sharing	Car-sharing allows residents to use their cars only when necessary, reducing the number of vehicles on the road and the need for parking spaces.
	The fully electrified car sharing DriveNow is the world's first all-electric freefloating car sharing system to be integrated into public transport in Copenhagen. It is also a test platform to measure how electric cars can influence passengers' patterns and behaviour over the last mile, from the bus stop to their doorstep.

Source: own compilation based on Cenre, 2017; Bager, Mundaca, 2021; Eltved et al, 2021; Doost, Rezaie, 2020.

Copenhagen's mobility development plans include the implementation of GoA4, the latest upgrade to the S-bane network, using state-of-the-art technology. This technology allows trains to run completely without human intervention, using advanced sensors, artificial intelligence and complex communication systems. The system provides high-precision operation, using real-time data analysis to optimise route management and energy consumption. This level of automation not only increases train efficiency and frequency, but also enhances safety by minimising human error and inconsistencies.

Key technical specifications of Siemens Mobility's GoA4 technology:

- fully automated operation: trains run without drivers on board, managed entirely by automated systems;
- advanced sensor systems: Uses a combination of radar, lidar and optical sensors to provide accurate real-time perception of the environment;
- artificial intelligence: artificial intelligence algorithms interpret sensor data, make operational decisions and learn from vast amounts of operational data to improve performance and safety;

- real-time data processing: Ability to process and react to real-time data to make immediate decisions on speed adjustments, routes and station stops;
- remote monitoring: Equipped with a central monitoring system that monitors all train operations from a remote location, ensuring that any potential problems are quickly resolved;
- communications-based train control (CBTC): Uses CBTC technology to precisely control train movements, increasing the capacity and reliability of rail services;
- emergency management systems: Integrated systems designed to deal autonomously with emergency situations with contingency options (Drab- Kurowska, Drożdż, 2021);
- energy efficiency optimisation: Has built-in mechanisms to reduce energy consumption, adjusting operations based on real-time conditions and demand.

In summary, the decisions made in Copenhagen regarding intelligent transport systems indicate that the decisions made were definitely based on the needs of the citizens and the transport specificities of the city. In the case of Copenhagen, this is primarily cycling, sustainable mobility or pedestrian movement and safety. It is important to emphasise that decision-making on smart mobility in Copenhagen is based on a consistent strategy, based on modern solutions, with a particular focus on sustainability.

D. Cities in Central and Eastern Europe

Singapore and Copenhagen are among the most developed cities and are leaders in smart mobility. Other cities, including those in central and eastern Europe, are also striving to provide their citizens with comfortable yet sustainable mobility options and the aforementioned cities are leading by example. For example, the Slovak capital, Bratislava, has implemented an integrated transport system that includes a combination of electric buses, trams and trolleybuses, as well as a bike-sharing system. Meanwhile, a mobile app allows users to plan journeys and pay for tickets. Prague has implemented a smart parking system that uses sensors to monitor parking spaces and provide drivers with real-time information. One component of this system is a mobile app that indicates available parking spaces to drivers and allows online payment. Smart technologies in cities should also serve to improve public safety. One example of such solutions is a platform that integrates data from various sensors and systems, including CCTV cameras, traffic management systems and emergency services, which Warsaw has implemented.

According to a recent PwC report (PwC, 2024), the biggest challenge for smart cities in central and eastern Europe is currently improving air quality, this is due in part to traffic jams. Of the cities surveyed, only one city Tallinn meets the safe air standard set by the World Health Organisation. Action on environmentally friendly forms of urban mobility is therefore required. CEE cities are implementing the Green Transformation of Public Transport programme. Progress in electrification of public transport fleets is evident in almost all cities, as well as experiments with hydrogen buses and other innovations.

A second major problem is the underdeveloped infrastructure for battery electric vehicles (BEVs), which is mainly led by the private sector. An important factor, as in Copenhagen, in guiding the development of smart mobility is Sustainable Urban Mobility Plans (SUMPs), which should be developed with the involvement of different stakeholder groups, especially citizens themselves. The need for cross-sectoral cooperation in financing new projects and providing solutions to support the smart mobility concept is also recognized.

The use of modern AI technology is primarily used to ease congestion and speed up traffic flow, while prioritising public transport, cyclists and pedestrians. In addition, these cities are implementing data- and cloud-based smart mobility for long-term and short-term traffic management.

5. DISCUSSION

On the basis of the research carried out, it can be concluded that today, smart mobility is considered a driving force of modern cities and an important economic factor and facilitator of smart, sustainable development. Smart cities in terms of smart transport systems are developing urban transport infrastructures that use innovation to optimise resource management, improve urban transport and enhance the quality of life for residents as well as all those moving around in the city.

Hence, it is very important to carry out the decision-making process properly, taking into account the cities' resources, its potential and internal and external determinants. It should be emphasised that planning smart mobility that provides efficient and optimal urban mobility solutions is one of the key challenges facing cities around the world. Current and future smart mobility challenges require effective smart mobility solutions using AI solutions. AI takes cities to the next level, allowing them to use this data and knowledge to support decision-making. This will facilitate collaboration across ecosystems (including information ecosystems) and achieve sustainability goals. It is important to emphasise that these challenges are part of the rapidly changing landscape of urban mobility, as perceived by decision-makers responsible for planning and environmental decisions of smart cities. The decision-making process of the planned strategies, aims to address and solve urban mobility challenges. Figure 2 shows the elements that should be included in the process of building a smart mobility strategy.

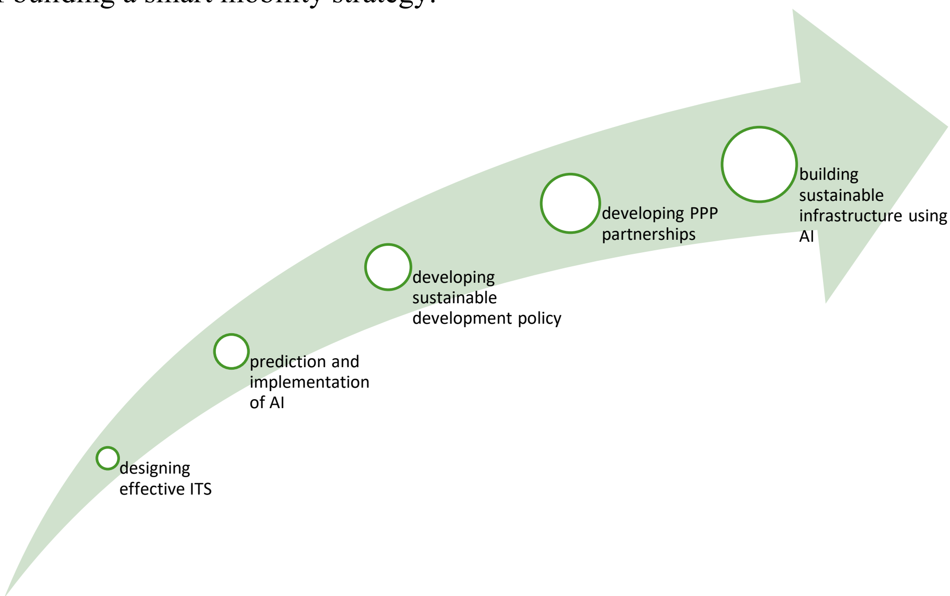

Figure 2. Elements of the smart mobility strategy building process
Source: own elaboration.

The starting point of the decision-making process is the project, which should respond to the identified needs. The high level of specificity of each city should be emphasised here (Budziewicz-Guźlecka, Drab-Kurowska, 2017). It is important to design efficient, equitable, safe and secure public transport systems that are integrated with mobility services (MaaS) and other platforms. The next element of an effective decision-making process is predisposition and implementation of AI. A key activity throughout the decision-making process is the development of policies and strategies to promote adherence to air quality and other measures to improve quality of life. Another area requiring the right decisions by decision-makers is the development of public-private partnerships (PPPs) and collaboration with scientific institutions to address air quality, traffic congestion and sustainability issues. The bonding element between the above elements is the construction of sustainable infrastructure - based on the use of AI.

However, it should be emphasised that achieving a high level of sustainable urban mobility requires not only investment in infrastructure, but also a change in the context of the decision-making process, the mindset and the daily habits of the inhabitants. Despite even the developed capabilities of AI and the willingness of institutions to implement the use of the opportunity provided by these systems, if the inhabitants of a city do not have the skills to use these capabilities, the concept of smart city, including smart mobility, will not develop smoothly (Budziewicz-Guźlecka, 2017). Therefore, it is also important to support the residents' skills in the opportunities offered.

The common platform for the above, on the other hand, is society's needs for safe, clean, reliable and affordable ways to get around. One of the key roles AI plays in the evolution of the smart city, is its ability to analyse data to improve public safety: pedestrians and drivers, optimising traffic management.

The challenge for policy makers, is to find ways to improve urban mobility while reducing congestion, accidents and pollution. A particular challenge for all major cities in the world is to reduce pollution caused by CO2 emissions. It is crucial to take measures to reduce and control pollution levels. It is also important to point out that among the challenges facing societies and economies is the challenge of car/public transport dependency. Urbanisation processes and continued car dependence inevitably lead to road disruptions[4], emissions and mobility safety issues that transport policy makers and city planners are grappling with. While cities are recognising the benefits of public transport in terms of pollution and congestion reduction, local government efforts to deliver these benefits can clash with disruptive business models such as Uber and other ride-hailing services. Ridesharing services and other forms of sharing that complement public transport are a solution that deserves attention (Budziewicz-Guzlecka, 2017; Drobiazgiewicz, Pokorska, 2023). However, the challenge is to overcome the first-mile, last-mile problem and enable citizen-oriented travel by integrating public transport with ride ordering, ride sharing, ride sharing and smart ticketing services. Another challenge facing decision-makers is safety. Despite high investment in improving the safety of urban mobility, "road fatalities are increasing in many cities" (Glasco, 2019). It should be emphasised that urban population density, combined with cars, trucks and public transport vehicles "sharing congested streets with vulnerable road users (pedestrians, cyclists and motorcyclists), makes the task of ensuring safe mobility a complex challenge. The safety problem is further complicated by unsafe driving habits and insufficient infrastructure for bicycle and micromobility users.

6. CONCLUSION

The examples of solutions presented in the article generate questions. Could similar intelligent management solutions be applied universally? Are other cities ready for smart mobility? Would authorities and residents be willing to change their habits in favour of more sustainable urban mobility?

In order to obtain answers, it is necessary to focus on carrying out a broad analysis as a route to smart mobility, taking into account a number of determinants, as shown in Figure 3.

Figure 3. Areas of analysis on the way to AI-based smart mobility
Source: own elaboration.

This in-depth analysis will be the starting point for action, which is depicted in Figure 4. Decision makers in the field of AI and smart mobility can use this model solution, which will guide them step by step to implement AI-based smart mobility solutions efficiently, depending on the level of intensity of the impact of each dimension.

[4] According to the European Joint Research Centre, "the cost of traffic jams in Europe is around 1% of GDP, and mitigating them is a top priority for most infrastructure measures, traffic management and road pricing. [...] The cause of traffic jams in many cases is not a lack of road infrastructure capacity, but rather a demand management issue."

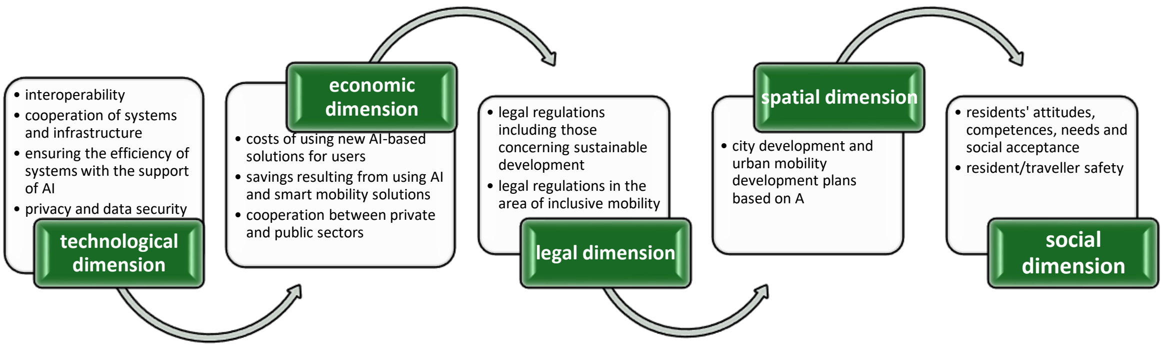

Figure 4. AI implementation model in smart mobility
Source: own elaboration.

The starting point is an analysis of the determinants influencing the development of smart mobility. The dimensions identified are important at each stage of building an AI implementation model for smart mobility.

As a first step, decision-makers need to verify the potential of the AI infrastructure in terms of its interoperability and compatibility with other systems operating in the city. The issue of ensuring data privacy and security is also important. This determines the next action, which is the economic dimension of the model. Decision-makers, when deciding to use AI, have to estimate the costs and benefits both at the level of the administration and for the resident using AI-based smart mobility technology. Particularly valuable are analyses showing savings made in the context of using AI. Openness in AI implementation is also important, especially in the area of broadly understood cooperation between the private and public sectors. Legislative issues, often different at the level of different countries, are then considered. In particular, an analysis of the regulation of inclusive mobility is necessary, targeting the openness of regulation in the development of smart mobility concepts or the support of AI. Another area that needs to be addressed in the context of implementing smart mobility solutions with AI support is the potential of cities and their ability to adapt smart solutions. The assumptions made by decision-makers in the context of urban infrastructure. It should be emphasised that a prerequisite for the implementation of smart mobility solutions is dialogue between all stakeholders and, above all, openness to change and commitment to long-term strategies. Cooperation between the community and urban decision-makers is a key element in the successful development of smart cities. Artificial intelligence can be used to increase community engagement through communication platforms that allow residents to share their ideas and opinions on city development. The model also needs to be socially validated. Artificial intelligence can be used to gather residents' opinions. Through mobile apps and online platforms, residents can make suggestions about the development of the city, making the decision-making process more democratic and accessible to all. The right steps and taking the correct course of action will benefit both current and future generations.

In conclusion, to be able to implement the above model, it is not only necessary to have knowledge of reality, but it is necessary to anticipate the future. The importance of AI-enabled management in shaping the future of urban life will continue to grow. The synergy between artificial intelligence and urban planning for intelligent transport solutions is becoming increasingly important. The integration of artificial intelligence goes beyond simple efficiency improvements; it becomes the foundation for a more regenerative, resilient urban future. The road to intelligent urban transport management is undoubtedly a challenge, but with artificial intelligence as a driving force, cities around the world are poised to discover new possibilities and define a new essence of urban existence.

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