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URBAN TRANSPORT AS A KEY ELEMENT OF SMART CITY DEVELOPMENT: A COMPARATIVE ANALYSIS OF WARSAW AND LONDON

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Purpose: The purpose of the article is to compare the development and implementation of smart mobility and sustainable urban transport solutions in Warsaw and London in the context of smart-city development, transport accessibility, environmental sustainability, and quality of life improvement.
Design/methodology/approach: The study applies a comparative case-study approach based on a literature review, analysis of strategic and policy documents, statistical data, and secondary sources related to smart mobility, sustainable transport systems, and urban governance in Warsaw and London
Findings: The study applies a comparative case-study approach based on a literature review, analysis of strategic and policy documents, and secondary statistical data related to smart mobility and sustainable urban transport systems in Warsaw and London. In the first stage of the research, a set of original indicators was developed to quantitatively assess the efficiency and sustainability of urban transport systems in both cities. These indicators were subsequently used to compare smart mobility solutions, transport accessibility, environmental performance, and the level of integration of intelligent transport systems.
Originality/value: The article provides a comparative perspective on smart mobility development in two European capitals characterised by different historical, economic, and institutional conditions. It contributes to the discussion on sustainable urban transport by integrating smart-city concepts, intelligent transport systems, quality of life, and inclusive urban development.
Keywords: smart city; smart mobility; sustainable transport; intelligent transport systems; urban mobility; quality of life.
Category of the paper: Research paper.

1. Introduction

Urban transport systems are increasingly recognised as a fundamental component of the smart-city paradigm, whereby cities leverage digital technologies, integrated infrastructure, and sustainable mobility practices in order to enhance the quality of life, reduce environmental impact and improve urban competitiveness (Angelidou, 2022). In this context, the capitals of Poland and the United Kingdom, Warsaw and London present particularly instructive cases. They exemplify different trajectories in implementing smart-mobility solutions, offering a rich basis for comparative analysis and policy learning.

The concept of the "smart city" has evolved to integrate multiple dimensions including governance, infrastructure, economy, society and environment (Masik et al., 2021). For example, in the case of Warsaw, its "Towards a Smart City" document outlines key pillars such as intelligent city management, sustainable economic growth, infrastructure and public transport as foundational elements of its smart-city agenda (Knight Frank/Poland report, 2018).

Within this broader lens, "smart mobility" or "smart transport" has emerged as a critical sub-domain: technologies such as ICT, IoT, big data analytics and real-time information systems are increasingly deployed to improve transport efficiency, accessibility and sustainability (Paiva et al., 2021). As one study notes, the deployment of smart-mobility solutions in public transport is central to cities aspiring to the "smart city" status (Korneć et al., 2018).

Transport remains a major challenge for metropolitan areas, given the dual imperatives of reducing congestion and emissions, while also ensuring accessibility and inclusivity (Shakibamanesh et al., 2018). Smart-mobility approaches therefore offer potential to address these challenges by promoting integration of modes, optimising use of data and enhancing citizen-centric service delivery (Chen et al., 2021).

The rationale for positioning urban transport as a key element in smart-city development is multi-fold. First, transport systems influence urban form, connectivity and the spatial distribution of social and economic opportunities. For instance, smart-growth strategies emphasise transit-oriented development (TOD) to create compact, reachable neighbourhoods that reduce car dependency (Shakibamanesh et al., 2018).

Second, from a technological perspective, transport networks generate vast streams of data which can feed into decision-making systems, real-time operations and citizen services. In the London context, the city data strategy identifies transport data as a major enabler for urban management and innovation (Greater London Authority, 2015).

Third, sustainable transport is integral to the environmental dimension of smart cities: public and active transport reduce emissions, support air-quality improvement and align with sustainable-development targets (Zawieska, 2018). Finally, transport is a deeply social and civic realm: accessibility, equity and user experience are core concerns of smart-mobility agendas (Warchoł-Jakubowska et al., 2024).

Warsaw and London represent contrasting yet complementary cases for analysis. London is an established global city with mature transport infrastructure, extensive digital innovation in mobility and ambitious smart-city governance frameworks (London Data Strategy, 2018). Warsaw, while dynamically developing, is in a somewhat earlier phase of smart-mobility transformation, with specific challenges in accessibility and integration (Mościcka, 2019).

By comparing these two capitals, we can explore how differing urban contexts — scale, governance structure, legacy infrastructure, level of digitalisation — influence the uptake and impact of smart transport strategies. Moreover, lessons from London's advanced development may inform Warsaw's ongoing journey, while Warsaw offers insight into emerging-market conditions, path-dependency and incremental institutional change.

The aim of this paper is to conduct a comparative analysis of urban transport as a key element of smart-city development in Warsaw and London. Attention will focus on governance and organisational mechanisms, technological and infrastructural innovations, and measurable performance outcomes (e.g., accessibility, integration, sustainability). The comparative lens enables identification of success factors, obstacles and transferable lessons.

The remainder of the paper is structured as follows. First, the theoretical background related to smart cities, smart mobility, and sustainable urban transport is presented. Next, the research methodology and comparative approach applied to Warsaw and London are described. The subsequent section discusses and compares smart mobility solutions and transport policies implemented in both cities. Finally, the paper concludes with a discussion of the findings, practical implications, limitations, and directions for future research.

2. Research Methods

The study applies a comparative quantitative-qualitative research design focused on evaluating urban transport systems as a fundamental component of smart-city development in Warsaw and London. The analysis takes into account both long-term infrastructure transformations and short-term fluctuations caused by global events such as the COVID-19 pandemic.

The research objective was to identify differences and similarities between both cities in the domains of sustainable mobility, intelligent transport systems (ITS), and accessibility, and to determine how these features contribute to broader smart-city strategies (Angelidou et al., 2022; Chen, Silva, 2021).

2.1. Sources of data

The study is based primarily on secondary data sources, complemented by statistical and documentary analysis. The main sources include:

- official reports and datasets from Warsaw Public Transport Authority (ZTM), Transport for London (TfL), Eurostat, and the OECD Urban Indicators Database,
- strategic documents: Smart London Plan (Greater London Authority, 2015) and Warsaw – Towards a Smart City (Knight Frank, 2018),
- sectoral publications and media reports addressing Intelligent Transport Systems (ITS) and accessibility solutions.

Quantitative data for Warsaw and London were standardised to ensure comparability between the two cities. For each indicator, units were adjusted to common measures (e.g., per 1000 inhabitants or per km²), which enabled the development of comparable metrics across time and space (Paiva et al., 2021).

2.2. Research procedure

In the first stage, a set of proprietary (author-developed) indicators was designed to quantitatively assess the performance and sustainability of urban transport systems in Warsaw and London. Each indicator was constructed to ensure comparability between cities and over time, using standardised ratios and population-adjusted values.

The first proposed indicator is the *number of public transport vehicles per 1000 inhabitants (PTV)*, which is described by formula 1.

$$PVT = \frac{Number\ of\ buses,\ trams,\ and\ metro\ trains}{Population} \times 100 \tag{1}$$

This indicator indicates the availability of public transport vehicles relative to the city's population. Higher values suggest greater service capacity.

The second indicator is the *density of transport infrastructure (TID)* - formula 2.

$$TID = \frac{Total\ length\ of\ metro,\ tram,\ and\ bus\ routes}{City\ area\ (\mathrm{km}^2)} \times 100 \tag{2}$$

TID measures the spatial coverage and availability of transport infrastructure; higher density indicates stronger network connectivity.

The next proposed indicator is *urban CO_2 emissions per capita ($CO_2\ pc$)*, presented in Formula (3).

$$CO_2pc = \frac{Total\ annual\ CO_2\ emissions}{Population} \tag{3}$$

Indicator (3) measures the average level of urban carbon emissions generated per resident; lower values indicate better environmental sustainability and a higher level of transport decarbonisation.

Another proposed indicator is *the average number of passengers per vehicle in public transport (PPV)*, presented in Formula (4).

$$PPV = \frac{Total\ annual\ passengers}{Number\ of\ vehicles\ in\ public\ transport} \tag{4}$$

PPV measures the operational efficiency and occupancy level of the public-transport fleet; excessively high values may indicate overcrowding and reduced travel comfort.

The following indicator is *the average annual number of public transport trips per resident (PTT)*, presented in Formula (5).

$$PTT = \frac{Total\ annual\ number\ of\ trips}{Population} \tag{5}$$

Indicator (5) indicates the intensity of public-transport usage among urban residents; higher values suggest stronger reliance on collective transport and lower dependence on private cars.

An additional indicator included in the analysis is *the number of available city bikes per 1000 inhabitants (CB)*, presented in Formula (6).

$$CB = \frac{Number\ of\ available\ city\ bikes}{Population} \times 1,000 \tag{6}$$

CB measures the availability and accessibility of shared micromobility services within the urban transport system; higher values reflect stronger development of sustainable and active mobility.

The final indicator applied in the study is *the share of low-emission vehicles in total traffic (LEV)*, presented in Formula (7).

$$LEV = \frac{Number\ of\ low - emission\ vehicles}{Total\ number\ of\ vehicles} \times 1,000 \tag{7}$$

This indicator indicates the proportion of environmentally friendly vehicles within the overall transport system; higher values reflect greater progress in transport decarbonisation and sustainable mobility policies.

The temporal scope of the analysis differs among indicators because of variations in data availability from official and municipal sources. In several cases, continuous data were accessible only from 2014 or 2016, while for other indicators, longer historical series (2000-2023) could be obtained. These differences were considered when interpreting long-term trends.

In addition, qualitative indicators were included to evaluate the level of ITS implementation, integration of transport modes, road-infrastructure quality, and accessibility for persons with disabilities (Warchoł-Jakubowska et al., 2024).

The analytical model combines elements of benchmarking and multi-criteria evaluation (Shakibamanesh et al., 2019), assessing both performance outcomes and policy implementation frameworks. Each indicator was interpreted through the lens of sustainable-mobility principles and smart-city governance (Cohen, 2012; Angelidou et al., 2022).

The methodological procedure consisted of four stages:

- Selection of indicators – based on literature review and alignment with ISO 37120:2018 standards for sustainable cities.
- Data compilation and normalization – collection of time-series data from official and open sources.
- Comparative analysis – descriptive statistics and graphical representation of trends for both cities.
- Interpretation and contextualization – linking observed patterns with policy interventions, such as low-emission zones, fleet electrification, or public-bicycle programs.

A combination of trend analysis, ratio comparison, and contextual interpretation was applied to ensure consistency across indicators and time horizons (Creswell, Plano Clark, 2018).

3. Results

The research findings are presented in two main parts, corresponding to the methodological framework described in the previous chapter. In the first stage, a quantitative analysis was conducted based on statistical indicators describing the structure, performance, and sustainability of urban transport systems in Warsaw and London. This analysis covered indicators such as the number of public-transport vehicles per 1000 inhabitants, density of transport infrastructure, urban CO_2 emissions per capita, average number of passengers per vehicle in public transport, average annual number of public transport trips per resident, number of available city bikes per 1000 inhabitants and share of low-emission vehicles in total traffic. These metrics made it possible to identify long-term trends, measure efficiency, and evaluate the environmental dimension of transport development in both cities.

In the second stage, a qualitative analysis was performed to assess institutional, technological, and social aspects of smart mobility. This part focused on evaluating the implementation of Intelligent Transport Systems (ITS), multimodal integration, quality of road infrastructure, and accessibility for persons with disabilities. These qualitative indicators provide insight into the level of technological advancement, governance efficiency, and inclusiveness of transport systems—dimensions that cannot be fully captured by numerical data alone (Angelidou et al., 2022; Masik et al., 2021).

The first indicator, the number of public transport vehicles per 1000 inhabitants, is shown in Figure 1.

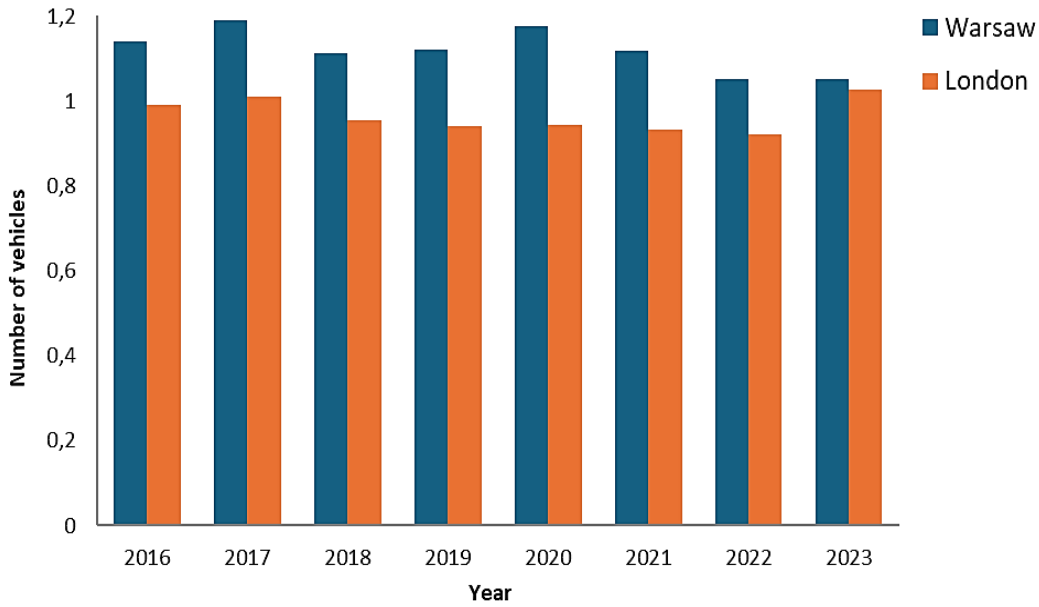

Figure 1. Number of public transport vehicles per 1000 inhabitants in London and Warsaw (PVT).

Source: own analysis based on secondary data.

The analysis of public-transport vehicle density (Figure 1) shows noticeable differences between Warsaw and London in both magnitude and dynamics. Throughout the analysed period, Warsaw consistently maintained a higher number of vehicles per 1000 inhabitants compared to London. In 2016-2023, Warsaw's ratio ranged between approximately 1.0 and 1.2 vehicles, while London's fluctuated between 0.7 and 0.9.

This difference is primarily explained by population scale and fleet composition. London operates a smaller number of vehicles with larger passenger capacity (e.g., double-decker buses and long metro trains), enabling efficient transport coverage with fewer units per capita. Warsaw, in contrast, relies on a denser bus and tram fleet composed of smaller-capacity vehicles, which increases the number of units required to serve the metropolitan area effectively (Korneć, Wereda, 2018).

The overall upward trend in both cities until 2020 reflects continuous investment in public transport and growing urban mobility demand. The temporary stagnation observed in 2021-2022 corresponds to the COVID-19 pandemic, which reduced passenger numbers and limited fleet expansion due to fiscal constraints (Chen, Silva, 2021). By 2023, the indicator in both cities had begun to rise again, suggesting a gradual recovery of public transport operations and renewed fleet modernisation, especially through the introduction of low-emission and electric buses (Paiva et al., 2021).

The density of transport infrastructure, i.e. the total length of tram lines, metro and bus routes per 1 km^2 of area, is shown in Figure 2.

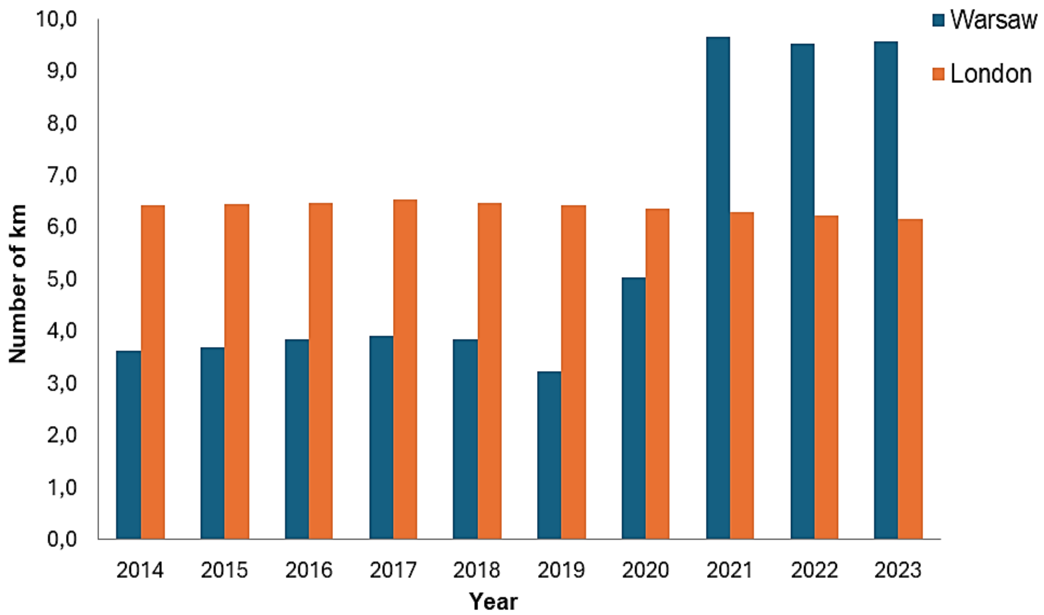

Figure 2. Density of transport infrastructure (number of km per 1 km²) in London and Warsaw (TID).
Source: own analysis based on secondary data.

As can be seen in Figure 2, the comparison of transport-infrastructure density between Warsaw and London demonstrates clear differences in both scale and development dynamics.

Throughout the analysed period (2014-2023), London maintained a higher infrastructure density, ranging between 5 and 7 km of network per km², while Warsaw's level ranged from approximately 3 to 4 km/km².

London's results reflect a long-term, stable system that has reached a high degree of spatial coverage, with only incremental improvements in recent years.

Warsaw, in contrast, shows a progressive upward trend after 2021, primarily driven by the expansion of the metro's second line and the construction of new tram corridors linking peripheral districts with the city centre.

These results confirm that Warsaw's transport policy emphasises infrastructure expansion and integration, whereas London focuses on optimising and digitalising an already mature network (Masik et al., 2021; Angelidou et al., 2022).

Another indicator, average CO_2 emissions in cities per capita, is shown in Figure 3.

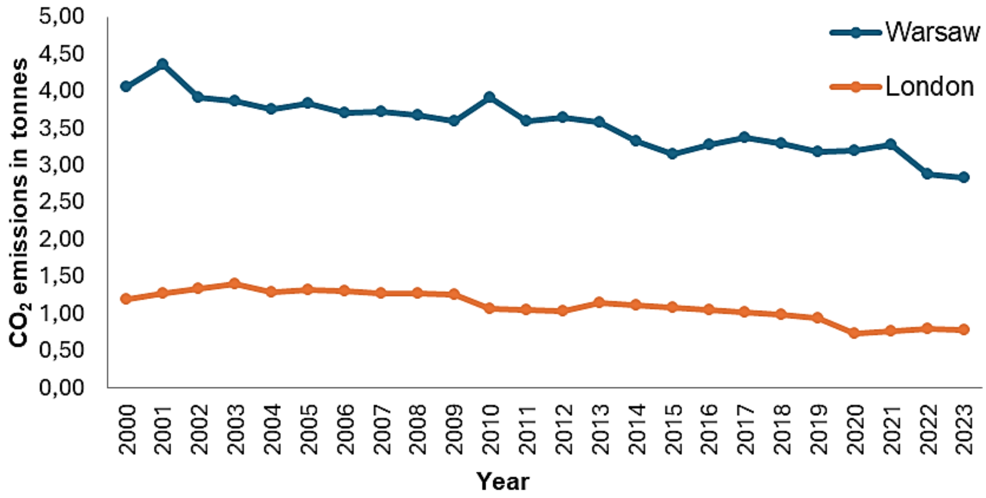

Figure 3. Average CO_2 emissions in London and Warsaw per capita in tonnes (CO_2 pc).
Source: own analysis based on secondary data.

The results show a systematic decrease in CO_2 emissions per capita in both Warsaw and London between 2000 and 2023, though the magnitude of reduction differs. In Warsaw, emissions declined from approximately 4.2 to 2.5 tonnes per capita, while in London they fell from about 1.1 to 0.6 tonnes per capita.

This demonstrates the stronger and earlier implementation of low-emission policies in London, including the Ultra Low Emission Zone (ULEZ) and congestion charging, introduced already in the early 2000s (Greater London Authority, 2015). Warsaw's improvement corresponds to the electrification of bus fleets, the expansion of the metro system, and new Clean Transport Zone (CTZ) initiatives.

Overall, both cities have achieved significant progress towards emission decarbonisation, confirming that smart mobility and clean technologies are central to sustainable urban transport development (Zawieska, Pieriegud, 2018; Paiva et al., 2021).

The average number of passengers per vehicle in public transport is shown in Figure 4. It highlights the differences in the capacity and efficiency of the transport system in the analysed cities.

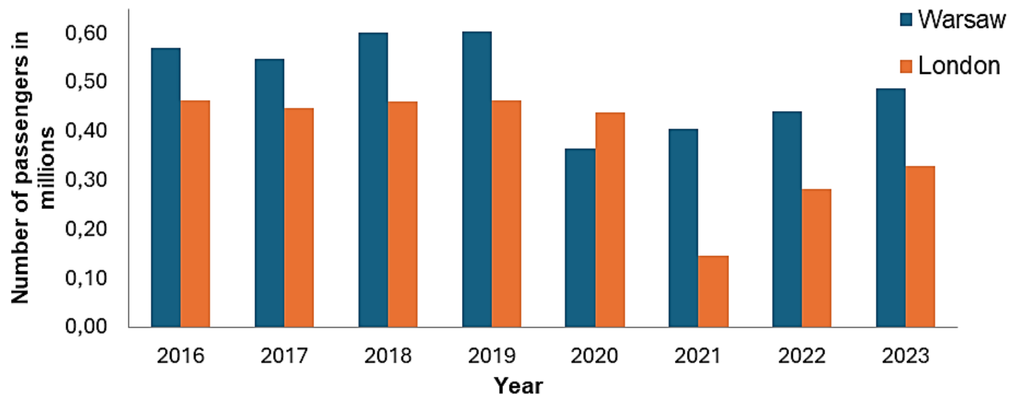

Figure 4. Average number of passengers per vehicle in public transport (in millions) - PPV.
Source: own analysis based on secondary data.

Between 2016 and 2019, Warsaw recorded higher passenger loads per vehicle, indicating more intensive fleet use and higher occupancy levels (Figure 4). During the COVID-19 period (2020–2021), both cities experienced sharp declines in this indicator, reflecting reduced mobility demand and social-distancing measures. London's decline was more pronounced due to stricter restrictions and the widespread adoption of remote work. After 2022, a gradual recovery trend emerged in both cities, with passenger levels rising but still below pre-pandemic figures.

These results underline the impact of external shocks on public-transport performance and the resilience of smart-transport systems in maintaining service continuity (Chen, Silva, 2021).

The average annual number of public transport trips per resident is shown in Figure 5. The data in Figure 5 indicate that Warsaw experienced a strong increase in the number of public transport trips per capita between 2000 and 2019, from roughly 400 to 700 trips annually. This reflects growing user confidence, fleet modernisation, and fare integration. London maintained a stable level of 500–550 trips per person per year during the same period.

The COVID-19 pandemic caused a drastic fall in ridership in both cities (Warsaw ≈ 400; London < 200), exposing the vulnerability of public transport to behavioural and health crises.

Recovery began in 2022, but ridership remains lower than pre-pandemic levels, particularly in London, where remote work continues to reduce daily commuting (Mościcka et al., 2019).

The indicator confirms the importance of policy adaptation and user-oriented innovation to rebuild trust and increase modal share in the post-pandemic era.

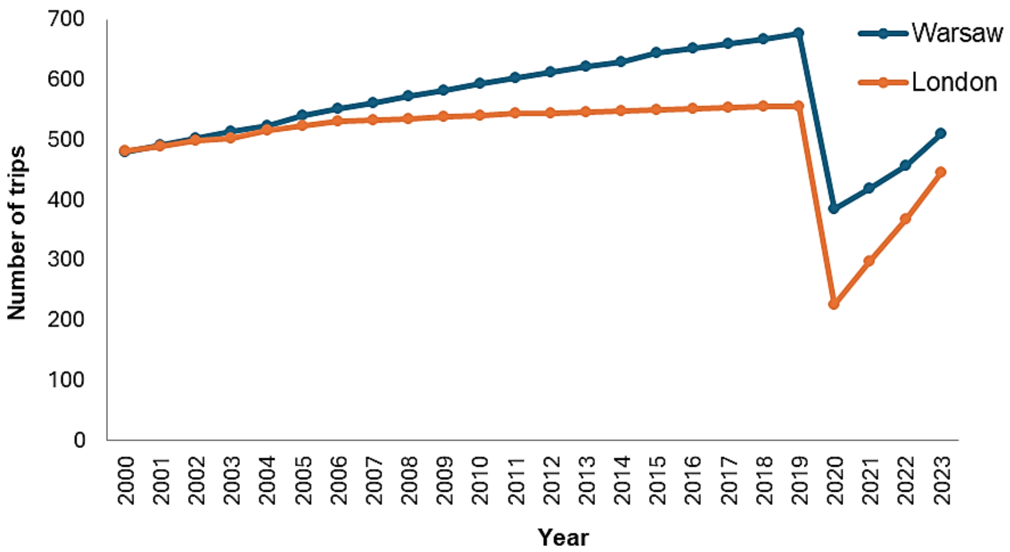

Figure 5. Average annual number of public transport trips per resident (PTT).

Source: own analysis based on secondary data.

Figure 6 shows the changes in the number of available city bikes per 1,000 inhabitants of Warsaw and London in the years 2012-2023. The development of public-bicycle systems reflects contrasting dynamics in Warsaw and London. Between 2012 and 2020, Warsaw achieved a rapid increase in bicycle availability—from less than 1 to around 3 bicycles per 1000 inhabitants, positioning the city among the leading Central European capitals in shared cycling. After 2020, a moderate decline occurred due to the temporary suspension and restructuring of the Veturilo system during the pandemic. In London, the Santander Cycles network remained relatively stable (≈ 0.1-0.2 bicycles per 1000 inhabitants), targeting primarily the city centre and tourist areas.

The results indicate that Warsaw's strategy prioritises expansion and accessibility, while London focuses on integration with other mobility modes and safety infrastructure (Shakibamanesh et al., 2019).

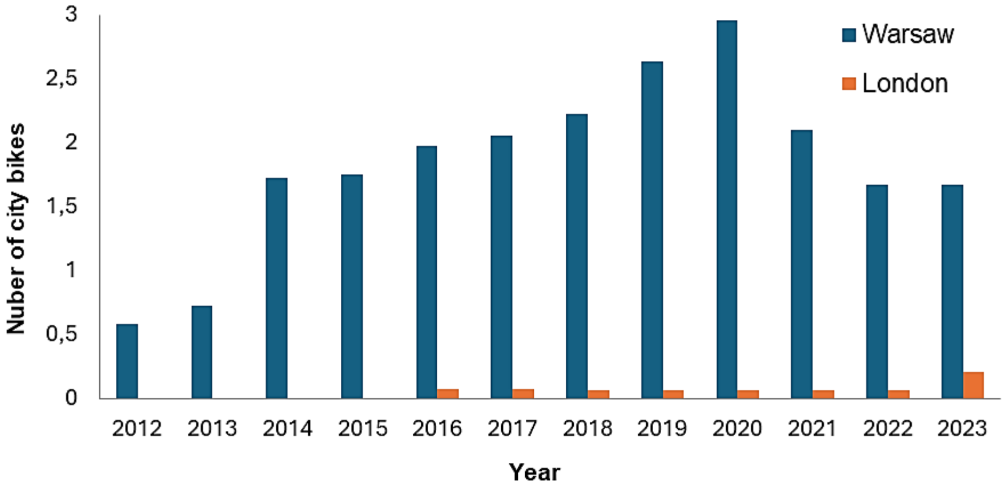

Figure 6. Number of available city bikes per 1000 inhabitants (CB).

Source: own analysis based on secondary data.

Changes in the share of low-emission transport over the years 2011-2023 in London and Warsaw are shown in Figure 7.

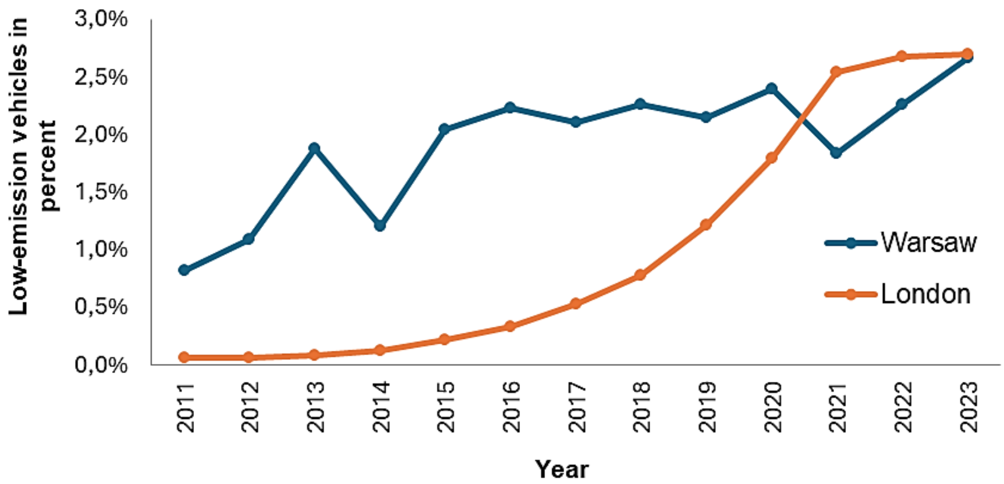

Figure 7. Share of low-emission vehicles in total traffic (in percent) - LEV.

Source: own analysis based on secondary data.

As can be seen in Figure 7, in the years 2011-2023 the share of low-emission vehicles was different in both cities. Warsaw showed steady growth until 2016, reaching around 2.5 %, after which the trend stabilised due to limited funding for further fleet replacement.

London, on the other hand, achieved a rapid increase after 2018, surpassing Warsaw by 2021 and reaching approximately 3 % in 2023. This dynamic reflects London's regulatory measures, such as ULEZ expansion and electric-vehicle incentives (Greater London Authority, 2015), while Warsaw's efforts remain primarily municipally driven.

The results confirm that policy instruments and financial incentives are crucial for accelerating low-emission transitions in urban transport (Angelidou et al., 2022).

After examining the quantitative indicators, the analysis proceeds to the qualitative dimension, which explores governance mechanisms, innovation levels, and accessibility aspects that underpin the development of smart and sustainable transport systems.

The qualitative assessment focuses on four interrelated dimensions of smart urban transport: the implementation of Intelligent Transport Systems (ITS), multimodal integration, the quality of road infrastructure, and accessibility for persons with disabilities.

These dimensions reflect the non-material components of smart mobility related to governance, innovation and inclusiveness, which complement quantitative transport performance indicators.

In this context, the comparative qualitative analysis of Warsaw and London shows noticeable differences in the level of development, integration, and accessibility of their transport systems.

In terms of the implementation of Intelligent Transport Systems (ITS), both cities use a wide range of modern technological solutions, but their level of integration differs (Warsaw Public Transport, 2025; Transport for London, 2025). In London, ITS solutions are more advanced and better coordinated. Real-time traffic management systems, data analysis tools, and open-data platforms are integrated into everyday transport management, which allows for more efficient traffic control and supports decision-making processes (Dona, 2023).

In Warsaw, many ITS elements have also been introduced, such as adaptive traffic lights, passenger information systems, and mobile applications (Kamiński, 2022). However, these solutions do not yet form a fully integrated system. This is typical for cities that are still developing their smart mobility solutions, where the implementation of new technologies happens faster than their full integration. In this context, a comparative qualitative analysis of Warsaw and London reveals significant differences in the maturity, integration, and inclusiveness of their transport systems.

A similar situation can be observed in the area of multimodal integration. London represents a high level of integration, supported by unified ticketing systems, coordinated timetables, and the implementation of Mobility as a Service (MaaS), which allows users to plan and carry out journeys using different modes of transport within one system (Hensher et al., 2020; Transport for London, 2025). This makes travelling more convenient and easier for users.

Warsaw has also made noticeable progress in this area, especially through the development of metro infrastructure, the introduction of integrated tickets, and the expansion of shared mobility systems such as public bicycles (Warsaw Public Transport, 2025). However, the level of integration is still lower than in London. This indicates that Warsaw is still in a stage where the main focus is on infrastructure development rather than full system integration. This observation is consistent with the general direction of smart mobility development, in which cities are gradually moving from infrastructure expansion to more integrated, user-oriented systems (Mitieka et al., 2023). At the same time, improving the efficiency of transfers between different modes of transport remains an important aspect of further system development.

In terms of road infrastructure, London has a well-developed and maintained transport network, which is additionally supported by modern traffic management systems. This contributes to the stable and efficient operation of the whole system (INRIX Global Traffic Scorecard, 2024). Warsaw, on the other hand, is still developing its infrastructure, for example, through metro expansion and new tram lines (General Directorate for National Roads and Motorways, 2024). These investments improve connectivity and support the development of sustainable transport. At the same time, differences between central and peripheral areas are still visible. Reducing these differences is important for improving the overall functioning of the transport system, and this situation is typical for cities that are still developing their smart city solutions (Augustyn, 2020).

Accessibility for persons with disabilities is the last analysed dimension and shows how inclusive the transport system is. London has implemented many solutions in this area, such as step-free access, low-floor vehicles, and clear passenger information systems (Hill, 2024). These measures help ensure that transport is accessible to all users (Wang et al., 2020). In Warsaw, accessibility has also improved, especially thanks to modern vehicles and metro infrastructure. However, not all elements of the system are fully adapted, particularly older infrastructure and some interchange points. Ensuring full accessibility across the entire transport system is still a challenge, which is consistent with the assumption that accessibility is an important element of sustainable urban development (Augustyn, 2020; Wolniak, 2023).

To synthesise the qualitative findings, Table 1 presents a comparative overview of the analysed dimensions.

Table 1.
Comparative qualitative assessment of smart mobility in Warsaw and London

Dimension	Warsaw	London	Assessment
ITS implementation	Developing, partially integrated	Advanced, fully integrated	London more mature
Multimodal integration	Expanding, improving	Highly integrated (MaaS)	London more seamless
Infrastructure quality	Rapidly developing, uneven	Mature and stable	Warsaw catching up
Accessibility	Improving, but inconsistent	Comprehensive and standardised	London more inclusive

Source: own study.

Overall, the qualitative analysis demonstrates that while both cities align with the principles of smart mobility, they differ significantly in terms of system maturity and integration. London represents a highly developed, optimised, and user-oriented transport system, whereas Warsaw is undergoing dynamic transformation, gradually moving towards greater integration and inclusiveness. These findings confirm that the effectiveness of smart mobility strategies depends not only on technological implementation, but also on governance capacity, coordination between stakeholders, and the ability to ensure equitable access to transport services (Wolniak, 2023; Mitieka et al., 2023; Nikitas et al., 2020).

4. Conclusion

The conducted comparative analysis confirms that urban transport plays a fundamental role in the development of smart cities and significantly influences the sustainability, accessibility, and quality of life of urban residents. Both Warsaw and London have implemented numerous smart mobility solutions; however, the scale, maturity, and level of integration of these systems differ considerably due to historical, economic, and institutional factors.

The results indicate that London represents a more advanced stage of smart mobility development, particularly in the areas of Intelligent Transport Systems (ITS), multimodal integration, low-emission transport policies, and the application of data-driven governance. The implementation of solutions such as the Ultra Low Emission Zone (ULEZ), integrated Mobility as a Service (MaaS) systems, and extensive open-data platforms demonstrates a high level of technological and organisational maturity. Warsaw, on the other hand, has achieved significant progress in the expansion of transport infrastructure, fleet modernisation, and the development of sustainable mobility solutions such as public bicycle systems and low-emission public transport. Nevertheless, the city is still undergoing a transition from infrastructure-oriented development towards fully integrated and user-centred smart mobility systems.

The study also confirms that the integration of digital technologies, including Big Data, Internet of Things (IoT), artificial intelligence, and autonomous systems, increasingly determines the effectiveness of urban transport management. Smart mobility solutions contribute not only to reducing congestion and emissions, but also to improving transport accessibility, operational efficiency, and urban resilience. In this context, the findings of Nikitas et al. (2020) emphasise that artificial intelligence and autonomous transport systems are becoming one of the key dimensions of future smart-city development, particularly in relation to connected and autonomous vehicles (CAVs), data integration, and intelligent infrastructure management. At the same time, as highlighted by Wang et al. (2020), the development of autonomous vehicles also requires particular attention to safety issues, legal regulations, and public trust, which remain significant barriers to large-scale implementation.

The obtained results are also consistent with previous studies concerning smart city development and sustainable urban transformation. Jonek-Kowalska and Wolniak (2021) emphasise that the implementation of smart city solutions strongly depends on the economic capacity, governance quality, and technological maturity of urban areas. Furthermore, Jonek-Kowalska and Wolniak (2023) indicates that sustainable smart-city development should not be limited solely to technological advancement, but should also focus on improving residents' quality of life, environmental conditions, and social inclusiveness. Similar conclusions were formulated by Jonek-Kowalska (2023), who demonstrated that environmental effectiveness and air-quality improvement constitute important determinants of sustainable smart-city development. Additionally, Jonek-Kowalska and Wolny (2025) underline the importance of inclusiveness and age sustainability in smart cities, particularly in the context of adapting urban services and infrastructure to the needs of senior citizens. The sustainable development of smart cities should therefore focus not only on technological progress, but also on improving the quality of life of residents, inclusiveness and everyday living conditions in the city (Jonek-Kowalska, 2025).

The analysis, therefore shows that sustainable urban mobility should not be limited to technological innovations alone. Equally important are governance quality, multimodal integration, accessibility for vulnerable groups, environmental responsibility, and long-term strategic planning. Smart transport systems should therefore be understood as socio-technical ecosystems in which technology supports broader sustainability and inclusiveness objectives.

From a practical perspective, London may serve as a benchmark for Warsaw in the areas of transport-system integration, digital governance, and low-emission policy implementation. Conversely, Warsaw illustrates how rapidly developing cities can effectively modernise transport infrastructure and gradually implement smart mobility solutions despite financial and institutional limitations.

Future research should extend the comparative framework by including a broader group of European cities representing different levels of economic development, transport maturity, and smart-city implementation. This would make it possible to identify whether the differences observed between Warsaw and London are city-specific or reflect wider regional patterns in smart mobility development.

A particularly important direction would be the inclusion of primary empirical research among urban transport users. Surveys, interviews, and focus groups could help assess residents' satisfaction, perceived accessibility, willingness to use low-emission transport, and attitudes towards digital mobility services. Such research would allow future studies to complement statistical indicators with the social dimension of smart mobility.

Future research should also focus more strongly on transport equity and social inclusion. This includes the accessibility of smart mobility services for elderly people, persons with disabilities, low-income residents, and inhabitants of peripheral districts. Such studies would help determine whether smart transport systems reduce or reproduce existing inequalities in urban mobility.

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