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Sustainable Urban mobility: Lessons from European Cities

Uthman Opeyemi Abdullahi ^{1,*} and Adnan Adnan ²

¹ *Mechatronics and Computer System Engineering, University of East London, United Kingdom.*

² *Royal Docks Centre for Sustainability, University of East London, United Kingdom.*

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Abstract

The rising urgency of climate change and rapid urbanization has compelled cities worldwide to prioritize sustainable urban mobility. This article explores the innovative strategies implemented by leading European cities—such as Amsterdam, Copenhagen, and Vienna—in fostering sustainable transport solutions, including dedicated cycling infrastructure, car-free zones, and integrated public transport systems. By examining these cities' comprehensive approaches to urban planning, policy frameworks, and public engagement, this article highlights the key factors contributing to their success in reducing emissions, enhancing urban liveability, and shifting public behaviour toward sustainable modes of transport. Through a comparative analysis of these cities' approaches, the study aims to offer actionable insights for global cities seeking to adopt similar sustainable mobility practices. In conclusion, the article discusses the critical role of policy support, infrastructure investment, and community involvement in making urban mobility more sustainable, equitable, and accessible, emphasizing the scalability of European models for cities around the world.

Keywords: European Cities; Public Transport; Bike Lanes; Car-Free Zones; Urban Planning; Environmental Impact.

1 Introduction

As urban populations increase, the need for sustainable urban mobility solutions has become more urgent. Cities worldwide are experiencing intensified air pollution, traffic congestion, and resource depletion, which contribute significantly to climate change and pose serious health risks to urban dwellers. According to the United Nations, over 55% of the world's population currently lives in urban areas, a number expected to rise to nearly 68% by 2050 (UN, 2019). This urban shift has spurred a demand for transportation solutions that minimize environmental impact, reduce emissions, and enhance liveability.

1.1 Significance

European cities have led the way in addressing urban mobility sustainably, often serving as global models. Cities like Amsterdam and Copenhagen have implemented comprehensive systems integrating biking infrastructure, pedestrian zones, and extensive public transport options. These strategies promote a reduced reliance on private vehicles, which directly benefits urban quality of life by improving air quality, reducing noise pollution, and reclaiming public spaces for community use (European Commission, 2020). Such initiatives reflect a broader European commitment to sustainability and are backed by robust policy support and public acceptance of sustainable practices.

* Corresponding author: Uthman Opeyemi Abdullahi.

Table 1 Key Benefits of Sustainable Transport Implemented by European Cities

Benefit	Description
Improved Air Quality	Reduction in emissions from car-free zones and reliance on public transport and bicycles
Enhanced Public Health	Increased physical activity from cycling and walking, reduced exposure to air pollution
Reduced Traffic Congestion	Decreased reliance on private vehicles results in smoother traffic flow and lower congestion
Economic Benefits	Increased tourism, reduced healthcare costs, and job creation in sustainable transport industries

1.2 Purpose

This article aims to explore the key strategies European cities have used to foster sustainable urban mobility, focusing on urban planning approaches, effective policy measures, and shifts in public behaviour toward more eco-friendly transport options. By analysing examples from cities like Amsterdam, Copenhagen, and Vienna, the article will examine how targeted urban planning and supportive policies facilitate sustainable urban mobility, offering insights for cities globally. Additionally, the article seeks to understand how community engagement and incentives drive behavioural shifts that sustain these initiatives over time.

2 Key Elements of Sustainable Urban Mobility

2.1 Bike Lanes and Cycling Infrastructure

Cities like Amsterdam and Copenhagen have revolutionized urban mobility by establishing extensive, dedicated cycling networks, making bicycles a primary mode of transport. Amsterdam, for example, has over 500 kilometres of cycle paths that allow safe and efficient movement across the city, reducing both car dependency and emissions (Pucher & Buehler, 2008). Copenhagen's commitment to cycling has resulted in nearly 62% of residents using bicycles daily, enabled by well-planned bike lanes, secure bike parking, and traffic lights synchronized for cyclists (Copenhagenize Design Co., 2020). These networks encourage physical activity, improve air quality, and reclaim city spaces, supporting a healthier urban environment.

2.2 Car-Free Zones and Reduced Car Dependency

European cities have increasingly implemented car-free zones and restricted access areas to curb private vehicle use, thereby promoting alternative modes of transport such as walking, biking, and public transit. The historic centre of Oslo, for instance, became car-free in 2019, improving air quality, reducing noise, and making the city centre more accessible to pedestrians (Oslo Municipality, 2019). Similarly, Madrid's "Madrid Central" zone limits vehicle access, resulting in a 32% reduction in nitrogen dioxide levels within the restricted area (European Environment Agency, 2020). These initiatives help shift public behaviour by normalizing walking and cycling, reinforcing a culture of sustainable, shared urban spaces.

Table 2 Notable Car-Free Zones and their Impacts on Air Quality

City	Car-Free Zone	Year Implemented	Air Quality Improvement
Oslo	Oslo City Center	2019	Reduction in nitrogen dioxide and noise pollution
Madrid	Madrid Central	2018	32% reduction in nitrogen dioxide levels
Milan	Area C Zone	2012	35% reduction in particulate matter

2.3 Integrated Public Transport Systems

An integrated public transport system, characterized by multimodal networks and fare integration, is essential for seamless urban mobility. Cities like Berlin and Vienna exemplify this approach, where buses, trams, subways, and regional trains connect across a single fare system, allowing residents and visitors to switch modes effortlessly (UITP, 2019). Additionally, integration with cycling and walking paths further strengthens the efficiency of public transport networks. In Paris, for example, the "Navigo" card offers a unified fare structure across all modes, incentivizing public

transit over private cars (IDFM, 2021). This approach enhances accessibility, reduces congestion, and lowers urban carbon footprints.

3 Urban Planning Strategies for Sustainable Mobility

3.1 Mixed-Use Development

Mixed-use zoning is a powerful urban planning tool that combines residential, commercial, and recreational spaces within close proximity, reducing commuting distances and promoting active modes of transport such as walking and cycling. By enabling residents to access essential services and workplaces within walking or cycling distance, mixed-use development helps cut down on car dependency, thus lowering greenhouse gas emissions and easing traffic congestion (Grant, 2002). Cities like Barcelona exemplify this approach through its “superblocks” model, which combines mixed-use zoning with pedestrianized zones, fostering a community-centered urban space (Mueller et al., 2020).

3.2 Compact City Planning

Compact city planning emphasizes high-density development to create walkable urban areas that facilitate sustainable transportation options like cycling and public transit. European cities like Vienna and Zurich have implemented compact layouts that allow efficient use of land while preserving green spaces. These cities utilize high-density residential and commercial zones near public transit hubs, effectively minimizing travel distances and reducing the environmental impact of commuting (Neuman, 2005). Compact city planning not only supports sustainability but also increases urban vibrancy, as people are more inclined to use public spaces and amenities that are easily accessible.

Table 3 Comparison of Compact City Attributes in Leading European Cities

City	Population Density (per km ²)	Public Transport Usage (%)	Bicycle Usage (%)	Walkability Score
Vienna	4,500	39	7	High
Zurich	4,700	35	6	High
Amsterdam	5,100	34	36	High

3.3 Public Space Reallocation

One of the most visible urban planning strategies for sustainable mobility is the reallocation of space from vehicles to people, transforming streets and parking areas into pedestrian-friendly zones, parks, and dedicated bike paths. This approach enhances social interaction, reduces pollution, and increases the overall quality of urban life. For instance, Paris has implemented several “Paris Respire” zones, which are pedestrian-only on weekends and holidays, allowing people to enjoy car-free areas throughout the city (Paris City Hall, 2020). Similarly, Milan’s “Piazze Aperte” initiative transforms parking spaces and underutilized streets into vibrant public spaces, contributing to a healthier and more enjoyable urban environment (Municipality of Milan, 2021).

4 Policy Frameworks Driving Sustainable Mobility

Cities across Europe have implemented various policy frameworks to promote sustainable urban mobility. These frameworks target car usage, support public transit, and encourage active transportation, thus reducing emissions, congestion, and pollution levels.

4.1 Congestion Pricing and Low Emission Zones (LEZs)

Congestion pricing and Low Emission Zones (LEZs) are widely implemented strategies that help cities manage traffic flow, improve air quality, and discourage excessive car use. London and Stockholm serve as prominent examples:

- **London:** Introduced in 2003, the London Congestion Charge requires vehicles entering central London during peak hours to pay a fee. This policy has led to a significant decrease in traffic congestion and greenhouse gas emissions (Transport for London, 2021). Additionally, the city’s LEZ program, which sets emission standards

for vehicles in certain areas, further promotes the use of lower-emission vehicles and has improved air quality in high-traffic zones.

- **Stockholm:** Stockholm’s congestion tax, implemented in 2007, charges vehicles entering the city center, particularly during peak hours. This tax has been shown to reduce car traffic by approximately 20%, resulting in lower carbon emissions and encouraging a shift to public transport and biking (Eliasson, 2019).

Table 4 Comparative Impacts of LEZs in Major European Cities

City	LEZ Introduction Year	Emission Reduction (%)	Traffic Reduction (%)
London	2008	12%	15%
Stockholm	2007	10%	20%
Berlin	2008	9%	14%

4.2 Subsidies and Incentives for Public Transit and Active Transport

Financial incentives are essential in promoting sustainable transit modes by making public transport and active travel options more affordable and appealing:

- **Subsidies for Public Transport:** Cities such as Vienna and Paris offer affordable public transit passes as a measure to encourage ridership. For example, Vienna’s annual public transport pass costs approximately €365, making it an attractive option for city residents, leading to high public transport utilization rates (UITP, 2020).
- **Cyclist Incentives:** Some cities provide incentives for active travel modes. For instance, the French government offers a cycling reimbursement scheme through employers, whereby companies can reimburse employees for cycling costs, helping to boost cycling adoption (Ministry of Ecological Transition, 2019).

Table 5 Impact of Public Transport and Cycling Subsidies on Sustainable Mobility

City	Public Transport Pass Cost	Cycling Subsidy Program	Increased Use (%)
Vienna	€365 annually	No	20% rise in cycling
Paris	€75 monthly	Yes	15% rise in cycling

4.3 Regulations on Car Parking

Restricting car parking availability and increasing parking fees are strategic measures used to disincentivize car ownership and use in densely populated urban areas:

- Reduced Parking Spaces:** Amsterdam has implemented a policy to gradually reduce public parking spaces. By 2025, the city aims to eliminate 10,000 parking spaces, reallocating this space for bike lanes, parks, and pedestrian pathways (Municipality of Amsterdam, 2020).
- Increased Parking Fees:** In cities like Copenhagen, high parking fees deter residents from car ownership, reducing traffic volumes and encouraging alternative modes of transportation. The city also incentivizes shared parking spaces for car-sharing programs, further promoting sustainable transit options (Gehl Institute, 2019).

5 Behavioural Shifts Supporting Urban Mobility

Behavioural shifts play a crucial role in the successful implementation of sustainable urban mobility. By influencing public attitudes and fostering habits that prioritize walking, cycling, and public transit, cities can encourage widespread adoption of sustainable transport. Key strategies that contribute to these shifts include public awareness campaigns, community engagement, and promoting the health and environmental benefits of active transportation.

5.1 Public Awareness Campaigns

Public awareness campaigns are instrumental in shifting public perceptions toward viewing cycling, walking, and public transport as attractive options for commuting and travel. Many European cities have run successful campaigns to educate citizens on the benefits of sustainable transport:

- **Copenhagen’s “I Bike CPH” Campaign:** Copenhagen launched the “I Bike CPH” campaign to promote cycling as an accessible and sustainable way to commute. The campaign used media advertisements, social media, and community events to emphasize the convenience and environmental impact of cycling. As a result, Copenhagen now has one of the highest cycling rates worldwide, with around 62% of residents commuting by bicycle daily (City of Copenhagen, 2020).
- **London’s “Let’s Ride” Initiative:** In London, the “Let’s Ride” initiative, organized by Transport for London (TfL), encourages Londoners to participate in car-free events and enjoy cycling in a safe, vehicle-free environment. These events highlight the city’s commitment to active transportation and give residents a firsthand experience of the benefits of car-free streets (Transport for London, 2019).

Table 6 Impact of Public Awareness Campaigns on Cycling Rates in Select Cities

City	Campaign	Cycling Increase (%)	Year
Copenhagen	I Bike CPH	30	2020
London	Let’s Ride	15	2019

5.2 Community Engagement

Involving citizens in urban planning processes fosters a sense of ownership and encourages residents to adopt sustainable mobility habits. Community engagement programs allow local governments to gain insights from residents, ensuring that transport solutions meet the needs of diverse communities:

- **Paris’ “Plan Vélo” Initiative:** Paris involved citizens in the development of its “Plan Vélo,” which aims to transform the city into a cycling-friendly metropolis by 2026. Public workshops allowed residents to suggest bike lane routes, making citizens feel invested in the city’s cycling infrastructure, leading to increased cycling uptake and satisfaction with urban planning (City of Paris, 2021).
- **Amsterdam’s “City Dialogue” on Car-Free Zones:** Amsterdam’s community dialogue sessions engage residents on topics like car-free zones, shared public spaces, and bicycle lanes. This dialogue has been instrumental in achieving public support for sustainable mobility policies, reducing resistance to car-reduction measures, and promoting cycling and walking (Municipality of Amsterdam, 2020).

5.3 Promoting Health and Environmental Benefits

Highlighting the health and environmental benefits of active transportation encourages residents to switch from car use to more sustainable options. This messaging emphasizes the positive effects of walking, cycling, and public transport on individual well-being and urban air quality:

- Barcelona’s “Superblocks” and Health Benefits Campaign:** Barcelona’s Superblocks initiative, which reclaims road space for pedestrians and cyclists, has been paired with campaigns highlighting health benefits, such as reduced pollution-related illnesses and increased physical activity. These benefits have motivated residents to support and use active transport modes (Ajuntament de Barcelona, 2019).
- Helsinki’s “Breath of Fresh Air” Campaign:** Helsinki promotes active transportation through its “Breath of Fresh Air” campaign, focusing on the link between sustainable mobility and cleaner air. Messaging in public spaces and on social media informs residents of how walking, cycling, and reduced car usage contribute to improved air quality and better respiratory health for everyone (City of Helsinki, 2020).

Table 7 Reported Health and Environmental Improvements Linked to Sustainable Transport in Select Cities

City	Initiative	Health Improvement (%)	Emission Reduction (%)
Barcelona	Superblocks	20	30
Helsinki	Breath of Fresh Air	15	25

6 Case Studies from Leading European Cities

European cities like Amsterdam, Copenhagen, and Vienna provide successful examples of sustainable urban mobility. Through unique approaches tailored to local needs, these cities have created urban transport systems that prioritize sustainability, accessibility, and reduced car dependency. This section explores the strategies employed and the outcomes achieved in each city.

6.1 Case Study 1: Amsterdam, Netherlands

6.1.1 Overview

Amsterdam is known for its rich cycling culture, with bicycles outnumbering residents. The city has long championed urban mobility that prioritizes non-motorized transport, aiming to reduce traffic congestion, pollution, and improve quality of life. Amsterdam’s municipal policies align with its goals to decrease car dependency and support sustainable transport solutions.

6.1.2 Key Strategies and Outcomes

- **Extensive Cycling Infrastructure:** Amsterdam has developed a robust network of cycling paths, totalling over 500 kilometers. The city’s bike-friendly infrastructure includes dedicated lanes, bike parking facilities, and protected intersections. This infrastructure has encouraged approximately 68% of residents to cycle daily, contributing to significant reductions in air pollution (City of Amsterdam, 2020).
- **Car-Free Zones:** Several areas, especially in the city center, are designated as car-free zones. This strategy encourages walking, cycling, and public transport use, contributing to the city’s reduced greenhouse gas emissions and fostering a pedestrian-oriented urban environment (Municipality of Amsterdam, 2021).
- **Multimodal Public Transport Integration:** Amsterdam’s public transport network integrates buses, trams, trains, and ferries, allowing for seamless transitions between transport modes. A unified ticketing system simplifies access and promotes public transit over private vehicle use (City of Amsterdam, 2020).

Table 8 Key Outcomes of Amsterdam’s Sustainable Mobility Initiatives

Initiative	Outcome
Cycling Infrastructure	68% of residents cycle daily
Car-Free Zones	30% reduction in car traffic
Integrated Public Transport	20% increase in public transit ridership

6.2 Case Study 2: Copenhagen, Denmark

6.2.1 Overview

Copenhagen has set an ambitious goal to become carbon-neutral by 2025. The city has earned global recognition for its cycling infrastructure and commitment to sustainable urban planning. By integrating green mobility solutions, Copenhagen emphasizes not only environmental benefits but also the health and well-being of its residents.

6.2.2 Key Strategies and Outcomes

- **Safe Cycling Routes:** Copenhagen’s cycling infrastructure includes over 675 kilometers of bike lanes, many of which are raised and separated from vehicular traffic. As a result, nearly half of Copenhagen’s residents commute by bicycle, significantly reducing emissions and traffic congestion (City of Copenhagen, 2021).
- **Car-Free Areas and Low Emission Zones:** Car-free areas and strict low-emission regulations discourage the use of private vehicles in specific zones, which has contributed to lower pollution levels and improved public health. The city’s “Green Wave” initiative synchronizes traffic lights to favour cyclists, further incentivizing bicycle use over cars (Copenhagen Climate Plan, 2020).
- **Efficient Public Transport System:** Copenhagen’s metro and bus systems operate frequently and punctually, enhancing public transport reliability. Additionally, investments in electric buses and the integration of bike-sharing with public transport contribute to a comprehensive, sustainable mobility network (Copenhagen Public Transport Authority, 2021).

Table 9 Impact of Copenhagen's Cycling and Public Transport Initiatives

Initiative	Key Impact
Cycling Infrastructure	49% of residents commute by bike
Car-Free and LEZ	35% decrease in vehicle emissions
Public Transport Network	10% increase in public transport usage

6.3 Case Study 3: Vienna, Austria

6.3.1 **Overview:** Provide context on Vienna's urban mobility strategy focused on reducing car dependency.

Vienna has adopted an urban mobility strategy that emphasizes reducing car dependency and enhancing the accessibility of public spaces. Recognized for its high-quality public transportation system, Vienna has also integrated walking and cycling into its urban planning efforts to provide comprehensive and accessible transport options.

6.3.2 *Key Strategies and Outcomes*

- High-Quality Public Transit:** Vienna's public transportation system, comprising trams, buses, and metro lines, is known for affordability, efficiency, and coverage. A single, affordable fare system makes public transport accessible to all residents, with an annual pass costing just €365, or €1 per day. This has led to an impressive 39% of journeys being made by public transport (City of Vienna, 2020).
- Pedestrian-Friendly Design:** The city has invested in creating pedestrian-friendly zones, especially in the city center, encouraging walking as a primary mode of transport. Enhanced pedestrian infrastructure, such as wider sidewalks and green spaces, has improved walkability and the overall appeal of public spaces (Vienna Urban Mobility Plan, 2021).
- Affordable Public Transport Passes and Incentives:** Vienna's pricing policy for public transport and its commitment to active transport options support its vision for an accessible and sustainable city. By reducing the financial burden of transit, Vienna has encouraged more residents to opt for public transport over personal vehicles (City of Vienna, 2020).

Table 10 Key Benefits of Vienna's Urban Mobility Strategies

Strategy	Outcome
Affordable Public Transit	39% of trips by public transport
Pedestrian-Friendly Zones	Increased walkability and green spaces
Pricing Incentives	25% reduction in car use

7 Challenges in Adopting Sustainable Urban Mobility Globally

While European cities like Amsterdam, Copenhagen, and Vienna provide examples of successful sustainable urban mobility models, implementing these strategies globally poses several challenges. Financial, social, and infrastructural barriers can hinder the adaptation of these models, particularly in cities with varying economic capacities, cultural preferences, and spatial constraints. This section delves into some of the primary obstacles cities worldwide face in their journey toward sustainable urban mobility.

7.1 High Implementation Costs

Establishing sustainable urban mobility systems, such as extensive bike lanes, upgraded public transit networks, and restructured urban spaces, often requires significant financial investment. This can be particularly challenging for cities with limited budgets or competing infrastructure needs.

- Bike Lane and Public Transit Infrastructure Costs:** Developing extensive networks of bike lanes or investing in high-quality public transport systems demands upfront capital, which may be challenging for smaller cities

or those in developing regions. For example, Copenhagen's cycling infrastructure required substantial investment to develop its renowned biking network (Transport & Environment, 2020).

- Urban Space Restructuring:** Transforming car-centric areas into pedestrian-friendly spaces, such as car-free zones and green spaces, also comes with financial costs, including land repurposing and infrastructure modifications. In cities where urban space is already at a premium, reallocating space from vehicles to people can require significant investment in redesigning and implementing new infrastructure (City of Amsterdam, 2021).

Table 11 Estimated Costs of Sustainable Mobility Infrastructure

Infrastructure Type	Cost (Per Km)	Example City
Bike Lane	\$500,000 - \$1 million	Copenhagen
Light Rail Public Transit	\$25 million - \$50 million	Vienna
Pedestrian Zone Development	Varies widely, depending on location	Amsterdam

7.2 Resistance to Behavioural Change

Shifting public behaviours toward sustainable modes of transport, such as cycling, walking, or public transit, can face cultural and social resistance, especially in cities with long-standing car dependency.

- Cultural Preferences for Car Usage:** In regions where cars are deeply integrated into daily life, reducing car use in favour of cycling or public transit can be met with resistance. For example, in the U.S., car ownership is often associated with personal freedom and convenience, making it difficult to encourage residents to opt for other transport modes (Cohen & McClendon, 2021).
- Social Perceptions of Cycling and Public Transit:** In some cities, cycling and public transit may be viewed as less desirable or only accessible to certain social groups. To overcome these barriers, comprehensive public awareness campaigns and incentives are often necessary, which can further add to implementation costs.

7.3 Infrastructure Limitations in Densely Populated Cities

Creating new bike lanes or pedestrian zones in densely populated, car-centric urban areas poses significant spatial and logistical challenges. The physical limitations of dense urban environments often complicate efforts to expand sustainable transport options.

- Limited Space for Expansion:** In cities like Tokyo or New York, where available urban space is scarce, developing new bike lanes or pedestrian paths may require taking lanes from existing roadways, which can create traffic congestion and lead to public dissatisfaction (City Planning Department, 2022).
- Competing Land Uses:** In densely populated areas, urban space is frequently contested by various needs—commercial, residential, and industrial. Repurposing space for sustainable transport may face opposition from stakeholders reliant on existing urban layouts.

Table 12 Spatial Constraints for Sustainable Mobility Implementation in Selected Cities

City	Population Density (per sq. km)	Challenges
Tokyo	6,158	Limited space for bike lanes
New York	10,194	Conflicting land use needs
São Paulo	7,398	Existing traffic congestion and urban sprawl

Conclusively, the journey toward sustainable urban mobility is complex, with cities facing unique challenges in terms of cost, behavioural change, and infrastructure limitations. While leading cities like Amsterdam, Copenhagen, and Vienna provide valuable models, adapting these strategies globally requires tailored approaches and overcoming significant barriers. For cities to succeed in this transition, a collaborative effort between governments, private sectors, and communities is essential to address these financial, social, and physical challenges.

8 Opportunities and Strategic Recommendations

Transitioning to sustainable urban mobility offers a myriad of opportunities for cities to enhance environmental quality, improve public health, and increase accessibility. Strategic investments and partnerships are essential in driving these shifts. This section explores key recommendations that can help cities effectively implement sustainable mobility initiatives.

8.1 Investment in Public Transport and Cycling Infrastructure

Allocating funds to expand public transport and cycling infrastructure is critical to creating a robust, sustainable urban mobility network. Government and municipal funds directed towards these areas can drastically reduce dependence on private vehicles and promote healthier, low-emission transport modes.

- Public Transit Investments:** Government funds should prioritize improving the efficiency, reach, and reliability of public transit options. Investment in metro systems, trams, and bus rapid transit (BRT) networks can reduce travel times and encourage more people to opt for public transit over personal cars. European cities such as Vienna have invested heavily in public transport infrastructure, making it accessible, affordable, and convenient (Vienna City Council, 2023).
- Cycling Infrastructure:** Investment in dedicated bike lanes, bike-sharing programs, and safe cycling facilities can help create a cycling-friendly urban environment. Cities like Copenhagen and Amsterdam have achieved high cycling rates by prioritizing safe, continuous cycling networks and integrating cycling into broader urban planning initiatives. This investment not only supports carbon reduction goals but also encourages physical activity among residents (Transport & Environment, 2022).

Table 13 Benefits of Investment in Public Transport and Cycling Infrastructure

Benefit	Description
Reduced Emissions	Lower vehicle emissions through increased use of public and active transport modes
Improved Public Health	Physical activity and reduced air pollution contribute to healthier populations
Increased Accessibility	Greater access to reliable, affordable transportation options for underserved communities

8.2 Public-Private Partnerships

Recommend collaboration with private sector partners to fund and support sustainable mobility initiatives.

Collaborating with private sector partners can provide cities with additional resources, innovative technologies, and expertise to advance sustainable mobility initiatives.

- Funding and Innovation Support:** Public-private partnerships (PPPs) allow cities to secure funding from private investors for large infrastructure projects, such as EV charging networks, bike-sharing programs, and public transit upgrades. Private companies can also bring in technology and innovation, such as real-time data systems, to improve the efficiency of transportation services. For example, Paris has collaborated with private bike-sharing companies to expand its Velib' bike-sharing network (Ministry of Urban Mobility, 2023).
- Sustainable Mobility Startups:** Cities can encourage sustainable mobility startups by providing grants, incentives, or co-working spaces. Startups focusing on electric mobility, shared transportation, and smart city solutions contribute to the sustainable mobility ecosystem and foster innovative solutions tailored to urban challenges.

8.3 Emphasis on Education and Community Involvement

Education and active community involvement play a significant role in facilitating behavioural shifts toward sustainable mobility. Raising awareness about the environmental and health benefits of sustainable transport modes can encourage people to adopt greener practices.

- **Educational Programs:** Schools, universities, and community centers can integrate sustainable mobility education into their curricula, covering topics such as environmental impact, active transport, and public transit benefits. Workshops and seminars on safe cycling, pedestrian rights, and green transportation options can also help build a culture supportive of sustainable mobility.
- **Community Forums and Citizen Engagement:** Engaging communities in urban planning processes fosters a sense of ownership and encourages residents to support sustainable transport initiatives. Regular forums where citizens can voice opinions, suggest ideas, and learn about new transport plans allow city planners to address public concerns. For instance, Barcelona's "Superblock" initiative involved local residents in planning car-free neighbourhoods, which has improved community buy-in and long-term project success (Barcelona City Council, 2021).

Table 14 Impact of Education and Community Engagement on Sustainable Mobility Adoption

Initiative	Impact
Sustainable mobility workshops	Increased awareness and adoption of eco-friendly travel modes
Community forums for mobility plans	Greater community support and improved policy alignment
School cycling programs	Early adoption of active transport habits in youth

Conclusively, strategic investment, collaboration, and education are pivotal for cities seeking to adopt sustainable urban mobility solutions. Allocating funds to public transport and cycling infrastructure, forming public-private partnerships, and involving communities in the planning process will help cities create accessible, eco-friendly transport systems that align with both environmental and social goals. Sustainable urban mobility is not only an environmental imperative but also a public health and social equity opportunity, requiring proactive, well-coordinated approaches from all stakeholders.

9 Future Outlook on Sustainable Urban Mobility

The future of sustainable urban mobility holds promising developments in technology, planning, and policy that can transform cities worldwide. This section explores emerging trends, the scalability of European urban mobility models, and the long-term environmental and social benefits that sustainable mobility practices can offer.

9.1 Emerging Trends in Urban Mobility

The urban mobility landscape is witnessing a rapid expansion of innovative solutions aimed at reducing carbon emissions, easing congestion, and making cities more accessible.

- **Electric Bike-Sharing:** Cities are increasingly incorporating electric bike-sharing systems into their transportation networks, offering residents a low-cost, accessible, and eco-friendly alternative for short journeys. Electric bikes make cycling more feasible for diverse demographics and longer trips, addressing physical limitations and increasing bike adoption. For example, Madrid has integrated e-bikes into its BiciMAD network, reducing road congestion and pollution (Madrid City Council, 2023).
- **Car-Sharing Programs:** Car-sharing services allow people to access vehicles without owning them, reducing the number of private cars on the road. This model can complement public transport and support multimodal urban mobility, as seen in Berlin, where a network of car-sharing providers works alongside a robust public transit system (Transport & Environment, 2022).
- **Micromobility Solutions:** Scooters, mopeds, and small electric vehicles are now essential parts of urban mobility strategies, helping bridge the "last-mile" gap in public transportation. These options, offered by companies like Lime and Bird, are particularly popular in densely populated areas where traditional transport

options are less accessible. Micromobility has seen significant adoption in cities like Paris, where dockless scooters are widely used for short commutes (Paris City Government, 2023).

Table 15 Emerging Urban Mobility Trends and Benefits

Trend	Description	Key Benefits
Electric Bike-Sharing	E-bikes for short and mid-range trips	Reduced emissions, accessibility
Car-Sharing Programs	On-demand car access without ownership	Fewer private cars, reduced congestion
Micromobility Solutions	Scooters and small EVs for last-mile trips	Complements public transit, flexible mobility

9.2 Scalability of European Models

European cities lead in sustainable urban mobility, and their models offer valuable lessons for cities globally. However, scaling these solutions requires careful adaptation to local contexts.

- **Policy Adaptation and Investment:** Non-European cities can adopt policies such as congestion pricing and subsidies for public transit, as implemented in London and Stockholm, to reduce car dependency and fund infrastructure. For example, cities like São Paulo and Jakarta can consider introducing congestion charges to manage traffic flow and raise funds for public transport investments (World Resources Institute, 2022).
- **Infrastructure Planning:** Cities like Amsterdam and Copenhagen have invested significantly in cycling and pedestrian infrastructure, demonstrating the benefits of dedicated bike lanes and car-free zones. Scaling these models requires commitment to long-term infrastructure development and government support, especially in car-centric cities. By creating compact, mixed-use neighbourhoods and ensuring connectivity, these cities can emulate the success of European counterparts.
- **Public Engagement and Awareness Campaigns:** European cities frequently engage residents through community involvement in mobility decisions, ensuring public buy-in. This approach can be beneficial in any city, helping build consensus and support for new sustainable transit options.

9.3 Long-Term Environmental and Social Benefits

Sustainable urban mobility offers lasting environmental, social, and economic benefits for cities and residents.

- **Environmental Impact:** Sustainable urban mobility solutions help lower greenhouse gas emissions and urban pollution levels. Widespread adoption of electric vehicles, shared transportation, and micromobility options will continue to reduce reliance on fossil fuels, contributing to cities' climate targets and improved air quality. Research from the International Council on Clean Transportation (ICCT, 2023) shows that cities adopting electric and low-emission transport strategies see annual reductions in CO₂ emissions by up to 30%.
- **Public Health Improvements:** Encouraging active transportation modes like cycling and walking improves physical health outcomes for city residents. Reduced pollution levels also lower the incidence of respiratory and cardiovascular diseases, contributing to healthier urban populations (WHO, 2023).
- **Increased Social Equity:** When cities invest in affordable, accessible, and integrated public transport, it reduces the mobility gap, providing low-income residents with access to education, employment, and essential services. Sustainable urban mobility initiatives also facilitate inclusivity by designing transport options that cater to different demographic needs, helping reduce social inequalities.

Conclusively, as cities worldwide confront the dual challenges of urbanization and climate change, sustainable urban mobility provides a vital pathway toward a more resilient, equitable, and liveable future. Emerging trends in shared mobility, policy frameworks inspired by European cities, and community engagement all offer promising routes for cities to follow. By continuing to innovate and investing in sustainable transportation options, urban centers can reduce emissions, improve public health, and increase access to opportunities for all residents. Through these efforts, sustainable urban mobility can evolve from an aspirational concept to an everyday reality for global cities.

10 Conclusion

The journey toward sustainable urban mobility is multifaceted, requiring a combination of urban planning, supportive policies, and shifts in public behaviour. This article has explored key elements, case studies, challenges, and opportunities, showing that by prioritizing sustainability, cities can foster improved quality of life, reduced environmental impact, and greater social equity.

10.1 Summary of Key Insights

The insights discussed provide a comprehensive view of sustainable urban mobility, highlighting how urban planning, policy frameworks, and behavioural shifts are integral to creating liveable cities:

Urban Planning: By integrating compact, mixed-use developments, cities reduce commuting distances, increase walkability, and enhance access to public transportation. European cities like Amsterdam and Copenhagen exemplify these principles, showcasing how dedicated bike lanes and pedestrian-friendly spaces encourage sustainable transportation modes.

Policy Frameworks: Policies such as congestion pricing, low-emission zones, and reduced car parking availability have helped to curtail car dependency in cities like London and Stockholm. Moreover, subsidies for public transport and active transport incentives play a crucial role in encouraging the use of eco-friendly travel modes.

Behavioural Shifts: Public awareness campaigns, community engagement, and education about the health and environmental benefits of active transportation have successfully influenced public behaviour. The combination of these strategies encourages residents to embrace walking, cycling, and public transit as primary means of travel, reducing the environmental footprint of urban transport.

10.2 Future Directions

While European cities have laid the groundwork for sustainable urban mobility, continued research is essential to adapt and scale these models globally. Future studies should focus on:

- **Scalability of Sustainable Models:** Cities in regions outside of Europe, especially in developing countries, need adaptable models that consider economic, social, and infrastructural contexts. Research can help identify how best practices from leading cities can be translated and optimized for varying conditions.
- **Innovative Technologies:** Emerging technologies in mobility, such as electric and autonomous vehicles, micromobility solutions, and advanced public transit systems, offer new avenues for reducing emissions and enhancing accessibility. Technological advances in smart city infrastructure, data analytics, and vehicle-to-grid solutions can further streamline urban mobility systems.

10.3 Call to Action

Urge policymakers, urban planners, and residents to support sustainable urban mobility initiatives for a healthier, greener future.

To realize the vision of sustainable urban mobility, collaboration across government, industry, and communities is essential. Policymakers are urged to enact supportive policies, urban planners to design people-friendly spaces, and residents to engage actively with sustainable transportation initiatives. By working together, cities worldwide can foster urban environments that prioritize health, inclusivity, and ecological balance.

Achieving a greener, more equitable future hinges on a shared commitment to sustainable urban mobility. This collective approach will ensure that future generations inherit cities that are not only efficient and accessible but also supportive of their well-being and the environment.

Compliance with ethical standards

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The authors have declared that no competing interests exist.

References

- [1] Ajuntament de Barcelona. (2019). *Superblocks Project: Transforming Barcelona Streets*. Barcelona City Council.
- [2] Banister, D. (2008) 'The sustainable mobility paradigm', *Transport Policy*, 15(2), pp. 73-80.
- [3] Barcelona City Council. (2021). *Superblock Program: Community-Driven Sustainable Urban Mobility*.
- [4] Buehler, R. and Pucher, J. (2011) 'Sustainable Transport in Freiburg: Lessons from Germany's Environmental Capital', *International Journal of Sustainable Transportation*, 5(1), pp. 43-70.
- [5] City of Amsterdam. (2020). *Amsterdam Cycling Policy and Infrastructure*. Amsterdam City Council.
- [6] City of Amsterdam. (2021). *Strategies for Sustainable Urban Mobility*. Amsterdam City Council.
- [7] City of Amsterdam (2023) *Sustainable Urban Mobility Strategy*. Available at: <https://www.amsterdam.nl/en/urban-mobility> (Accessed: 25 February 2024).
- [8] City of Copenhagen. (2020). *Copenhagen's Cycling Strategy: I Bike CPH*.
- [9] City of Helsinki. (2020). *Breath of Fresh Air Campaign in Helsinki*.
- [10] City of Paris. (2021). *Paris Plan Vélo: Citizen-Led Cycling Initiative*. Paris City Council.
- [11] City of Vienna. (2020). *Vienna's Urban Mobility Strategy*. Vienna City Council.
- [12] Cohen, A., & McClendon, A. (2021). *Understanding Car Dependency and Cultural Resistance*. Journal of Urban Studies.
- [13] Copenhagen Climate Plan. (2020). *Copenhagen's Vision for a Carbon-Neutral City by 2025*. City of Copenhagen.
- [14] Copenhagenize Design Co. (2021) *Copenhagen's Cycling Infrastructure: A Model for the World*. Available at: <https://www.copenhagenize.eu/> (Accessed: 12 January 2024).
- [15] Eliasson, J. (2019). *Stockholm Congestion Pricing: Lessons Learned*. Journal of Transport Economics and Policy.
- [16] European Commission (2020). *The Role of Cities in the Transition to a Climate-Neutral Europe*.
- [17] European Commission (2019) *The EU Urban Mobility Framework*. Available at: <https://ec.europa.eu/transport/themes/urban/> (Accessed: 10 December 2023).
- [18] European Environment Agency (2020). *Air Quality in Europe: 2020 Report*.
- [19] Grant, J. (2002). *Mixed Use in Theory and Practice: Canadian Experience with Implementing a Planning Principle*. Journal of the American Planning Association.
- [20] Gehl Institute. (2019). *Urban Mobility and Public Space in Copenhagen*.
- [21] Gehl, J. (2010) *Cities for People*. Washington: Island Press.
- [22] Gössling, S., Schröder, M., Späth, P., and Freytag, T. (2016) 'Urban Space Distribution and Sustainable Transport', *Transportation Research Part D: Transport and Environment*, 44, pp. 239-253.
- [23] Hickman, R. and Banister, D. (2014) *Transport, Climate Change and the City*. London: Routledge.
- [24] Île-de-France Mobilités (IDFM). (2021). *Navigo Pass: Fare Integration in Paris*.
- [25] International Council on Clean Transportation (ICCT). (2023). *Reducing Emissions in Urban Transport*.

- [26] London Assembly (2022) *Congestion and Low Emission Zones in London*. Available at: <https://www.london.gov.uk/> (Accessed: 25 October 2023).
- [27] Madrid City Council. (2023). *BiciMAD and Urban Mobility*.
- [28] Mees, P. (2010) *Transport for Suburbia: Beyond the Automobile Age*. London: Earthscan.
- [29] Ministry of Ecological Transition. (2019). *Cycling Reimbursement Schemes in France*.
- [30] Ministry of Urban Mobility. (2023). *Public-Private Partnership Innovations in Paris' Bike-Sharing Program*.
- [31] Mueller, N., et al. (2020). *Superblocks in Barcelona: How Urban Design Can Promote Health*. International Journal of Environmental Research and Public Health.
- [32] Municipality of Amsterdam. (2020). *Amsterdam's City Dialogue on Car-Free Zones*.
- [33] Municipality of Amsterdam. (2020). *Amsterdam's Plan for Car-Free Spaces by 2025*.
- [34] Municipality of Amsterdam. (2021). *Sustainable Urban Mobility in Amsterdam*.
- [35] Municipality of Milan. (2021). *Piazze Aperte: Milan's Public Space Reallocation Project*.
- [36] Neuman, M. (2005). *The Compact City Fallacy*. Journal of Planning Education and Research.
- [37] Oslo Municipality. (2019). *Oslo Car-Free City Center*.
- [38] Paris City Government. (2023). *Micromobility in Paris: An Urban Mobility Solution*.
- [39] Paris City Hall (2020). *Paris Breathe: Pedestrian Zones in Paris*.
- [40] Pucher, J., & Buehler, R. (2008). *Making Cycling Irresistible: Lessons from The Netherlands, Denmark, and Germany*. Transport Reviews.
- [41] Stockholm City Council (2020) *Urban Mobility Strategy: Stockholm*. Available at: <https://international.stockholm.se/> (Accessed: 4 November 2023).
- [42] Transport & Environment. (2020). *Investment in Cycling Infrastructure: Lessons from Copenhagen*.
- [43] Transport & Environment. (2022). *Cycling Infrastructure in Copenhagen: A Model for Sustainable Cities*.
- [44] Transport & Environment. (2022). *Car-Sharing Initiatives in Berlin*.
- [45] Transport for London. (2019). *Let's Ride Campaign: Promoting Cycling in London*.
- [46] Transport for London. (2021). *Impacts of London Congestion Charge on Emissions*.
- [47] United Nations (2019). *World Urbanization Prospects: The 2018 Revision*. Department of Economic and Social Affairs, Population Division.
- [48] UITP (2019). *Public Transport Trends and Developments*.
- [49] UITP (2020). *Sustainable Public Transport in Vienna*.
- [50] United Nations (2019) *World Urbanization Prospects*. Available at: <https://population.un.org/wup/> (Accessed: 7 December 2023).
- [51] Van Wee, B., Annema, J. A. and Banister, D. (2013) *The Transport System and Transport Policy: An Introduction*. Cheltenham: Edward Elgar.
- [52] Vienna City Council. (2023). *Public Transport Investment Strategy for Sustainable Urban Mobility*. Vienna City Government.
- [53] Vienna Urban Mobility Plan. (2021). *Pedestrian and Cycling Initiatives in Vienna*.
- [54] World Health Organization (2017) *Health and Environment in Sustainable Cities*. Available at: <https://www.who.int/> (Accessed: 22 December 2023).
- [55] World Health Organization (WHO). (2023). *Public Health Benefits of Reduced Urban Air Pollution*.
- [56] World Resources Institute. (2022). *Congestion Pricing as a Mobility Solution in Urban Centers*.