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Review

The Role of Land Use Planning in Urban Transport to Mitigate Climate Change: A Literature Review

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Abstract

With the growing urbanisation phenomenon, ambitious policy interventions are needed to limit transport-related greenhouse gas emissions in urban areas. Cities are a predominant source of pollution, with urban transport contributing significantly to emissions. To address climate change, decision-makers must implement appropriate and effective mitigation instruments. This literature review focuses on the different approaches and supporting measures of urban transport land-use planning, such as mixed-used zoning plans and the compact city approach. These solutions can increase the modal shift towards zero emissions transport options. They can also reduce reliance on private vehicles and bring co-benefits and positive externalities to urban residents. Many barriers exist for policymakers, such as financial limitations or institutional immobility. Nevertheless, innovative approaches such as Artificial Intelligence and Mobility-as-a-service provide new perspectives for policymakers and can be helpful in the fight against climate change.

Keywords
Transport planning; land-use planning; greenhouse gas emissions; mitigation; climate change; compact city; zoning; transport modelling; mobility-as-a-service

1. Introduction

Early literature focused only on the economic effects of transport systems in urban areas. But starting from the second half of the 20th century, along with the exponential development of transport in cities, the overall angle of analysis shifted, and researchers began to assess transport's environmental impacts [1].

Transport contributes almost a quarter of global greenhouse gas (GHG) emissions today [2]. The sector is indeed a significant source of air pollution by releasing particulate matter (PM), nitrogen dioxide (NO_2) and carbon dioxide (CO_2) [2]. Air pollution harms the population's health and quality of life, especially in cities. In addition, CO_2 creates urban heat island effects and contributes to global warming [1]. Noise pollution from road traffic, railways, air traffic, and raw material depletion are other adverse environmental consequences of transport. Lastly, due to land-use change, transport infrastructure transforms the urban landscape by strengthening sprawl and reducing the number of natural areas, affecting animals and plants [3].

A plethora of strategies can be implemented to mitigate these emissions. First, commuters can be encouraged to shift toward low-emission transport alternatives, with walking, biking, and public transport at the top of the transport hierarchy (Figure 1). Table 1 outlines the main pros and cons of each low or zero-emission transport option.

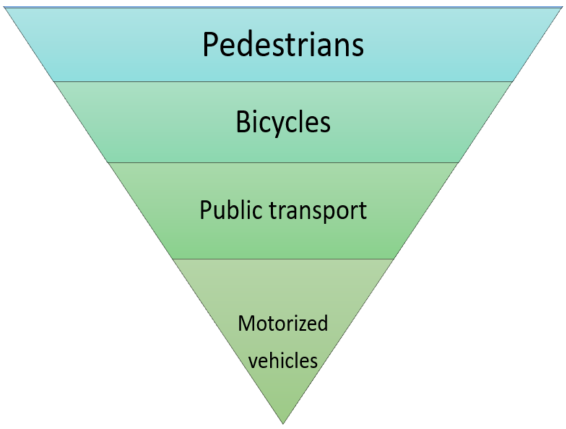

Figure 1 Transport priorities in more sustainable cities [4].

Table 1 Advantages and disadvantages of sustainable alternative modes of transport [4].

Walking	Advantages	Free, quiet, non-polluting, provides exercise.
	Disadvantages	Impracticable for long distances.
Bicycling	Advantages	Affordable, quiet, non-polluting, provides exercise, requires little parking space.

	Disadvantages	Impracticable for long distances, little to no protection from accidents and bad weather, bike lanes and secure bike storage are not widespread yet.
Buses	Advantages	Reduce car use and air pollution.
	Disadvantages	Can get caught in traffic and add to noise and pollution.
Mass-transit rail systems	Advantages	Use less energy, produce less pollution than cars, use less land than roads and parking lots, and cause fewer car accidents.
	Disadvantages	Expensive to build and maintain, cost-effective only in densely populated areas.
Rapid-rail systems	Advantages	Much more energy-efficient per rider and produce less air pollution than cars and planes can reduce the need for air travel, cars, roads, and parking areas.
	Disadvantages	Expensive to run and maintain, causes noise and vibration for nearby residents.

The main objective of this strategy is to strengthen the use of these low to zero-emission transport options to reduce commuters' reliance on private motorised vehicles. Private motorised vehicles are the world's largest source of outdoor air pollution, produce more than 70% of the overall emissions from the transport field and exacerbate urban sprawl [3, 4].

The second mitigation strategy to reduce urban emissions is to switch private motorised vehicles to low-emission power sources, such as biofuels, natural gas and electricity. Biofuels and natural gas are a source of clean energy, but their initial production is energy-intensive [5-8]. Electric vehicles appear to be a viable solution as no emission is emitted when the electric car runs. But indirect pollution is emitted during production processes, notably through batteries that produce toxic fumes [8, 9].

Lastly, encouraging the reduction of the number of trips can be an effective solution. This involves a transformation of the urban landscape into compact urban zones to reduce the need for travel. To this extent, effective and appropriate instruments, such as land-use planning, can be implemented to transform urban development in a sustainable, low-carbon and resilient way.

Land-use planning is a regulatory instrument that determines the activities undertaken in different locations within a planned area. Once a land-use plan is implemented, public authorities can control the uses of specific parcels of land by legal and economic methods [4]. Transport and land use are closely related as land use planning activities determine access to transport infrastructure and affect travel demand [10]. To this extent, land-use planning can help counter increasing traffic and urban sprawl and offset emissions.

This paper first describes the findings of the international literature on the role of land-use planning in mitigating emissions in the transport sector and the instruments that can be used to achieve this, such as transport modelling, transport-oriented developments (TOD) or zoning. The paper argues the necessity to implement these land use planning instruments through a polycentric governance approach and following the compact city concept to achieve transport decarbonisation targets effectively. Based on these findings, the paper then discusses the barriers policymakers can face and innovative approaches for land transport planning, such as Artificial Intelligence and

Mobility-as-a-service. This review then provides recommendations for future improvements and further research.

2. Materials and Methods

This section details the methods used during the research process, including the research problem this study intends to address, how the data was collected, the research strategy, and the significance of the study.

2.1 Statement of the Research Problem

Urban transport systems must be decarbonised as they significantly contribute to greenhouse gas emissions. The issue needs can be mitigated through urban land-use planning and environmental policymaking.

2.2 Statement of the Research Questions

This paper intends to address the following research questions:

- What is the role of land-use planning in limiting greenhouse gas emissions from urban transport systems? What are the main enabling instruments?

2.3 Data Collection

The research was conducted in Paris from April to June 2021 and in Brisbane from May to June 2022. The data collection stage involved a search of the research literature using the following parameters. The platforms used were Scopus and Google Scholar, with a date range from 2011 to 2022, and with the following key terms: 'transport', 'mitigation', 'transport planning', 'emissions', 'land-use planning', 'mixed-used', 'zoning', 'smart-growth', 'transit-oriented development', 'transport modelling', 'governance', 'ICTs', 'green infrastructure', and 'artificial intelligence'. The research is conducted primarily using peer-reviewed journal articles and international reports, such as the Global Environment Outlook (GEO) 6 of the United Nations Environment Programme.

Fifty-one articles were identified during the research process. Materials included in the study and evaluated for eligibility included the transport of people within urban areas, such as mass-transit systems and public transport, road transport, walking and bicycling. Transport of goods, water, and air, such as ships and planes, were removed from the data collection process. After this screening process, 38 articles were selected for analysis. Their content was analysed against the following themes: land-use planning instruments in the transport sector and their potential effects on mitigating urban emissions, the policy framework for sustainable land transport planning, the obstacles/barriers encountered, and innovative approaches.

2.4 Research Strategy

This paper is a systematic review of the international literature on urban land-use planning in the transport sector. It aims to use cities as a research scope to study transport management and show how sustainable urban planning and land-use management are essential to offset emissions in this sector.

The main goals of this review are the following:

- Find practical and appropriate mitigation instruments in urban transport systems through land use,
- Confront these instruments with real-world constraints to find the most reliable solutions and,
- Outline debates, controversies, and gaps in knowledge.

To address the research questions, the data analysis used sustainability's triple bottom line approach (i.e., across social, economic, and environmental dimensions). The analytical framework involved a comprehensive approach between transport, urban development, and climate change. Key drivers and conditions for a more sustainable transport future were identified, including travel behaviour, social and spatial organisation, urban design, and technological change.

This review provides guidelines for mitigation actions in urban transport planning. It can be relevant for any stakeholder interested in finding opportunities and planning instruments to decarbonise urban transport systems through land use.

3. Results

3.1 The Critical Role of Urban Land Use Planning in the Transport Sector

Many studies focused on the effects of land-use change from a physical, geographical or geochemical perspective. But the literature is scarcer regarding the impacts of land-use change on urban activities and emissions [11].

Land use planning determines the spatial distribution and densities of infrastructure, including transport infrastructure, directly affecting the urban form and travel demand. Travel demand includes residents' origin, destination, and choice of travel and impacts transport-related GHG emissions [11, 12]. The literature has a consensus that land-use planning is closely related to transport systems and can reduce transport-related urban emissions [11].

By promoting the efficient use of space, land-use planning can decrease travel distances and encourage more sustainable transport options [4, 12, 13]. Achieving this would reduce car dependency and traffic congestion and mitigate urban sprawl [4]. For example, reallocating road space with dedicated bus lanes would help achieve these outcomes by facilitating the use of public transport [6, 14, 15].

Land-use planning strategies supporting sustainable urban transport can provide co-benefits to residents, create new economic opportunities, and enhance their attractiveness. Indeed, improved transport infrastructure through better access to public transport socially benefits the most disadvantaged social groups. Fostering their mobility will give them more accessible access to employment, markets, and essential facilities such as schools and hospitals [14]. In addition, integrating more cycling and walking zones within cities will also positively affect health through increased physical activity [16].

3.2 Implementation Framework

3.2.1 The Compact City Approaches

The primary desired outcome of urban transport land-use planning is to develop compact urban areas. Compact cities are often privileged within urban planning perspectives in terms of sustainability, because of their more substantial reliance on walking, cycling and mass transit transport options, due to the increased proximity of urban facilities [17]. By increasing urban density, the literature argues that the compact city approach through land use contributes to a better urban quality of life and environmental/health improvements. These improvements result from a reduced need for travel, including long-distance trips, higher use of low to zero-emission transport options, such as walking, cycling, or public transport and improved use of urban resources [11].

For example, with a population density of 20,515 people per square kilometre, Paris (France) is a compact city [18]. In contrast, Brisbane (Australia) is a much more spread-out city, with an area 150 times larger than Paris and a population density of 346 people per square kilometre, 59 times less than Paris [18, 19]. The level of car use is higher in Brisbane, accounting for 85% of daily trips, whereas only 14.6% of the population uses a car daily in Paris [20, 21]. Furthermore, 67% of the Parisian population uses public transport, while this rate is only 8% in Brisbane [20, 21]. This comparison showed that compact cities are more prone to high use of low-emission transport options, such as public transport, and have lower dependence on cars.

3.2.2 Mixed-Used Zoning Plans

Several instruments can be used to manage land use in more compact urban areas. One of the critical instruments is called zoning. Zoning plans create mixed-use activities/developments (commercial, residential, commercial, and recreational) around a delimited urban area [4]. This approach aims to create neighbourhoods with a wide range of different facilities that are easily accessible so that the need to travel long-distance is considerably reduced [13].

Zoning instruments are used to delimit the extent of the urban footprint of a town by controlling growth and protecting areas from certain types of development, as well as to identify areas for future expansion or redevelopment. The desired outcomes are to create more compact urban areas to reduce traffic and car dependency, discourage urban sprawl, and enhance the city's attractiveness [4]. Traffic congestion issues are mitigated thanks to urban activities through closer travel distances, encouraging the gradual replacement of motorised trips with walking, cycling or public transport [11]. However, mixed-use zoning plans can only be implemented effectively if the city provides an efficient public transport system and appropriate fiscal and regulatory instruments [13].

For example, the city of Portland (United States) is widely recognised as a best practice model for comprehensive smart growth policies, including mixed-used zoning plans. Since the 1970s, the metropolitan planning organisation (MPO) called Metro has implemented a plethora of planning tools to prevent urban sprawl by clustering urban development near mass transit hubs, encouraging the creation of commercial facilities in residential areas and promoting walking and cycling activities [4, 22].

3.2.3 Transit-Oriented Developments

In the same logic applied to transport, transit-oriented developments (TODs) are essential planning tools to increase urban density around significant transport hubs. Through urban renewal and land-use change, TODs aim to cluster population and centralise employment around major public transport stations. TODs also work toward transforming transport infrastructure to make public transport networks more efficient, polycentric and multi-destination [23, 24]. For example, over the last 60 years in Stockholm, the city has become a multi-centred metropolis with a shallow level of car dependency, thanks to the concentration of most new urban developments into high-density clusters around rail stations [13].

3.2.4 Transport Modelling

Increasing urban density and encouraging a modal shift toward low-emission transport options are the main goals of land use plans to mitigate urban emissions within transport systems. Achieving this goal involves a combination of technical expertise, robust institutions, and appropriate policies.

In this context, transport models help simplify these complexities and give a clear understanding of the possible implications of such changes. Indeed, by showing different aspects of the urban system, transport models assist decision-making by providing national and local leaders with additional information on land use planning options for transport, allowing experimentation with different policies and providing internal perspectives [25]. The integration of transport models is therefore essential to plan, assess and communicate urban strategies to achieve mitigation targets. Transport modelling contributes significantly to identifying the optimal mitigation strategy by providing valuable information to decision-makers through simulation processes [25].

To this extent, land-use planning strategies can be integrated into transport models and are often combined with other features, such as transport costs, infrastructure renewal, socio-economic characteristics, environmental outcomes, and technology and behaviour scenarios to analyse their interrelationship [25-27]. For example, a transport model called the Ruhrgebiet model was created to model a transition from fossil fuels to renewable energy in the Ruhr area in Germany, one of the largest urban agglomerations in Europe (Figure 2). This model analysed the interrelationship between population, employment, land use, and transport [25] (Figure 2). The methodology used was the IRPUD model, initially developed by the Institute of Spatial Planning at the University of Dortmund [28].

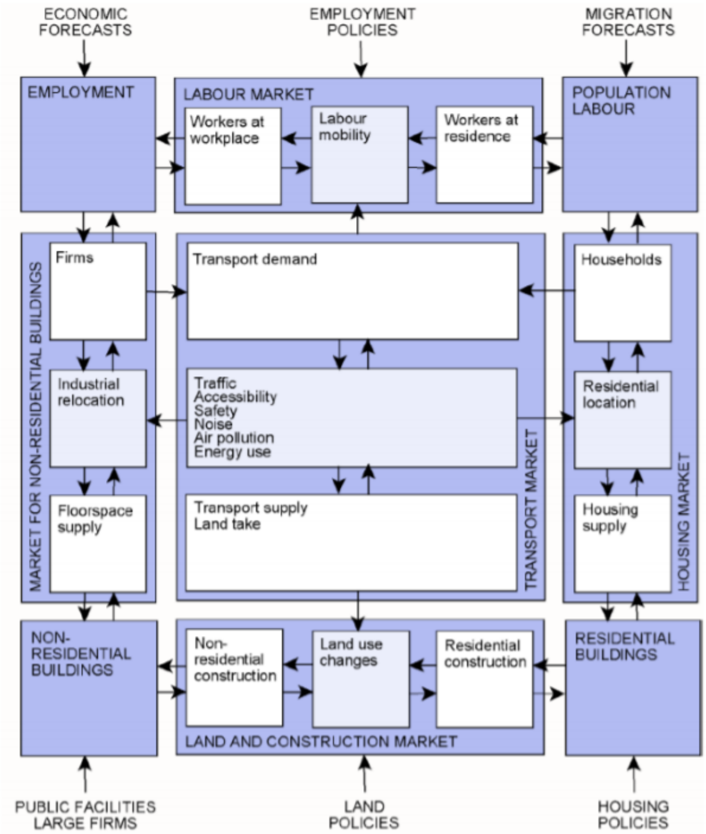

Figure 2 Conceptual decision of the IRPUD model showing linkages between population, employment, land-use, and transport via a series of markets [25].

3.3 Policy Effectiveness Assessment

This section details policymakers' role in implementing land use for transport planning. The instruments discussed in the previous section, such as mixed-use zoning plans and TODs, would lead to ineffective results in terms of transport decarbonisation if they are not implemented in a robust policy framework. Governments must actively push their policies and direct land-use changes towards a modal shift towards compact urban areas and low-emission transport options [17]. To achieve policy effectiveness, key governance requirements must be followed by policymakers.

Policymakers should adopt polycentric governance by integrating stakeholders at all levels in the implementation process [29]. For instance, this can be made through public-private partnerships [30]. Indeed, many professions have a role to play in the implementation process; this can include engineers, planners, local authorities and agencies, research institutions, businesses -including car industries-, non-governmental organisations, and local communities [29]. The main challenge for policymakers is coordinating their competing interests as the different professions approach climate change mitigation strategies differently. For instance, transport planners and researchers would emphasise local processes, such as mobility management and urban renewal. In contrast, businesses would provide more weight to economic measures such as costs and benefits [31].

To achieve polycentric governance, participatory methods are also relevant instruments to use by policymakers to reach policy effectiveness [30]. For example, developing surveys to know the preferred transport option of residents could be valuable and would allow a sustainable transport planning transition corresponding to residents' expectations [25]. Consultation programs with local communities to discuss future projects and scenarios help social acceptance of transport policies as a broader range of stakeholders are involved in the implementation process [14, 32]. For example, for building new green bridges in Brisbane (Australia), involving land-use change and urban infrastructure renewal to separate cycle and pedestrian paths from the main roads, consultation programs have been engaged with the community at the early planning stages of the bridges. This allowed policymakers to know which construction projects are more likely to be accepted or rejected by local communities [33].

Building scenarios are also beneficial for assessing the optimal land transport planning strategy for mitigating urban emissions and identifying appropriate policy alternatives. For example, Reisi et al. (2016) [10] developed three urban planning scenarios for Melbourne in 2030 based on compact to sprawled urban development patterns. Each scenario was then evaluated on its performance on transport sustainability through environmental, social and economic indicators. The results showed that a higher population density, additional pedestrian areas and improvements in public transport infrastructure would increase the transport sustainability index [10]. This example showed that policy and planning scenarios would help provide guidelines and better insights on the potential implications of specific land-use changes on emissions and sustainability.

4. Discussion

4.1 The Main Barriers Faced by Policymakers

Despite a broad range of planning instruments able to change the urban configuration to decarbonise transport systems, there are substantial barriers policymakers can face during the implementation process.

Many uncertainties within the transport field can, indeed, affect the effectiveness of transport policies. A lack of data, such as traffic congestion costs or the configuration of the residents' travel behaviour on a selected spatial scale, can lead to incomplete transport projection models or inadequate land-use policies [10]. Conducting appropriate network design studies can therefore be a challenge for policymakers. Lack of reliable data can lead to overestimation of transport demand or underestimation of transport capacity and, as a result, to the provision of inadequate transport supply [34]. For example, investments in public transport infrastructure in a given urban area are not automatically guaranteed to compete sufficiently with private motorised vehicle use to achieve positive emissions outcomes [24].

A lack of time and financial and institutional resources will also jeopardise the expected results [35]. Policymakers must carefully select cost-effective urban development projects and use a dynamic approach to transport planning, considering all the factors determining the chosen spatial location. These factors include the distribution of infrastructure and land use patterns, employment concentration and residential density, and their interactions in terms of traffic patterns [34].

Land-use change also involves a transformation of travel costs and accessibility. Improved accessibilities lead to changes in the population's spatial distribution and employment, affecting travel demand over time [34]. This transformation will achieve positive results in terms of emissions if urban density and the provision of low-emission travel options are increased.

However, additional issues such as increased spatial inequity among residents can occur. For instance, more compact urban areas and cities with higher environmental quality can boost real estate demand and make housing less affordable [36]. Consequently, low- and middle-income households will have longer distance trips than high-income households [37].

Lastly, a key challenge for governments in implementing transformative change in cities is to reach social acceptance, meaning that their transport policies are supported by communities and all other levels of society. Unsupported urban development projects can be a barrier to change. For example, in Paris, restrictive car access has been implemented in the city with the closure of the riverside lanes for cars along the Seine River in 2016 to encourage the reduction of car use. This measure has sparked debate and met with resistance, mainly from car users, taxi drivers, and political opposition. Their main arguments were the increase in traffic congestion, the lack of complementary policies to palliate the rebound effects of this closure, and the absence of the expected results to reduce air pollution [38].

These barriers to a successful implementation framework demonstrate that a sound strategy must support transport planning policies involving land-use change. This includes considering all indicators of the urban area and allocating sufficient resources to achieve decarbonisation objectives. To this extent, it may be worthwhile to have innovative approaches to mitigation strategies.

4.2 Innovative Approaches

This section discusses the role of innovative technologies in land transport planning. Artificial intelligence and Information and Communication Technologies (ICTs) appear promising land use planning strategies in urban transport systems. Implementing these emerging techniques could lead to more effective results in optimising land use patterns and, therefore, facilitating the sustainable transition of transport systems.

Artificial intelligence (AI) is an area of computer science using algorithms to perform like human brains [39]. Its application in transport systems requires a good understanding of the interrelationships between the data produced by the algorithms, land-use characteristics and transport variables [40]. The advantage of using AI in land use and transport models is its capacity to respond to the difficulties of traditional computational techniques to clarify complex issues, such as transport users' behaviour or travel patterns projection scenarios. Addressing these issues would assist decision-making by allowing more precise insights into the optimal methods to adopt in transport planning to address limited transport supply and increasing travel demand, as well as their impacts on the environment and GHG emissions [40, 41]. AI also allows rapid improvements in easing traffic congestion, providing more reliable information on travel times, and improving the overall results of transport models [40].

Several AI methods can be used for land transport planning, such as the genetic algorithm and simulated annealing. The genetic algorithm uses "fitness assessment" and "population reassembly" to address complex optimisation issues in urban design networks. The purpose is to minimise travel times and the number of transfers of transport users to optimise urban commuting [42]. Simulated annealing uses simulation processes to compare a combination of commuter transport solutions with given probabilities on associated results [41].

Another emerging approach in land transport planning strategies is Mobility-as-a-Service (MaaS). Some components of the MaaS approach propose digital online platforms by providing personalised multimodal travel planning, smart ticketing, real-time information services, booking systems and mobility packages for transport users [43, 44]. In contrast with AI, MaaS methods do not use projection scenarios and transport models to influence land-use patterns but are directly related to transport users.

The literature argues that innovative technologies effectively reduce car dependency, making public transport systems more efficient [45]. In this context, MaaS methods minimise travel delays and the number of cars on the roads, easing congestion and helping reduce air pollution and transport-related emissions. Indeed, more efficient transport systems through MaaS would leave additional available space from car traffic, and parking could be redistributed towards public transport and active mobility [43]. However, even if research on MaaS is growing, this approach still lacks a clear and universal definition today. In addition, the number of studies on the influence of MaaS on travel behaviour and urban configuration remains scarce [43].

5. Recommendations

Due to the time needed to build the necessary infrastructures, land-use planning has a limited impact on reducing transport-related GHG emissions in the short term. However, in a long-term perspective, the effect will be the opposite, with the gradual replacement of private vehicle dependency with public transport and more sustainable transport options [13].

But positive results will occur only if policymakers implement polycentric governance by combining all the instruments discussed in previous sections and coordinating the expertise and engagement of stakeholders at all levels. Polycentric governance should also be accompanied by education and communication programs to reach social acceptance and support from all spheres of society. This can be done through forums, workshops, information campaigns or regular releases available to the public from the early planning stage of new urban development projects or transport policies. These communication strategies must include the environmental and liveability benefits associated with the project.

In addition, policymakers should not only design compact urban areas in the city centre, as it can create rebound effects by increasing travel demand from the suburbs to the inner city. Investments should also be made to implement TODs and mixed-use activities in the suburban areas to prevent spatial inequity among residents, reduce long-distance trips and improve the attractiveness of the suburbs.

Further research should be undertaken on the impacts of emerging approaches on urban emissions and the built environment, such as integrating AI and ICTs into land transport planning strategies. AI approaches should not only be accessible to technical experts and engineers. Efforts to popularise artificial intelligence techniques among transport and land-use strategies should be implemented so that they are more accessible for planners and policymakers when an urban development project is underway. This would help mitigate the lack of data within transport models or projection scenarios and reduce the inefficiencies of dispersed policies.

6. Conclusions

Land-use planning plays a critical role in the transport sector. Its implementation mainly determines the urban form and configuration of city transport infrastructure and networks. Several key land-use planning instruments can be used for transport: transport models, mixed-use zoning plans and TODs. The appropriate use of these instruments can mitigate GHG emissions in urban areas by increasing urban density, reducing travel distances, and encouraging a modal shift towards low to zero-emission transport options, such as public transport and active mobility.

For successful results, these instruments should be implemented in a robust policy framework to achieve policy effectiveness. This includes polycentric governance (through, for example, participatory methods or public-private partnerships) and projection scenarios for transport design studies. New and innovative technologies can also be included in land transport projects for more dynamic transport planning approaches. This review argued that artificial intelligence approaches in transport models and MaaS methods for transport users are the cornerstones of innovative land-use planning.

However, many difficulties can be faced by policymakers in the implementation process. The first obstacles encountered are the lack of data, weak institutions and insufficient financial resources. Transport policies and urban development projects can also face reluctance for change from local communities or political opposition. All in all, in all cases, successful results in terms of emissions take time due to the time needed to create impactful land-use change and build the necessary infrastructure. Nevertheless, significant investments to accelerate the transition towards sustainable transport systems are required as the transport sector remains an important contributor to GHG emissions.

Glossary of Terms, Abbreviation and Acronyms

AI	Artificial Intelligence
CO	Carbon monoxide
CO_2	Carbon dioxide
EU	European Union
GEO	Global Environment Outlook
GHG	Greenhouse gas
ICTs	Information and Communication Technologies
IPCC	Intergovernmental Panel on Climate Change
HC	Hydrocarbons
MaaS	Mobility-as-a-service
PM	Particulate matter
NO_2	Nitrogen dioxide
NO_x	Nitrogen oxide
TOD	Transport-oriented developments

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TD – Writing (Draft, editing), Administration, AF – Writing (Draft, editing).

Competing Interests

The authors have declared that no competing interests exist.

References

1. Łatuszyńska M, Strulak-Wójcikieiwcz R. Computer simulation of transport impact on

environment. Transp Prob. 2014; 9: 37-47.
2. Sustainable transport and air pollution [Internet]. Kenya: UNEP; 2022. Available from: https://www.unep.org/explore-topics/resource-efficiency/what-we-do/cities/sustainable-transport-and-air-pollution.
3. Transport [Internet]. Copenhagen: European Environment Agency; 2020. Available from: https://www.eea.europa.eu/themes/transport/intro.
4. Miller GT, Spoolman S. Living in the environment. 18th ed. Cengage Learning; 2015.
5. Forsberg J, Krook-Riekkola A. Recoupling climate change and air quality: Exploring low-emission options in urban transportation using the times-city model. Energies. 2021; 14: 3220.
6. Gallo M, Marinelli M. Sustainable mobility: A review of possible actions and policies. Sustainability. 2020; 12: 7499.
7. Roberts LG, Patterson TJ. Biofuels. In: Encyclopedia of toxicology. 3rd ed. Oxford: Academic Press; 2014. pp.469-475.
8. Waters B. Introduction to environmental management: For the NEBOSH certificate in environmental management. London: Routledge; 2013.
9. Nanaki EA, Koroneos CJ. Climate change mitigation and deployment of electric vehicles in urban areas. Renew Energ. 2016; 99: 1153-1160.
10. Reisi M, Aye L, Rajabifard A, Ngo T. Land-use planning: Implications for transport sustainability. Land Use Policy. 2016; 50: 252-261.
11. Zhang R, Matsushima K, Kobayashi K. Can land use planning help mitigate transport-related carbon emissions? A case of changzhou. Land Use Policy. 2018; 74: 32-40.
12. Holz-Rau C, Scheiner J. Land-use and transport planning – A field of complex cause-impact relationships. Thoughts on transport growth, greenhouse gas emissions and the built environment. Transp Policy. 2019; 74: 127-137.
13. Dulal HB, Brodnig G, Onoriose CG. Climate change mitigation in the transport sector through urban planning: A review. Habitat Int. 2011; 35: 494-500.
14. Banister D. Cities, mobility and climate change. J Transp Geogr. 2011; 19: 1538-1546.
15. Zakharov D, Fadyushin A. Changes in the structure of urban mobility with the development of infrastructure for public transport and cyclists in cities. In: WIT Transactions on the Built Environment. Southampton: Wit Press; 2020. pp.49-60.
16. Rahul TM, Verma A. Sustainability analysis of pedestrian and cycling infrastructure – A case study for Bangalore. Case Stud Transp Policy. 2018; 6: 483-493.
17. Stevenson M, Thompson J, de Sá TH, Ewing R, Mohan D, McClure R, et al. Land use, transport, and population health: Estimating the health benefits of compact cities. Lancet. 2016; 388: 2925-2935.
18. Estimated population density in the Ile-de-France region in France in 2020, by department [Internet]. Hamburg: Statista; 2022. Available from: https://www.statista.com/statistics/1047176/population-density-ile-de-france-paris-region-by-department-france/#:~:text=This%20bar%20chart%20presents%20the,populated%20department%20in%20the%20region.
19. Brisbane Population 2022 (Demographics, Maps, Graphs) [Internet]. World Population Review; 2022. Available from: https://worldpopulationreview.com/world-cities/brisbane-population.
20. Tao S, Corcoran J, Mateo-Babiano I. Modelling loyalty and behavioural change intentions of

busway passengers: A case study of Brisbane, Australia. IATSS Res. 2017; 41: 113-122.
21. Calvier C, Jacquesson F. En Ile-de-France, l'usage de la voiture pour aller travailler diminue [Internet]. Paris: INSEE; 2015. Available from: https://www.insee.fr/fr/statistiques/1285604.
22. Dong H, Zhu P. Smart growth in two contrastive metropolitan areas: A comparison between Portland and Los Angeles. Urban Stud. 2014; 52: 775-792.
23. Kenworthy JR. 2.1 - Reducing passenger transport energy use in cities: A comparative perspective on private and public transport energy use in American, Canadian, Australian, European and Asian cities. In: Urban energy transition. Elsevier; 2018. pp.169-204.
24. McLeod S, Scheurer J, Curtis C. Urban public transport: Planning principles and emerging practice. J Plan Lit. 2017; 32: 223-239.
25. Ford A, Dawson R, Blythe P, Barr S. Land-use transport models for climate change mitigation and adaptation planning. J Transp Land Use. 2018; 11: 83-101.
26. Zhang R, Fujimori S, Dai H, Hanaoka T. Contribution of the transport sector to climate change mitigation: Insights from a global passenger transport model coupled with a computable general equilibrium model. Appl Energ. 2018; 211: 76-88
27. Wegener M. Land-use transport interaction models. In: Handbook of regional science. Berlin/Heidelberg: Springer; 2021. pp.229-246.
28. Wegener M. The IRPUD model [Internet]. Dortmund: S&W; 2011. Available from: https://www.spiekermann-wegener.de/mod/pdf/AP_1101_IRPUD_Model.pdf.
29. Global environment outlook 6. Kenya: UNEP; 2019. Available from: https://www.unep.org/resources/global-environment-outlook-6.
30. Butterfield BJ, Low NP. Reducing carbon emissions from transport: Multi-level governance and the problem of monitoring. Urban Policy Res. 2017; 35: 235-247.
31. Banister D, Schwanen T, Anable J. Introduction to the special section on theoretical perspectives on climate change mitigation in transport. J Transp Geogr. 2012; 24: 467-470.
32. Lefèvre J, Briand Y, Pye S, Tovilla J, Li F, Oshiro K, et al. A pathway design framework for sectoral deep decarbonization: The case of passenger transportation. Clim Policy. 2021; 21: 93-106.
33. Green Bridges Program [Internet]. Brisbane: Brisbane City Council. Available from: https://www.brisbane.qld.gov.au/traffic-and-transport/roads-infrastructure-and-bikeways/green-bridges.
34. Szeto WY, Jiang Y, Wang DZW, Sumalee A. A sustainable road network design problem with land use transportation interaction over time. Netw Spat Econ. 2015; 15: 791-822.
35. Macmillen J, Stead D. Learning heuristic or political rhetoric? Sustainable mobility and the functions of 'best practice'. Transp Policy. 2014; 35: 79-87.
36. Korthals Altes WK. Planning initiative: Promoting development by the use of options in Amsterdam. Land Use Policy. 2019; 83: 13-21.
37. Zhao P, Li S. Restraining transport inequality in growing cities: Can spatial planning play a role? Int J Sustain Transp. 2016; 10: 947-959.
38. Sleiman L, Crifo P, Schmutz B. Des centres plus verts, des banlieues plus grises? Paris: L'Institut des politiques publiques; 2021; Note IPP n°65. Available from: https://www.ipp.eu/wp-content/uploads/2021/05/n65-notesIPP-mai2021.pdf.
39. Borana J. Applications of artificial intelligence & associated technologies. Proceedings of the IETEBMS-2016; 2016 March 5-6; Jodhpur, India.
40. Abduljabbar R, Dia H, Liyanage S, Bagloee SA. Applications of artificial intelligence in transport:

An overview. Sustainability. 2019; 11: 189.
41. Feng F, Pang Y, Lodewijks G, Li W. Collaborative framework of an intelligent agent system for efficient logistics transport planning. Comput Ind Eng. 2017; 112: 551-567.
42. Nayeem MA, Rahman MK, Rahman MS. Transit network design by genetic algorithm with elitism. Transp Res Part C Emerg Technol. 2014; 46: 30-45.
43. Nikitas A, Michalakopoulou K, Njoya ET, Karampatzakis D. Artificial intelligence, transport and the smart city: Definitions and dimensions of a new mobility era. Sustainability. 2020; 12: 2789.
44. Kamargianni M, Li W, Matyas M, Schäfer A. A critical review of new mobility services for urban transport. Transp Res Procedia. 2016; 14: 3294-330.
45. Fernandez-Sanchez G, Fernandez-Heredia A. Strategic thinking for sustainability: A review of 10 strategies for sustainable mobility by bus for cities. Sustainability. 2018; 10: 4282.