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A review of modern sustainable transit systems in urban areas

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Abstract: Due to air pollution and traffic congestion brought on by the fast development in urban travel demand, there is an increasing need for alternate means of transportation in metropolitan areas. By reducing the negative effects of network congestion, a transit system may significantly contribute to improving the sustainability of transportation in these places. A substantial fraction of customers may be persuaded to leave their own vehicles at home and take public transportation instead if the service quality was comparable to that of the automotive mode. By reducing the number of circulating cars and raising the average speed of traffic flow, a competitive transit system can increase user mobility and lower emissions from circulating vehicles. However, the amount of network travel demand that a transportation system captures primarily relies on the level of user service it provides. As a result, it's critical to balance operating costs with service quality by reducing the social, economic, and environmental costs associated with putting in place an effective and sustainable transportation system design.

Keywords: Sustainable transit system; Direct route design; Electric buses; Emissions; Public transport; Sustainability; Transit network design; Urban Transit networks

1. Introduction

There is a growing demand for alternative modes of transportation in urban areas, as rapid growth in urban travel demand has resulted in congestion and air pollution. In these areas, a transit system can play a prominent role in improving the sustainability of transportation by alleviating the unpleasant impacts of congestion across the network [1]–[15]. A quality of service competitive with the automobile mode can convince a considerable portion of users to leave their private cars at home and use public transit for their trips in the network. A competitive transit system can improve user mobility and reduce emissions from circulating vehicles by decreasing the number of circulating vehicles and increasing average speed of traffic flow. However, the share taken by a transit system from network travel demand largely depends on the quality of service it offers to users. Meanwhile, improvement in service quality may entail a significant rise in operating cost of a system; therefore, it is essential to strike a balance between operating cost and service quality by minimizing social, economic, and environmental costs associated with design of sustainable transit system. Sustainable transit systems are structures that provide the mobility that society needs without consuming the non-human world at an unsustainable rate. The challenge of developing such systems is closely related to the challenges of developing new energy systems and agricultural practices [1]–[3], [6], [10], [13], [16]–[23]

When it comes to creating sustainable transit systems, a lot of people don't think as much about the steps that need to happen right now, as they think about some vague future time when we'll magically have high speed trains and flying cars that solve all of our problems. The truth is that right now, today, is the time when we can make changes to our transit infrastructure that will last for generations. By making those changes now while

technology and transportation paradigms are in flux, we can choose a direction that is optimized for the long term, rather than one based on old ideas and tech. Sustainable development is the key to ensuring that future generations have an intact, healthy planet. And if we are to achieve that, we need to find a way to eliminate our dependence on oil and fossil fuels. Mass transit systems can be the solution. Mass transit systems can provide alternatives not only to millions of people but they can also bring down your daily expenses by means of reduced expenses on gas and maintenance [1], [8], [9], [12], [15], [19], [24]–[27]. Figure 1 shows sustainable transportation development classifications.

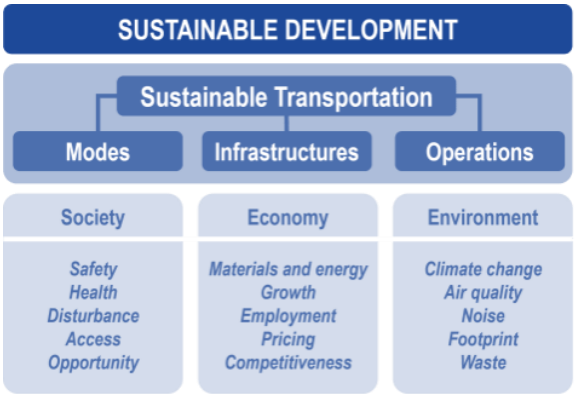

Fig. 1: Sustainable transportation development.

Transit systems are the circulatory system of a city. Most cities were structured to rely heavily on personal transportation. One way automobiles achieve this is by creating a direct route straight through town, connecting the suburbs right into downtown business districts. Because all traffic is forced to go through certain points in the city, local businesses and entertainment are concentrated there too [2], [12], [13], [24], [25], [28]–[39]. Figure 2 shows the criteria for sustainable transit system. Prioritizing sustainable transit system in city has been shown in Fig. 3.

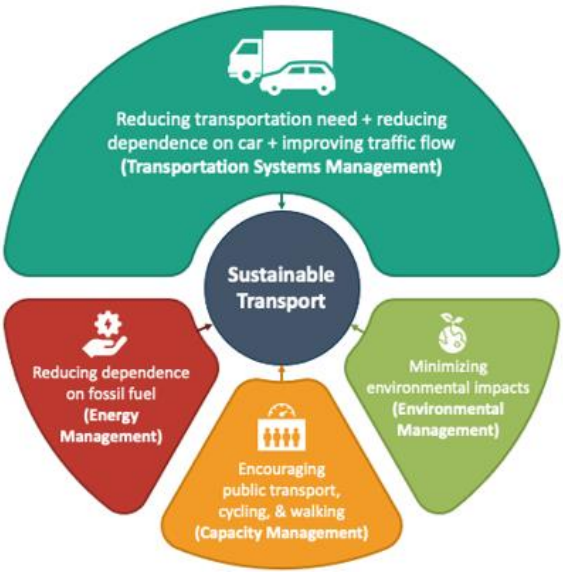

Fig. 2: Criteria for sustainable transit system.

2. Recent developments in mass transit

The new technology has been developed by the transportation industry to provide a comfortable and safe ride for passengers. The development of this technology has helped in reducing the cost of transportation and improving the efficiency of the system. The technology also helps in improving the safety standards of the public

transportation system [2], [3], [40]–[42][17]. There are several advantages of using this type of technology over other forms of public transportation systems. These include:

- It is eco-friendly because it reduces carbon emissions and noise pollution.
- It has reduced repair costs for vehicles and infrastructure due to its modular design which makes it easy for maintenance departments to access parts easily without having to replace entire components or entire systems if only one part fails or needs replacing then instead of replacing everything at once, it can be replaced as needed instead of doing so all at once which saves time and money on repairs/replacement costs which saves time and money on repairs/replacement costs

The transportation sector is one of the most important parts of modern life, and it has been undergoing a rapid transformation over the past few decades. The development of new types of mass transport systems has led to new ideas about how cities can be designed, and this has had a major impact on how people live and work. The first step in transitioning to a sustainable mode of transport is to reduce the amount of fuel used by vehicles. This can be done by using cleaner fuels such as natural gas, or hybrid engines fueled by both electricity and diesel. Additionally, there should be incentives for drivers who choose to use public transport or carpooling instead of their own car. Another way to reduce emissions from vehicles is through better urban planning practices that encourage people to walk or bike instead of driving everywhere they need to go. In addition, infrastructure such as sidewalks should be built around buildings so that pedestrians do not have to walk on roads that are prone to flooding during heavy rains due to inadequate drainage systems installed by developers decades ago.

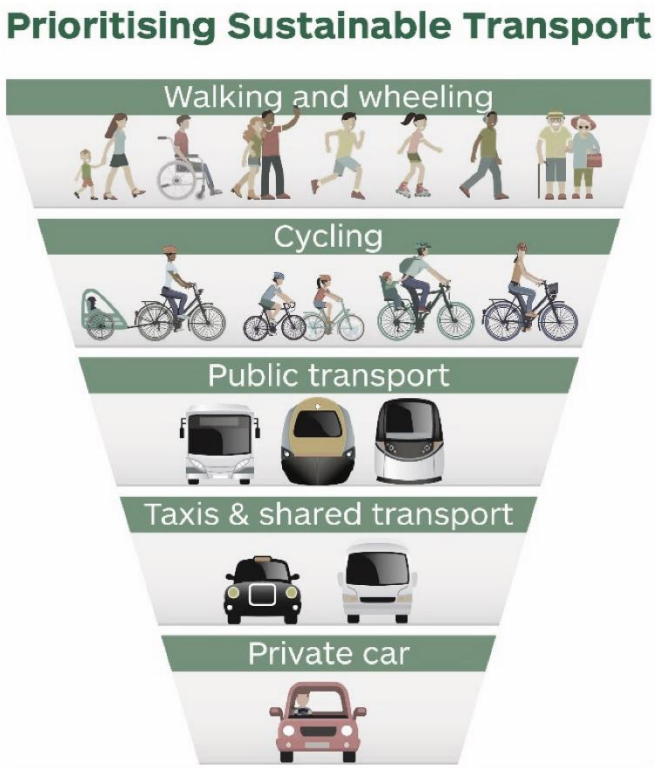

Fig. 3: Prioritizing sustainable transit system in city

In recent years, mass transport has seen a massive increase in growth. With this growth, cities have been able to expand their transportation systems to meet the needs of their residents. One of the most popular methods for mass transport is urban rail and metro train systems. Urban rail systems are made up of several different types of trains that move people around the city at speeds ranging from 30 to 150 miles per hour (mph). They allow riders to travel within city limits quickly and efficiently while also providing a safe environment for commuters who may be nervous about riding on public transportation.

Metro trains are another type of mass transit that has seen incredible growth over the past few decades. Metro trains run between stations throughout a city and can travel up to 60 miles per hour (mph). Metro trains usually consist of two sections: an upper section that travels above ground level and a lower section that runs below ground level. Additionally, there are also smaller sections called "tiles" that connect between certain stations

or lines during rush hour traffic jams when there is high demand for service at one location but not at another location nearby due to crowding on other lines causing delays in service. A recent study has been conducted to identify the most sustainable mass transport systems in the world. The results of this study were published in a scientific journal, and it was found that the use of electric buses is more sustainable than any other form of transport such as metros, trains, boats or airplanes. The authors also stated that if you want to reduce your carbon footprint by using electric buses then this should be done on a large scale because they are more efficient than other forms of transport such as metros and trains.

3. Types of urban transport systems

Urban transport systems are all about the infrastructure. The types of urban transport systems include:

- Public transport systems: These are transportation services that are operated by public authorities. They generally function as a monopoly, but not all public authorities operate public transport services. Examples of these include buses, trains and subways.
- Private transports: These are privately-owned vehicles such as taxis or Uber ridesharing. They often offer passengers more flexibility than public transport systems because they can pick up people who don't live near their destination.
- Commuter rail: Commuter rail is a form of mass transit that runs on tracks at grade with frequent stops and requiring few or no grade crossings. It's typically used in areas with dense populations where there isn't enough room for an elevated system or if there's a high demand for transit service without having to go underground.
- Light rail: Light rail is a form of mass transit which uses electric trains or diesel multiple units (DMUs) that can run in both directions on separate tracks at street level (e.g., streetcars). Light rail has been growing in popularity because it requires less space than other forms of mass transit like bus lanes, making it easier for cities to accommodate them within their transportation networks

In another way, there are three main types of urban transport systems:

- Fixed-route transit: This is the most common type of public transit system. It provides a fixed schedule of service that travels on a specific route, using fixed stops at each stop. Fixed-route transit systems are typically operated by government agencies or other organizations with significant financial resources and control over the roads.
- Mobility services: Mobility services are vehicles that are not used for moving people; they're used to transport goods or materials. Mobility services may also be called "light rail," "rapid rail," "trains," "light rail trains" or "rapid trams" depending on the country where they're being used. In some countries and cities, mobility services are known as "trams."
- Fixed-route bus service: Fixed-route buses are part of the public transportation system in some cities or countries but don't follow any particular route; instead, they stop at predetermined locations at each stop along their routes. Fixed-route buses provide frequent service during peak hours, but do not provide regular service throughout their routes.

Also, some researcher classify as following way. These include both private and public systems, as well as several hybrid models that combine elements from both.

- Private Transport Systems

Private transport systems are those that operate independently from a city's public transport network. They may be privately owned, or they may use an operator who is paid to offer the service.

- Public Transport Systems

Public transport systems are those that are operated by authorities rather than private companies. Public transport systems can either be run by government bodies or by the municipality itself (such as municipal buses). They often have a fixed route, stop at specific locations on the route, and require payment for entry into the system (though they may be free in some cases).

4. Metro systems

Metro systems use a combination of trains, metro buses, trams, trolleybuses, and other vehicles to provide service to passengers in urban areas[1], [2], [43]. The system is mainly used for long distance travel within cities and for some suburban travel. Metro systems may also take part in intercity transportations as well as being used as feeder networks for long distance trains or airports. Metro systems have several advantages over other types of public transportation. Metro systems are more reliable than bus or rail services because they run at comparable frequencies during peak hours and off-peak hours, thus providing a similar level of service throughout the day. Metro systems also have higher capacity than other types of public transportation. The average passenger load per train or bus is approximately 250 passengers; however, this number can increase when using multiple trains or buses at once due to faster speeds and fewer stops between transfers (higher frequency). Metro operators have to face many challenges in providing safe and reliable services while keeping fares low. Some problems faced by metro operators include the lack of accessibility to some areas due to the geographical layout of cities; lack of adequate parking spaces for vehicles; limited space for expansion; high maintenance cost (maintenance costs depend on the number of vehicles operating on a daily basis); low availability of routes (due to population growth); high cost per kilometer travelled by commuters; lack of sufficient funds allocated for maintenance works related to infrastructure development works. Metro systems are typically built in densely populated areas with a high demand for transit. They are designed to serve commuters who live within walking distance from the stations, but they can also be used by travelers who arrive at the station by other means of transportation. Metro systems vary in design depending on the region they serve and their purpose, but they all share some common features. These include:

- -An underground tunnel system with direct connections between stations and surface routes;
- -A wide range of train types including light rail vehicles (LRTs), heavy rail lines and subways;
- -Rapid transit stations with ticketing machines and ticket validation machines;
- -Security measures including guards at entrances/exits, security cameras and closed circuit television (CCTV);
- -A fare collection system that allows passengers to pay fares before boarding trains;
- -Information screens showing real-time information about train arrival times or service changes;

5. Light Rail Transit (LRT)

Light Rail Transit (LRT) systems are a form of public transit that uses vehicles to transport people on fixed rails[4]. The first LRT system was opened in 1981 in Salt Lake City, Utah, and since then there have been over 2,000 systems operating worldwide. LRT systems use trains that are longer and wider than those used on conventional railways, which make them easier to navigate and speed up passenger travel times. They are typically powered by electricity, though they may also be powered by diesel-fueled locomotives in some areas. A typical LRT train has fewer stops than a conventional train because it travels faster and requires fewer personnel at stations. As such, LRTs tend to attract fewer passengers than conventional trains and cost more to operate over their lifetime. Light Rail Transit (LRT) systems are a type of mass transit that uses a rail system to carry passengers. They are often referred to as "streetcars" or "trams", although they are more closely related to light rail. LRT differs from traditional buses in that they have their own set of tracks on which they run. This allows them to get around traffic more easily and make more direct stops than buses do, which makes them popular with riders who prefer convenience over speed.

In addition to being able to move faster than traditional bus systems, LRT systems can carry more passengers than buses with fewer stops and less time spent waiting for other buses along the route. This makes them very popular in cities where there's heavy traffic congestion or limited parking space available for cars. Light Rail Transit systems are a new form of transportation that uses street cars to transport passengers on the surface of streets. These systems offer a high level of passenger comfort and reliability, as well as reduced noise levels, less pollution, and more space per person. The trains can be powered by electricity or diesel engines, though they

are most commonly powered by electricity. The systems are also known for their speed - up to 160 km/h (100 mph).

6. Bus rapid transit BRT

Bus rapid transit (BRT) is a type of bus transit that provides faster and more reliable service than typical bus service by improving the reliability and speed of buses, which can bypass traffic congestion[1], [10], [36], [44]. The main advantage of BRT is that it allows for greater passenger capacity compared to other modes of transport. It also reduces travel time and increases sustainability. While there are many different BRT systems in use around the world, they all share these advantages. It is important to note that while BRT can be used by any kind of vehicle, it's most commonly associated with buses due to their large size and ability to carry more passengers than other forms of mass transit. Bus rapid transit (BRT) is a new type of public transit that uses dedicated lanes and other features to move people more efficiently. It can help reduce traffic congestion, improve environmental quality, and make public transportation more accessible. The first BRT system in the U.S., Bay Area Rapid Transit (BART), began operation in 1971 and now serves more than 400,000 passengers per day. The system has been so successful that it has inspired many cities around the world to create their own versions of BRT systems. Bus rapid transit (BRT) is a type of public transportation that uses dedicated lanes or exclusive rights-of-way for buses only, allowing them to bypass traditional traffic lights and merge with traffic. It is typically more comfortable and faster than other forms of public transportation, and it has the ability to carry significantly more riders per trip than other forms of public transportation. BRT systems have several advantages over other forms of transportation: they are cheaper to build and operate, they are more environmentally friendly because they use fewer cars than other modes, they provide better access for people with disabilities, and they can be used by many more people at once. The first BRT system was created in Bogota, Colombia in 1994; since then, there have been over 700 BRT systems worldwide. BRT is a type of public transportation that offers faster, more frequent service than traditional bus systems. BRT uses a dedicated lane and rapid transit stations to allow passengers to get from point A to point B faster than they would by taking the bus on regular streets. BRT can increase ridership because it allows more people to take advantage of the system's benefits as well as save them money on their commute.

7. Cable Cars

Cable cars are an innovative urban transportation system that uses a cable to haul people and goods up and down hills[23], [45]. The first cable car was invented by George Steers in 1852, when he connected two adjacent hills in San Francisco by using a rope to haul people and freight between them. Cable cars were used extensively in Europe for many years before they were introduced in North America. The first successful system was built in San Francisco in 1870 and still operates today. Cable cars are an innovative urban transportation system that exists in many cities around the world, including San Francisco and New York City[2], [24], [27]. Cable cars are a form of cable transportation that is similar to a streetcar or funicular in that they use a cable to pull vehicles up from one level to another. However, unlike other forms of cable transport systems, they don't use tracks or rails—they are suspended between two towers on either side of the city.

The passengers sit in a cabin and are transported to their destination by pulling against the cable with their feet. The cables move at walking speeds and can carry as many as eight people per car depending on how many cars are running at any given time. The cabins are designed so that they can be used by both people who have mobility issues and those who don't—it's very easy for someone with limited mobility to get on board without help from others. Cable cars were first developed in 1873 by John Wright Jr., who started working on his idea for what would become known as an aerial tramway system after watching his brother-in-law ride in an elevator at the World's Columbian Exposition (Chicago World's Fair) in 1893). Cable cars are an innovative urban transportation system. They were invented in the late 1800s and were used extensively in the San Francisco Bay Area until the 1970s. The cable car is a form of fixed-grip rail transport that uses a long, heavy cable running under the street to haul cars up steep inclines. The advantage of this system is that it requires no expensive or complicated infrastructure: it can be built on existing roads, or even along a steep hillside. Cable cars can also operate in areas where traffic is not allowed to drive; they are especially useful for getting around congested areas in cities like San Francisco, where there are too many vehicles on the road for them all to pass through at once!

Cable cars have been popular in their time because they make urban travel easier for people who live or work near steep hills—and also for tourists who want to experience something different about their trip. They're

also seen as a way to reduce pollution from automobile exhaust fumes by reducing carbon dioxide emissions from moving vehicles. The cable car is an innovative urban transportation system that was first used in the late 19th century. It was first used in California and later in France, Germany, Switzerland, and the United States. Cable cars are an interesting way to get around an urban area because they are easy to operate and are not limited by weather conditions. They also have a high capacity for traffic control because they can carry up to 300 people at a time. The cable car was designed with several advantages over other forms of transportation such as buses or cars. They can travel at speeds of up to 30 miles per hour making them more efficient than buses which only go about 15 miles per hour. The cable car also has less noise pollution than other forms of transportation because it does not make any noise when traveling up or down hills like buses or cars do.

8. Optimal design of sustainable transit systems in congested urban networks

This is the first study to consider the optimal design of transit systems in highly congested urban networks. The research questions are threefold: How should the network be designed to minimize total congestion costs? What kinds of complementary resources (reduced vehicle-kilometers, reduced number of vehicles, additional road capacity) are required to meet these requirements? What are the cost implications of these resource requirements? Sustainable urban transit networks are an important aspect of city planning. Agreeably, the optimal design of such systems depends on population and employment densities, as well as commuting patterns between these two parameters. However, a small number of decision vectors interfaces these parameters with qualitative variables such as land use and development policies.

Despite increases in fuel taxes, traffic congestion is still a major problem on many urban roads. One reason is the prevailing design choice of cities to have a uniform vehicular speed, leading to sub-optimal trajectories and congested intersections. In this paper we use a multi-agent simulation model of vehicle control and reconfigurable intersection bypasses to design a network whose intersections never suffer from congestion. Furthermore we compare the performance of different multi-agent strategies of individual vehicles and find that an optimal choice can greatly diminished travel times, while additional automatic intersection bypasses not only alleviate jams, but also drastically improves performance. Cities are the pillars of modern society. They unite a population into an aggregated economy, and multiply that economic productivity through population density. Without cities, most economic activity would be impossible or prohibitively expensive.

Mahyar Amirgholy et al. [17] reported a continuum approximation model that, by minimizing a linear combination, optimizes the network topology (line spacing and stop spacing) and the operational parameters of the transit system (headway and fare). MarwenElkamel et al.[46] have discussed the integrated simulation and optimization on transportation. The results confirm the effectiveness and robustness of the proposed PBUC methodology. Suman Majumder et al. [47] studied the E-bus-based transit system. It serves to increase the use of renewable energy sources while reducing harmful emissions. The study in this paper takes into account various pairings of these sources. The analysis's findings show that, given the state of the economy's costs, an electric-based transportation system's capital cost is more than its operational cost. Additionally, the usage of renewable energy sources can lower the lifespan (10-year) cost of an electric-based transit system. Further, Zhaodong Huang et al.[48] discusses the schedules of wheel inspections that fulfill the safety requirements for long-term train operation, a Bayesian model was built. Wheel reprofiling appears to follow a Weibull distribution, according to the case study, which collected and evaluated historical wheel inspection data from a real-world URT line.

9. Conclusions

In urban areas, the need for alternative modes of transport that are socially beneficial, economically justifiable, and environmentally friendly has grown tremendously. To meet this demand, a transit system can play a prominent role in improving the sustainability of transportation by alleviating the unpleasant impacts of congestion across the network. It provides a quality of service competitive with the automobile mode that convinces a considerable portion of users to leave their private cars at home and use public transit for their trips in the network. A competitive transit system can improve user mobility and reduce air pollution in the network by decreasing circulating vehicles and increasing average speed of traffic flow. However, the share taken by a transit system from network travel demand largely depends on its quality of service. Improvement in this service quality may entail significant rise in its operating cost due to costs related to capital investment required in building

new bus stops or extending existing ones or upgrading infrastructure such as roads or tracks etcetera which may not be feasible at all times depending upon availability of funds etcetera. Therefore, it is important to strike balance between operating cost and service quality by minimizing social, economic and environmental costs involved in implementing an efficient and sustainable transit system design.

References

[1] K. Sivakumaran, Y. Li, M. Cassidy, and S. Madanat, "Access and the choice of transit technology," *Transp. Res. Part A Policy Pract.*, vol. 59, pp. 204–221, 2014.

[2] Y. Yu, R. B. Machemehl, and C. Xie, "Demand-responsive transit circulator service network design," *Transp. Res. Part E Logist. Transp. Rev.*, vol. 76, pp. 160–175, Apr. 2015.

[3] S. Saidi, S. C. Wirasinghe, and L. Kattan, "Long-term planning for ring-radial urban rail transit networks," *Transp. Res. Part B Methodol.*, vol. 86, pp. 128–146, Apr. 2016.

[4] H. T. M. Nguyen, A. H. F. Chow, and C. shuo Ying, "Pareto routing and scheduling of dynamic urban rail transit services with multi-objective cross entropy method," *Transp. Res. Part E Logist. Transp. Rev.*, vol. 156, Dec. 2021.

[5] J. A. Laval and F. Castrillón, "Stochastic Approximations for the Macroscopic Fundamental Diagram of Urban Networks," *Transp. Res. Procedia*, vol. 7, pp. 615–630, 2015.

[6] J. Haddad and N. Geroliminis, "On the stability of traffic perimeter control in two-region urban cities," *Transp. Res. Part B Methodol.*, vol. 46, no. 9, pp. 1159–1176, 2012.

[7] C. F. Daganzo, "Urban gridlock: Macroscopic modeling and mitigation approaches," *Transp. Res. Part B Methodol.*, vol. 41, no. 1, pp. 49–62, 2007.

[8] L. Leclercq, N. Chiabaut, and B. Trinquier, "Macroscopic Fundamental Diagrams: A cross-comparison of estimation methods," *Transp. Res. Part B Methodol.*, vol. 62, pp. 1–12, 2014.

[9] S. I. Guler and M. J. Cassidy, "Strategies for sharing bottleneck capacity among buses and cars," *Transp. Res. Part B Methodol.*, vol. 46, no. 10, pp. 1334–1345, 2012.

[10] C. F. Daganzo, "Structure of competitive transit networks," *Transp. Res. Part B Methodol.*, vol. 44, no. 4, pp. 434–446, 2010.

[11] R. Arnott, A. de Palma, and R. Lindsey, "Route choice with heterogeneous drivers and group-specific congestion costs," *Reg. Sci. Urban Econ.*, vol. 22, no. 1, pp. 71–102, 1992.

[12] E. Christofa and A. Skabardonis, "Traffic signal optimization with application of transit signal priority to an isolated intersection," *Transp. Res. Rec.*, no. 2259, pp. 192–201, Dec. 2011.

[13] M. Pternea, K. Kepaptsoglou, and M. G. Karlaftis, "Sustainable urban transit network design," *Transp. Res. Part A Policy Pract.*, vol. 77, pp. 276–291, Jul. 2015.

[14] E. J. Gonzales, N. Geroliminis, M. J. Cassidy, and C. F. Daganzo, "On the allocation of city space to multiple transport modes," *Transp. Plan. Technol.*, vol. 33, no. 8, pp. 643–656, Dec. 2010.

[15] M. Amirgholy, M. Shahabi, and H. O. Gao, "Optimal design of sustainable transit systems in congested urban networks: A macroscopic approach," *Transp. Res. Part E Logist. Transp. Rev.*, vol. 103, pp. 261–285, 2017.

[16] M. Goerigk and M. Schmidt, "Line planning with user-optimal route choice," *Eur. J. Oper. Res.*, vol. 259, no. 2, pp. 424–436, Jun. 2017.

[17] M. Amirgholy, M. Shahabi, and H. O. Gao, "Optimal design of sustainable transit systems in congested urban networks: A macroscopic approach," *Transp. Res. Part E Logist. Transp. Rev.*, vol. 103, pp. 261–285, Jul. 2017.

[18] S. I. Chien, L. N. Spasovic, S. S. Elefsiniotis, and R. S. Chhonkar, "Evaluation of feeder bus systems with probabilistic time-varying demands and nonadditive time costs," *Transp. Res. Rec.*, no. 1760, pp. 47–55, 2001.

[19] C. F. Daganzo, V. V. Gayah, and E. J. Gonzales, "The potential of parsimonious models for understanding large scale transportation systems and answering big picture questions," *EURO J. Transp. Logist.*, vol. 1, no. 1–2, pp. 47–65, Jun. 2012.

[20] S. F. A. Batista, G. Tilg, and M. Menéndez, "Exploring the potential of aggregated traffic models for estimating network-wide emissions," *Transp. Res. Part D Transp. Environ.*, vol. 109, Aug. 2022.

[21] J. Haddad and A. Shraiber, "Robust perimeter control design for an urban region," *Transp. Res. Part B Methodol.*, vol. 68, pp. 315–332, 2014.

[22] J. Haddad, M. Ramezani, and N. Geroliminis, "Cooperative traffic control of a mixed network with two urban regions and a freeway," *Transp. Res. Part B Methodol.*, vol. 54, pp. 17–36, 2013.

[23] E. J. Gonzales and C. F. Daganzo, "The evening commute with cars and transit: Duality results and user equilibrium for the combined morning and evening peaks," *Transp. Res. Part B Methodol.*, vol. 57, pp. 286–299, 2013.

[24] E. J. Gonzales and C. F. Daganzo, "Morning commute with competing modes and distributed demand: User equilibrium, system optimum, and pricing," *Transp. Res. Part B Methodol.*, vol. 46, no. 10, pp. 1519–1534, 2012.

[25] J. K. Affum, A. L. Brown, and Y. C. Chan, "Integrating air pollution modelling with scenario testing in road transport planning: The TRAEMS approach," *Sci. Total Environ.*, vol. 312, no. 1–3, pp. 1–14, Aug. 2003.

[26] M. Amirgholy, H. Rezaeestakhruie, and H. Poorzahedy, "Multi-objective cordon price design to control long run adverse traffic effects in large urban areas," *NETNOMICS Econ. Res. Electron. Netw.*, vol. 16, no. 1–2, pp. 1–52, Aug. 2015.

[27] H. Sbayti, M. El-Fadel, and I. Kaysi, "Effect of roadway network aggregation levels on modeling of traffic-induced emission inventories in Beirut," *Transp. Res. Part D Transp. Environ.*, vol. 7, no. 3, pp. 163–173, 2002.

[28] M. Fosgerau and K. A. Small, "Hypercongestion in downtown metropolis," *J. Urban Econ.*, vol. 76, no. 1, pp. 122–134, Jul. 2013.

[29] K. S. Nesamani, L. Chu, M. G. McNally, and R. Jayakrishnan, "Estimation of vehicular emissions by capturing traffic variations," *Atmos. Environ.*, vol. 41, no. 14, pp. 2996–3008, May 2007.

[30] N. Geroliminis and C. F. Daganzo, "Existence of urban-scale macroscopic fundamental diagrams: Some experimental findings," *Transp. Res. Part B Methodol.*, vol. 42, no. 9, pp. 759–770, 2008.

[31] C. F. Daganzo and N. Geroliminis, "An analytical approximation for the macroscopic fundamental diagram of urban traffic," *Transp. Res. Part B Methodol.*, vol. 42, no. 9, pp. 771–781, 2008.

[32] M. Ramezani, J. Haddad, and N. Geroliminis, "Dynamics of heterogeneity in urban networks: Aggregated traffic modeling and hierarchical control," *Transp. Res. Part B Methodol.*, vol. 74, pp. 1–19, Apr. 2015.

[33] I. Dakic, L. Leclercq, and M. Menendez, "On the optimization of the bus network design: An analytical approach based on the three-dimensional macroscopic fundamental diagram," *Transp. Res. Part B Methodol.*, vol. 149, pp. 393–417, Jul. 2021.

[34] Y. Ji and N. Geroliminis, "On the spatial partitioning of urban transportation networks," *Transp. Res. Part B Methodol.*, vol. 46, no. 10, pp. 1639–1656, 2012.

[35] L. J. Tian, H. Yang, and H. J. Huang, "Tradable credit schemes for managing bottleneck congestion and modal split with heterogeneous users," *Transp. Res. Part E Logist. Transp. Rev.*, vol. 54, pp. 1–13, 2013.

[36] Y. Yang, X. Jiang, Y. Yan, T. Liu, and Y. Jiang, "Joint optimization of bimodal transit networks in a heterogeneous environment considering vehicle emissions," *J. Clean. Prod.*, vol. 373, p. 133859, Nov. 2022.

[37] J. Durán-Micco and P. Vansteenwegen, "Transit network design considering link capacities," *Transp. Policy*, vol. 127, pp. 148–157, Oct. 2022.

[38] N. Geroliminis and J. Sun, "Properties of a well-defined macroscopic fundamental diagram for urban traffic," *Transp. Res. Part B Methodol.*, vol. 45, no. 3, pp. 605–617, 2011.

[39] R. Shabanpour, M. Javanmardi, M. Fasihozaman, M. Miralinaghi, and A. Mohammadian, "Investigating the applicability of ADAPTS activity-based model in air quality analysis," *Travel Behav. Soc.*, vol. 12, pp. 130–140, Jul. 2018.

[40] Y. Liu, Y. M. Nie, and J. Hall, "A semi-analytical approach for solving the bottleneck model with general user heterogeneity," *Transp. Res. Part B Methodol.*, vol. 71, pp. 56–70, Jan. 2015.

[41] C. F. Daganzo, "System optimum and pricing for the day-long commute with distributed demand, autos and transit," *Transp. Res. Part B Methodol.*, vol. 55, pp. 98–117, 2013.

[42] W. X. Wu and H. J. Huang, "An ordinary differential equation formulation of the bottleneck model with user heterogeneity," *Transp. Res. Part B Methodol.*, vol. 81, no. P1, pp. 34–58, Nov. 2015.

[43] K. Ozakgul, F. Piroglu, and O. Caglayan, "An experimental investigation on flash butt welded rails," *Eng. Fail. Anal.*, vol. 57, pp. 21–30, 2015.

[44] M. Estrada, M. Roca-Riu, H. Badia, F. Robusté, and C. F. Daganzo, "Design and implementation of efficient transit networks: Procedure, case study and validity test," *Transp. Res. Part A Policy Pract.*, vol. 45, no. 9, pp. 935–950, 2011.

[45] L. Olsson, "Motor vehicle air pollution control in Sweden," *Sci. Total Environ.*, vol. 146–147, no. C, pp. 27–34, May 1994.

[46] M. Elkamel, A. Ahmadian, A. Diabat, and Q. P. Zheng, "Stochastic optimization for price-based unit commitment in renewable energy-based personal rapid transit systems in sustainable smart cities," *Sustain. Cities Soc.*, vol. 65, p. 102618, Feb. 2021.

[47] S. Majumder, K. De, P. Kumar, B. Sengupta, and P. K. Biswas, "Techno-commercial analysis of sustainable E-bus-based public transit systems: An Indian case study," *Renew. Sustain. Energy Rev.*, vol. 144, p. 111033, Jul. 2021.

[48] Z. Huang, S. Chien, W. Zhu, and P. Zheng, "Scheduling wheel inspection for sustainable urban rail transit operation: A Bayesian approach," *Phys. A Stat. Mech. its Appl.*, vol. 586, p. 126454, Jan. 2022.