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ORIGINAL

Urban Mobility and Social Justice: public transport in the Guadalajara metropolitan area, Mexico

Movilidad Urbana y Justicia Social: transporte público en la metrópoli de Guadalajara, México

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ABSTRACT

The study analysed public transport as a strategic public policy, fundamental to sustainable urban development. Academic sources from 1960 to 2020 were reviewed, focusing on economic, social, technological and urban aspects. The analysis showed that the efficiency of the system depends on factors such as ownership structure, fare policy and user perception. The research addressed operating revenues and costs, highlighting that fare setting should consider social equity criteria in addition to technical and financial criteria. The relationship between service quality and profitability was also studied, concluding that certain variables, such as safety, improved profitability, while others, such as negative user perception, decreased it. The social value of time was presented as key to assessing the efficiency and equity of the system, highlighting the need to reduce waiting and travel times. Financing and subsidies were identified as essential mechanisms for ensuring financial sustainability without compromising the social function of transport. The implementation of prepaid smart card systems was positively evaluated for their efficiency and ability to generate useful data for planning. Finally, it was emphasised that the sustainability of public transport depends on its integration with urban policies aimed at traffic, electrification, densification and territorial equity. It was concluded that a strategic vision, based on evidence, citizen participation and intersectoral cooperation, is crucial for building more inclusive and liveable cities.

Keywords: Mobility; Sustainability; Technical Tariff; Profitability; Equity.

RESUMEN

El estudio analizó el transporte público como una política pública estratégica, fundamental para el desarrollo urbano sostenible. Se revisaron fuentes académicas desde 1960 hasta 2020, centradas en aspectos económicos, sociales, tecnológicos y urbanísticos. El análisis mostró que la eficiencia del sistema depende de factores como la estructura de propiedad, la política tarifaria y la percepción del usuario. La investigación abordó los ingresos y costos operativos, destacando que la fijación de tarifas debe considerar criterios de equidad social, además de los técnicos y financieros. También se estudió la relación entre calidad del servicio y rentabilidad, concluyéndose que ciertas variables, como la seguridad, mejoraron la rentabilidad, mientras que otras, como la percepción negativa del usuario, la disminuyeron. El valor social del tiempo se presentó como clave para evaluar la eficiencia y la equidad del sistema, evidenciando la necesidad de reducir tiempos de espera y traslado. El financiamiento y los subsidios fueron identificados como mecanismos esenciales para asegurar la sostenibilidad financiera sin comprometer la función social del transporte. La implementación de sistemas de prepago con tarjetas inteligentes se valoró positivamente por su eficiencia y capacidad de generar datos útiles para la planificación. Finalmente, se subrayó que la sostenibilidad del transporte público depende de su integración con políticas urbanas orientadas al tránsito, la electrificación, la densificación y la equidad territorial. Se concluyó que una visión estratégica, basada en evidencia, participación ciudadana y cooperación intersectorial, es crucial para construir ciudades más inclusivas y habitables.

Palabras clave: Movilidad; Sostenibilidad; Tarifa Técnica; Rentabilidad; Equidad.

INTRODUCTION

In the context of contemporary urban dynamics, public transport has become an essential component for ensuring mobility, social equity, environmental sustainability, and economic efficiency in cities. Growing urbanization, population growth, and the expansion of metropolitan areas have highlighted the need for efficient, accessible, and sustainable public transport systems capable of responding to the demands of an increasingly diverse and demanding citizenry. Public transportation not only facilitates access to employment, educational, cultural, and health opportunities, but also plays a structural role in land use planning and the coordination of urban development policies.[1,2,3,4,5,6,7,8]

This study offers a comprehensive analysis of the public transport system, addressing key dimensions such as operating revenues and costs, service quality and profitability, the social value of time, financing mechanisms and subsidies, the implementation of prepaid systems, and challenges in terms of sustainability. Through an exhaustive review of specialized literature, including academic studies, theses, technical manuals, and conceptual frameworks developed between the 1960s and 2020s, this study seeks to understand how different theoretical and empirical approaches have addressed the structural and cyclical problems facing public transportation, with a special emphasis on Latin American urban contexts such as Guadalajara, Mexico.[9,10,11,12,13,14,15]

This analysis brings together economic, social, technological, and urban planning perspectives on public transportation, highlighting the need for an interdisciplinary approach to its evaluation and improvement. Determining factors that influence the efficiency of the system are identified, such as ownership structure, operational management, fare policy, user perception, urban planning, and the integration of new technologies. Likewise, the importance of establishing fair and sustainable technical fares is reflected upon, taking into account not only the operating costs of the service, but also criteria of social justice, territorial equity, and institutional transparency.[16,17,18,19,20,21,22,23]

Finally, this work seeks to provide a framework for decision-making in urban mobility public policies, raising the need to rethink traditional transport models and move towards more inclusive, resilient, and integrated schemes. Recognizing the strategic value of public transport in building more equitable and livable cities, the report underscores the urgency of designing and implementing structural solutions based on evidence, intersectoral collaboration, and citizen participation.[24,25,26,27,28,29,30]

DEVELOPMENT

Analysis of public transport revenues and costs

The analysis of public transport revenues and costs has been addressed by several relevant studies in the academic field. For example, Estrada et al.[1] detail the increase in public transport fares in different areas of Jalisco, generating controversy around their technical and social justification.

Contrasting these perspectives, Meyer[2] emphasizes that economic analysis of transportation goes beyond supply and demand, advocating for an interdisciplinary approach that considers social and environmental impacts. This broad view is also supported by a stury who stresses that understanding the economics of transportation is essential to addressing issues that affect both the economy and society.

Baumol et al.[3] conclude that urban public bus transport can be provided by the public or private sector, and that the decision depends on the relative costs of both options. The elimination of resources and assets to provide urban bus transport is analyzed, and it is concluded that it is possible for the public and private sectors to work together to provide the service.

In addition, Estrada et al.[1] highlight the oligopolistic structure of the public transport market in the ZMG, where the lack of competition could directly affect the quality of the service offered to users, showing concern about the lack of incentives to improve.

In turn, authors such as Hensher[4] propose solutions that include efficient management and appropriate public policies as means to improve the efficiency of urban public transport.

Highlights the importance of transport economics in the development of effective and sustainable transport policies. He also points out that transport economics is fundamental to understanding how transport systems work and how they affect the economy and society in general. He emphasizes that transport economics is a discipline that is constantly evolving due to technological advances and changing economic and social conditions.[31,32,33,34,35,36,37]

For Gihring et al.[5], the relationship between costs and production in public transport is complex and depends on several factors, such as the technology used, population density, and fleet size. They highlight the limitations of cost functions and propose new forms of analysis.

According to De Palma[6], urban transport systems are fundamental to the functioning of cities and have a major impact on the local and national economy. The author discusses the problems of congestion, demand for public transport, and the management of transport resources.

Ding et al.[7] conclude that economies of scale and public scope can be important for improving the efficiency of public transport, but that there are limits to their application due to the specific characteristics of each market. The need for proper management and adequate planning to take full advantage of these economies is highlighted.

In terms of operating costs, Oliva et al.[8] state that public transport operating costs depend on factors such as ownership structure, fleet age and condition, fare policy, payment system, and fixed and variable cost structure. The use of econometric models to analyze operating costs is proposed, and the need for proper management to improve efficiency is highlighted.

Thus, a study emphasize that cost-benefit analysis (CBA) is an essential tool for evaluating transportation projects, as it allows the costs and benefits of a project to be identified and its viability to be determined.

Finally, the need for a detailed analysis of public transport revenue and costs is supported by Estrada et al.[1] who suggest an exploratory approach to provide a clearer picture and relevant data to support informed decisions on public transport.[38,39,40,41,42]

Based on the above, we can conclude that the characterization of a technical, fair, and sustainable fare should not only consider the operating costs of public transport, but also socioeconomic aspects. It is essential to integrate economic and social analyses to establish fares that promote accessibility and equity, minimizing the impact on socioeconomically vulnerable groups.

The complexity of determining a fair and sustainable technical fare requires collaboration between various fields, such as economics, urban planning, transportation engineering, and social sciences. Interaction between these disciplines is crucial to consider economic, environmental, and social aspects in the formulation of equitable and sustainable fares.[43,44,45,46,47,48,49]

Transparency in the fare-setting process and active community participation are essential to ensure the legitimacy and acceptance of the established fares. The inclusion of public opinion and clear disclosure of the criteria used in fare determination strengthen trust and social support for the public transportation system.[50,51,52,53,54,55]

The characterization of a fair and sustainable technical fare is a dynamic process that requires continuous and adaptive monitoring. Constant monitoring of changes in operating costs, service demand, and socioeconomic conditions allows for timely fare adjustments to maintain fairness and sustainability over time.[56,57,58,59,60]

Quality and profitability in public transport

Many authors and experts in public transport have contributed research and publications on quality and profitability in the field.

In their work "The Urban Transportation Problem" Meyer et al.[2] highlight the need to address urban transportation problems, including congestion, pollution, and inefficiency, to improve the quality of life and economy in cities.

Cervero[9] analyzes how different cities around the world have addressed transportation problems and proposes solutions based on efficient public transportation planning and management.

In "A Very Public Solution: Transport in the Dispersed City" Mees[10], the author argues that it is possible to achieve high-quality public transport systems in dispersed cities through the implementation of appropriate policies and strategies.[61,62]

Another technical contribution in the areas of quality and profitability is the work "Urban Public Transportation Systems and Technology" which provides a detailed analysis of public transport technologies and systems, highlighting the importance of innovation and adaptation to the changing needs of cities.

Similarly, Hensher et al.[11] "Transport Strategy, Policy and Institutions" offers a comprehensive overview of transport policies and strategies, emphasizing the importance of collaboration between different actors and institutions to improve the quality and profitability of public transport.

On the other hand, Peñalosa et al.[12] in "Cities for All: Proposals for Enjoying Public Space" advocate the creation of inclusive and accessible public spaces, highlighting the need to invest in public transport and prioritize pedestrians and cyclists in urban design.

Kenworthy[13] in his work "An International Sourcebook of Automobile Dependence in Cities, 1960-1990" (An international reference book on car dependence in cities, 1960-1990), presents data and analysis on car dependence in cities, suggesting that greater investment in public transport could benefit communities and the environment.

In his book "Human Transit: How Clearer Thinking About Public Transit Can Enrich Our Communities and Our Lives," highlights how well-planned and managed public transportation can enrich urban life and improve people's quality of life.

Considering the thesis "Quality and Profitability in Public Transportation in Guadalajara," at the University of Guadalajara, his work states that in recent decades, and more acutely in recent years, public transportation in Guadalajara has faced strong criticism from both users and society in general, who cite poor service quality. For their part, the companies responsible for operating public transport in the city have stated on several occasions that an increase in the authorized fare is required to provide a better quality service, as the current fare is insufficient.[63,64,65]

A thesis conducts a quantitative economic analysis to understand the relationship between the quality of public transport and the profitability of the companies providing the service, as well as to determine whether the impact of quality on the profitability of the agents involved is positive or negative and to what extent.[66,67,68,69,70]

The main conclusion, after finding that there is a positive, albeit marginal, effect between some quality variables on profitability and that there are other quality variables that have a negative effect contrary to that expected is that passenger bus service is profitable in the short term, regardless of whether the level of quality offered is high or low. This is because public transportation is a basic necessity and there is a captive market with no substitute goods in the short term.[71,72,7,74,75,76]

In this regard, we can see that both the analysis by Estrada et al.[1] and the thesis reveal the importance of transport fares in both demand and supply, as well as their impact on users.

Similarly, in 2015, the manual entitled "Streetfight: Handbook for an Urban Revolution" proposed a revolutionary approach to urban design and transportation policy with the aim of creating more livable and sustainable cities.[77,78,79,80,81,82]

No.	Año	Autor(es)	Obra (Título)
1	1977	John R. Meyer, John F. Kain, y Martin Wohl	The Urban Transportation Problem (El problema del transporte urbano).
2	1983	Robert Cervero	The Transit Metropolis: A Global Inquiry (La metrópolis de tránsito: una investigación global).
3	1992	Paul Mees	A Very Public Solution: Transport in the Dispersed City (Una solución muy pública: transporte en la ciudad dispersa).
4	1998	Vukan R. Vuchic	Urban Public Transportation Systems and Technology (Sistemas y tecnologías de transporte público urbano).
5	2004	David Hensher y Kenneth Button	Handbook of Transport Strategy, Policy and Institutions (Manual de estrategia, política e instituciones de transporte).
6	2008	Enrique Peñalosa y Dario Hidalgo	Ciudades para todos: Propuestas para disfrutar el espacio público (Ciudades para todos: propuestas para disfrutar del espacio público).
7	2011	Jeffrey R. Kenworthy	An International Sourcebook of Automobile Dependence in Cities, 1960-1990 (Un libro de consulta internacional sobre la dependencia del automóvil en las ciudades, 1960-1990).
8	2012	Jarrett Walker	Human Transit: How Clearer Thinking About Public Transit Can Enrich Our Communities and Our Lives (Tránsito humano: cómo un pensamiento más claro sobre el transporte público puede enriquecer nuestras comunidades y nuestras vidas).
9	2014	Carlos Enrique Aceves Gonzáles	"Calidad y Rentabilidad en el Transporte Público de Guadalajara".
10	2015	Janette Sadik-Khan y Seth Solomonow	Streetfight: Handbook for an Urban Revolution (Streetfight: manual para una revolución urbana).
11	2018	Christof Spieler	Trains, Buses, People: An Opinionated Atlas of US Transit (Trenes, autobuses, personas: un atlas opinado del tránsito en los Estados Unidos).

Figure 1. Summary of the main authors on Public Transport Quality and Profitability 1977-2018

Finally, in "Trains, Buses, People: An Opinionated Atlas of US Transit," examines public transportation systems in the United States and offers recommendations for improving their quality and profitability, based on successful examples from both the United States and abroad.

In summary, the works mentioned above address various issues related to the quality and profitability of public transport from multiple perspectives. Some authors analyze urban transport problems and how they affect quality of life and the economy. Other studies focus on solutions to improve the efficiency and accessibility of public transport in sprawling cities through appropriate policies and strategies.[83,84,85,86,87,88]

In addition, aspects of car dependency in cities are discussed, along with how greater investment in public transport can benefit communities and the environment. The works also address the importance of creating inclusive public spaces and how urban design and transport policies can contribute to an urban revolution that improves people's lives.

Together, these publications provide a comprehensive overview of public transport quality and cost-effectiveness issues over time, offering solutions and strategies to address urban mobility challenges. These conclusions are essential for decision-makers in urban mobility, transport, and land use policy to understand and apply in their future projects and interventions.[89,90,91,92,93,94]

The findings of this research also reflect the importance of addressing public transport challenges to improve quality of life, sustainability, and efficiency in cities. They highlight the need for innovation, appropriate policies, and collaboration between different actors and institutions to achieve high-quality and cost-effective public transport systems. These conclusions also emphasize the importance of considering the needs of all public transport users and designing inclusive and accessible solutions.[95,96,97]

Furthermore, these works underscore how greater investment in public transport and prioritizing pedestrians and cyclists in urban design can contribute to reducing car dependency. This, in turn, can have positive effects on public health, the environment, and overall quality of life.[98,99]

Finally, the conclusions of these studies provide a solid basis for the planning and management of effective and sustainable public transport systems. They highlight the importance of addressing current and future urban transport challenges through the implementation of appropriate policies and strategies, innovation in technology and systems, and the promotion of inclusive and accessible public spaces.[100,101,102,103]

Public transport and the social value of time

In this section, we present some notable authors and their respective works that address issues related to the social value of time in public transport. These authors come from various disciplines, such as economics, urban planning, and sociology, and their works offer different perspectives on the subject.[104,105,106]

- John Douglas Hunt (economist and transport planner) - "Value of Time in Public Transport".[14] This work explores how the value of time affects the decisions of public transport users and how it can be used in the planning and evaluation of transport projects.
- David A. Hensher (transportation economist) - "Valuing Travel Time Savings in Public Transport".[15] Hensher addresses the issue of travel time valuation in public transportation, analyzing how individuals make travel decisions and how these decisions are affected by travel time and other factors.
- Eric J. Gonzales (transportation engineer) - "The Social Value of Time in Public Transit Systems".[16] Gonzales examines how public transportation policies can be designed to maximize the social value of users' time, taking into account the needs and priorities of different demographic groups.
- Jonas Eliasson (economist and transportation planner) - "The Value of Time in Public Transport: Time, Money, and the Importance of Travel Time Variability".[17] Eliasson analyzes how variability in travel time on public transportation affects users' perception of the value of time and how these changes can be used in the planning and evaluation of transportation projects.
- Karel Martens (transport planner and urbanist) - "Transport Justice: Designing Fair Transportation Systems".[18] In this book, Martens addresses the concept of justice in transportation and how it can be achieved through the equitable distribution of public transportation resources, including time.

It should be noted that the above table includes only a selection of authors and works that are relevant to this thesis, and is therefore not an exhaustive list of all authors and works that address issues related to the social value of time in public transport.

For Hunt[14], the value of time is an important factor in the decisions of public transport users. Research on the value of time can be useful for the planning and evaluation of public transport projects.

Hensher[15] states that individuals make travel decisions based on travel time and other factors, such as cost and comfort. The valuation of travel time in public transport is crucial to understanding and predicting user behavior, which helps in the planning and design of public transport systems.

No.	Autor	Obra	Año
1	John Douglas Hunt	Value of Time in Public Transport	2000
2	David A. Hensher	Valuing Travel Time Savings in Public Transport	2008
3	Eric J. Gonzales	The Social Value of Time in Public Transit Systems	2014
4	Jonas Eliasson	The Value of Time in Public Transport: Time, Money, and the Importance of Travel Time Variability	2016
5	Karel Martens	Transport Justice: Designing Fair Transportation Systems	2017

Figure 2. Summary of the main authors on Social Value of Time and Public Transportation 2000-2017

However, Gonzales[16] mentions that public transport policies can be designed to maximize the social value of users' time, considering the needs and priorities of different demographic groups. Investment in public transport infrastructure and services that reduce travel time can improve social well-being.

However, Eliasson[17] concludes that variability in travel time on public transport affects users' perception of the value of time. Public transport projects should consider reducing travel time variability as a key objective, which can improve user satisfaction and system efficiency.

Similarly, Martens[18] asserts that transport justice is a key aspect of achieving equitable and socially sustainable public transport systems. The equitable distribution of public transport resources, including time, is essential to ensuring that all members of society have access to economic and social opportunities.

These conclusions provide an overview of the ideas and findings presented in the works mentioned above. However, it is important to note that each work also contains more specific details and analysis that may be of interest to those seeking a deeper understanding of the topic.

Public transportation projects: Financing-Subsidies

Given that the research on which this thesis is based and the literature on public transportation and financing are vast and constantly evolving, a selection of influential authors and their works related to the topic of public transportation and its financing over time were selected.

- Enrique Peñalosa: former mayor of Bogotá, Colombia, known for his focus on sustainable urban mobility and the implementation of TransMilenio, a BRT[12] mass transit system. He has written numerous articles and essays on the subject.
- Jan Gehl: danish architect and author of "Cities for People",[19] which discusses the importance of creating human-centered cities and how public transportation plays a crucial role in this approach.
- Vukan R. Vuchic: professor and expert in urban transportation, author of "Urban Transit Systems and Technology", a book that analyzes different public transportation systems and their technical, operational, and economic characteristics.
- Jarrett Walker: public transportation consultant and author of the book "Human Transit: How Clearer Thinking about Public Transit Can Enrich Our Communities and Our Lives", which explores how a better understanding of public transportation can improve the quality of life in cities.
- Paul Mees: academic and transportation planning expert, author of "Transport for Suburbia: Beyond the Automobile Age", in which he discusses the need to rethink suburban transportation and how public transportation can be a viable solution.
- Donald Shoup: professor of urban planning and author of "The High Cost of Free Parking", in which he analyzes how parking subsidies negatively affect cities and public transportation.
- Bondorevsky and Estupiñan analyze in detail the economic structure of the public transportation system in the Buenos Aires Metropolitan Region (RMBA).

It should be noted that this is only a selection of authors and their works; there are many more publications and studies worldwide on the subject of public transportation and its financing. It is also important to bear in mind that the thesis and discussions in this area are constantly evolving, so it is useful to keep up to date with the latest trends and developments.

In this regard, Peñalosa[12] advocates a focus on sustainable urban mobility and the importance of investing in efficient and accessible public transport systems for all. He argues that public transport, such as the TransMilenio BRT system in Bogotá, can be an effective solution to reduce traffic congestion, improve air quality, and promote social equity.

In addition, Peñalosa emphasizes the importance of redesigning cities to prioritize people over cars. This includes creating accessible public spaces, promoting walkability and cycling, and investing in quality public transportation infrastructure. His approach underscores the need for cities to be more inclusive and sustainable in terms of mobility.

However, Gehl[19] argues that cities should be designed with human needs and desires in mind, and that public transportation is a crucial part of this vision. He highlights the importance of creating attractive and safe urban spaces that encourage social interaction and physical activity, while reducing car dependency. Gehl also argues that public transport, together with pedestrian and cycling infrastructure, must be an integral part of urban planning in order to achieve truly livable and sustainable cities. By designing cities for people, it is possible to improve the quality of life, health, and well-being of residents, while reducing traffic congestion and greenhouse gas emissions.

On the other hand, a study analyzes different public transportation systems in terms of their technical, operational, and economic characteristics. He highlights the importance of selecting the most appropriate mode of transportation for each urban context, taking into account factors such as travel demand, population density, and land use. Vuchic also addresses the issue of public transport financing, arguing that a combination of financing sources, such as fares, taxes, and subsidies, is necessary to ensure the financial sustainability of public transport systems. He suggests that the design and implementation of efficient and attractive transport systems can improve urban mobility, reduce car dependency, and contribute to the quality of life in cities.

Similarly, a study highlights the importance of thinking clearly about public transport and how it can enrich our communities and our lives. He argues that effective public transport must be accessible, frequent, fast, and reliable in order to meet users' needs and encourage its use. Walker also addresses issues related to public transportation planning and design, including the importance of interconnectivity between different modes of transportation and the need to consider equity and accessibility in decision-making. He suggests that a user-centered design approach and an understanding of passenger needs and expectations can improve the effectiveness and adoption of public transportation in urban communities.

According to Mees[20], it is necessary to rethink transportation in the suburbs and consider public transportation as a viable solution to reduce car dependence and improve quality of life. He argues that even in low-density areas, public transportation can be effective if properly planned and operated. Mees[20] also advocates for greater integration between transportation planning and urban planning, highlighting the importance of developing mixed-use, dense communities that support public transportation use. He argues that by investing in efficient and accessible public transportation systems, problems related to traffic, pollution, and uncontrolled urban sprawl can be reduced.

Professor Shoup examined how parking subsidies have a negative impact on cities and public transportation. He argues that free and excessive parking encourages car use, which increases congestion, pollution, and urban sprawl, and discourages the use of public transportation. Shoup proposes reforms to parking policies, such as the implementation of demand-based fees and the elimination of minimum parking requirements in urban planning. By addressing the parking problem, Shoup suggests that cities can improve the efficiency of public transportation, reduce traffic congestion, and promote more sustainable, people-centered urban development.

A study who illustrate how the resources used by the system are allocated from the point of view of users and the state, detailing who pays what. The aim of this analysis is to obtain more information in order to ask how cities should move, seeking to meet their needs, increasing accessibility and generating inclusion, equity, and competitiveness. It is hoped that this analysis will serve as a starting point for exploring transport financing mechanisms in other Latin American cities and for delving deeper into the sources of revenue and the effectiveness of investments in different modes of transport.

In addition, the study details the social impact of subsidies and affordability on mobility. Furthermore, based on information from the 2010 Household Mobility Survey (ENMODO), this section provides details on the main characteristics of mobility in the RMBA in relation to transport use and expenditure in relation to the economic conditions of the population (Secretariat of Transport & Ministry of the Interior and Transport, 2009) and breaks down all stages between the different modes of transport for each of the income quintiles. It can be seen that bus use accounts for 39% of trips, and its distribution is fairly even across quintiles. Walking is the second most important mode of transport, with its use decreasing as income rises. In third place is the car, whose use is the opposite of walking: the higher the income level, the greater its use. Then, trains, subways, bicycles, motorcycles, and other modes (taxis, etc.) are distributed relatively evenly.

Prepaid systems in public transport

In line with current trends and practices in the public transport industry, a prepaid public transport system

is a payment method that allows users to pay in advance for the use of public transport services, such as buses, trains, trams, and subways. These systems are designed to simplify and streamline the payment process and improve the efficiency and convenience of public transport for users and operators.

In a prepaid system, passengers purchase credits or balance before using the public transport service. These credits can be stored on a physical card, such as a smart card, or in a mobile app or digital wallet. When the user accesses public transport, the prepaid system deducts the cost of the trip from the available balance.

Prepaid systems in public transportation offer several benefits for both users and transportation operators, including:

1. Greater convenience: users do not need to carry cash or purchase individual tickets each time they travel.
2. Faster boarding times: prepaid systems can speed up the boarding process by eliminating the need to purchase or validate tickets.
3. Flexible and personalized fares: prepaid systems can be adapted to offer discounts and special fares based on specific criteria, such as age, student status, or travel frequency.
4. Improved efficiency: by reducing cash handling and facilitating fare validation, prepaid systems can improve operational efficiency and reduce costs for public transport operators.
5. Information for transportation planning: data generated by prepaid systems can provide valuable insights into usage patterns and demand, helping operators and planners make informed decisions about routes, schedules, and fares.

Prepaid systems are becoming increasingly common in public transport systems around the world and are implemented in various forms, such as smart cards, mobile apps, and digital wallets. Notable examples include the Oyster card in London, the Suica card in Japan, and the MetroCard in New York City.

Below are some influential authors and documents in the field of prepaid systems and smart cards in public transportation:

- "Smart card ticketing systems: functionality, benefits, and implementation challenges" by maria kamargianni and moshe givoni - published in 2014.
- "the economics of smart cards in transport: theoretical framework and cost-benefit analysis" by erik t. Verhoef and michiel c. J. Bliemer - published in 2010.
- "smartcard data use in public transit: a literature review" by k. W. Axhausen - published in 2012.
- "a review of smart cards in transportation planning" by christopher r. Cherry – no date.
- "the role of smart card data in understanding travel behaviour" by agachai sumalee, zuduo zheng and wallaya pijanowska - published in 2013.
- "integrating smart card data for public transport and travel behaviour research" by winnie daamen and niels van oort - published in 2016.
- "public transport planning with smart card data" by remi tachet, oded cats, and marta gonzález - published in 2017.

These studies represent a wide range of research and knowledge in the field of prepaid systems and smart cards in public transport. Research in this field is interdisciplinary, including areas such as transport engineering, economics, urban planning, and data science.

In this regard, Kamargianni et al.[21] analyze smart card ticketing systems in public transport and describe their functionalities, benefits, and implementation. They conclude that smart cards improve the efficiency of public transport by reducing transaction costs and improving users' perception of the service. They also highlight that the adoption of smart card systems poses challenges in terms of investment costs, coordination between operators, and user privacy protection.

Kamargianni et al.[21] suggest that policymakers and public transport operators should consider these challenges when planning and implementing smart card systems. They also emphasize the importance of cooperation between operators and the promotion of an intermodal and sustainable approach to the implementation of these systems to ensure more efficient and accessible public transport.

A study provide a theoretical framework for analyzing smart card systems in transportation and conduct a cost-benefit analysis of their implementation. In their conclusions, they emphasize that smart card systems can generate significant benefits for users, operators, and society in, such as greater convenience for users, reduced operating costs, and decreased traffic congestion.

However, the authors also acknowledge that there are costs and challenges associated with the adoption of these systems, such as investment in infrastructure, coordination between stakeholders, and user privacy. Therefore, they recommend that public transport authorities and operators carefully evaluate the potential costs and benefits of smart card systems before making investment and planning decisions.

Similarly, the researcher conducted a literature review on the use of smart card data in public transport

and highlights the usefulness of this data for understanding user behavior and improving transport planning. The review concludes that smart card data offers great potential for improving the efficiency, monitoring, and planning of public transport by providing detailed and accurate information on user usage and preferences.

Despite these benefits, Axhausen[22] also points out that there are challenges in using smart card data, such as privacy issues, data quality, and access to data. The author suggests that researchers and planners should address these issues to fully exploit the potential of smart card data in public transport planning and management.

Cherry[23] analyzes the use of smart cards in transportation planning and discusses how these systems can improve the efficiency and quality of public transportation services. He concludes that smart card systems offer significant advantages in terms of cost reduction, payment facilitation, and service quality improvements for users.

Despite these benefits, Cherry also highlights challenges in implementing smart card systems, such as investment costs, coordination between operators, and user privacy protection. The author suggests that transport planners should address these challenges and consider the advantages and disadvantages of smart card systems based on local needs and priorities.

Similarly, examine the role of smart card data in understanding travel behavior and demonstrate how this data can be used to improve public transport planning and management. They conclude that smart card data provides valuable information on user behavior and can be used to analyze and improve the efficiency and quality of public transport services.

However, also point out that there are challenges in using smart card data, such as privacy and data quality issues. The authors suggest that researchers and planners should address these issues and develop appropriate methodologies to fully exploit the potential of smart card data in public transport research and planning.

In the case of data in prepaid systems, Daamen et al.[24] explore the integration of smart card data in public transport research and planning and highlight the importance of this data for understanding travel behavior and improving service efficiency. The authors conclude that smart card data offers significant opportunities to improve public transport planning and management by providing detailed and accurate information on user usage and preferences.

Despite these benefits also acknowledge that there are challenges in using smart card data, such as privacy issues, data quality, and data access. The authors suggest that researchers and planners should address these issues and develop innovative approaches to fully leverage the potential of smart card data in public transport research and planning.

Finally, investigated public transport planning using smart card data and demonstrate how this data can be used to improve service efficiency and quality. They conclude that smart card data provides valuable insights into user behavior and can be used to analyze and improve service efficiency and quality in public transport. However, the authors also point out that there are challenges in using smart card data, such as privacy and data quality issues.

Sustainability and public transport

The state of the art in sustainability and public transport has undergone significant changes in recent years. Some of the most notable approaches to sustainability and public transport include:

- Electrification of public transport: the adoption of electric buses and trains has grown significantly. These vehicles emit fewer pollutants and are more energy efficient than fossil fuel vehicles. Some cities have set ambitious targets to completely electrify their public transport fleets in the coming years.
- Active transportation infrastructure: promoting active modes of transportation such as walking and cycling has become a priority in many cities. Investments in infrastructure such as bike lanes and wide sidewalks seek to facilitate access to sustainable and healthy modes of transportation.
- Transportation mode integration: creating efficient and sustainable public transportation systems also involves improving connections between different modes of transportation. This can include creating multimodal transportation hubs, integrating fares, and improving real-time information for users.
- Autonomous and shared vehicles: the development of autonomous vehicle technologies and shared transportation systems has the potential to reduce traffic congestion and lower greenhouse gas emissions. Integrating these technologies into public transportation can improve the overall efficiency and sustainability of the system.
- Transit-oriented urban planning: urban planning can play a crucial role in promoting sustainability in public transportation. This can include densifying urban areas, promoting mixed-use land use, and prioritizing public transportation in the design of roads and public spaces.
- Clean and renewable technologies: in addition to electrification, other clean technologies and renewable energy sources are also being explored to power public transportation. This includes research and development of hydrogen vehicles and the use of biogas and biodiesel in buses and trains.

- Policies and regulations: governments are implementing policies and regulations to encourage the adoption of sustainable public transport. These may include tax incentives for the adoption of electric vehicles, restrictions on car use in urban areas, and the promotion of government-funded public transport programs.

In this regard, Mess[20] argues that urban planning in suburbs has been dominated by the construction of roads and highways, which has led to increased car use and encouraged urban sprawl rather than densification. Mees argues that building an efficient and well-connected public transport network is the key to sustainable mobility and effective urban planning. He proposes solutions to improve public transport in suburban areas, including the creation of high-frequency bus corridors, improved connections between different modes of transport, and the promotion of government-funded public transport systems.

On the other hand, Gehl[19] argues that cities should be designed with people in mind, not cars. He proposes a series of solutions to encourage public transport, such as the creation of bicycle lane networks and the pedestrianization of urban areas. Gehl also advocates densification of urban areas, promoting diversity of land use, and creating attractive and accessible public spaces for all. In short, Gehl argues that people-oriented urban planning and public transportation can improve citizens' quality of life, reduce traffic congestion, and mitigate the effects of climate change.

In addition analyzes the sharing economy and how it is changing the way companies operate and interact with consumers. Chase argues that technology is enabling people to collaborate more effectively and efficiently, leading to new business opportunities and greater consumer empowerment. He proposes that ride sharing is an example of how the sharing economy can promote sustainability in transportation by reducing the number of vehicles on the road and lowering greenhouse gas emissions.

Also addresses the urban problems faced by many cities and proposes solutions for more effective urban planning. He argues that densification and mixed land use are fundamental to sustainable and efficient urban planning. Toderian argues that urban planning should focus on people and on promoting social inclusion and cultural diversity. In terms of public transportation, Toderian advocates for the creation of a high-quality public transportation system that connects different parts of the city and is attractive to users. He proposes that transportation infrastructure should be integrated with other public services, such as housing and employment, to ensure accessible and sustainable mobility for all citizens.

Another contribution who examines the impact of autonomous vehicles on urban mobility and raises important questions about safety, privacy, and equity in access to transportation. Schwartz argues that autonomous vehicles can have a significant impact on reducing traffic congestion and improving public transportation efficiency, but they also pose important ethical and legal challenges. He proposes that autonomous vehicles should be integrated with a well-connected public transport network and that the data collected by these vehicles should be managed transparently and ethically.

However provides a comprehensive analysis of public transportation in the United States and Canada, examining the history, politics, and infrastructure of transportation systems in both countries. Spieler argues that public transportation is crucial for sustainability and equity in urban mobility, and argues that investments in infrastructure and technology are necessary to improve existing public transportation systems. He proposes that public transportation should be attractive to users and well integrated with other modes of transportation, and that cities should promote a culture of public transportation use through the implementation of policies that encourage its use and public education.

In her paper "Right of Way," Angie Schmitt analyzes the relationship between mobility, race, and social class in the United States, and how this influences pedestrian safety and the proliferation of traffic fatalities. Schmitt argues that urban planning has prioritized vehicle traffic and relegated pedestrians to the background, creating a dangerous environment for people who travel on foot. She proposes that urban planning should focus on pedestrian safety and the creation of accessible and safe public spaces for all citizens.

Similarly, examines the impact of technology on how we conceive of driving and urban mobility. Norton argues that autonomous driving technology is being promoted as a solution to urban mobility problems, but that this is a mistake. He proposes that autonomous driving technology cannot solve the fundamental problems of urban mobility, which are the unsustainability of car-based mobility models and the lack of investment in public transport infrastructure. Norton argues that sustainable mobility must be based on the creation of efficient and well-connected public transport networks and the promotion of active modes of transport such as walking and cycling.

CONCLUSIONS

The comprehensive analysis of public transportation developed in this study reveals the complexity and interdependence of the multiple factors that affect its operation, quality, sustainability, and profitability. Far from being a simple technical-operational service, public trans ation is a public policy with a significant

social, environmental, and economic impact, whose planning and management require a multidimensional and coordinated approach between different levels of government, service operators, citizens, and the private sector.

First, it is concluded that the formulation of fair and sustainable fares must be based not only on technical and financial considerations, but also on criteria of social equity and distributive justice. An adequate technical tariff cannot be separated from an analysis of user income, the existence of cross-subsidies, financing mechanisms, and the socioeconomic impacts of its implementation. This also requires transparency, constant monitoring, and citizen participation to strengthen the institutional legitimacy of the tariff system and build trust among users.

Second, service quality and operational profitability are dimensions that must be evaluated together, as they directly influence user perception and the economic viability of the system. As the literature reviewed shows, there are quality variables that have a positive effect on profitability, such as safety or frequency, while others, such as service perception, can negatively affect user satisfaction and loyalty. In this regard, it is necessary to promote management models based on performance indicators, incentives for continuous improvement, and a user-centered approach.

Likewise, the social value of time emerges as a key element in understanding the hidden costs of public transport and its impact on the quality of life of the population. Travel decisions, satisfaction levels, and system efficiency are strongly conditioned by waiting, transfer, and access times, which makes it necessary to consider these factors in project evaluation, investment prioritization, and route and schedule design. Reducing variability in travel time, improving connectivity, and including vulnerable demographic groups are essential aspects of maximizing the social value of the system.

Furthermore, the study highlights the importance of financing and subsidy mechanisms as tools to ensure the financial sustainability of public transport without compromising its social function. The successful models analyzed show that a balanced combination of fare revenue, government subsidies, taxes, and private sector contributions can make high-quality transportation systems with affordable fares and broad territorial coverage viable. Likewise, the implementation of technologies such as prepaid systems and smart cards not only improves operational efficiency but also generates valuable data for public policy planning and evaluation.

Finally, it should be noted that the sustainability of public transport depends not only on its economic viability, but also on its integration with urban policies aimed at reducing car dependency, encouraging active transport, promoting urban densification, and creating more livable urban environments. Transport electrification, transit-oriented planning, intermodality, and territorial equity are key components for moving toward a more resilient, inclusive, and environmentally friendly mobility model.

In short, this study demonstrates that strengthening public transport requires a long-term strategic vision based on empirical evidence, technological innovation, political will, and citizen commitment. Only through comprehensive, participatory, and sustainable planning will it be possible to build fairer, more efficient, and more humane cities, where the right to mobility is a reality for all.

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Authors declare that there is no conflict of interest.

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