Prospects For Adaptation And Cultural Changes In Citizenship For The Modernization Of Urban Mobility In Public Transport In Medium-Sized Cities: A Systematic Review (2020-2025)

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Abstract

The transformation of urban public transport systems towards smart, sustainable, and responsive models is imperative for cities with populations of up to one million inhabitants, which face different challenges than megacities, including infrastructure limitations, dependence on informal transport, and institutional weakness. A systematic review of literature published between 2020 and 2025 was conducted, using an interdisciplinary approach that integrated urban planning, social sciences, technology, and public policy analysis. The findings show an accelerated technological transformation with projections of 85 million electric vehicles in global circulation by 2025 and the European Union's commitment to eliminate combustion vehicles by 2035. The case of Seoul demonstrated that deliberate policies can achieve 66% of daily traffic on public transport, with nearly 100% adoption of smart cards. A decline in attachment to private vehicles was identified among Generation Z, although the perception of climate change lacks significant predictive value in individual modal choice without tangible personal benefits. The case of the transmicable in Bogotá revealed that informal transport persists in meeting needs not served by formal systems. The modernization of public transport transcends the technical exercise, constituting a social and cultural process that requires holistic planning, citizen-centered design, adaptive governance, and integration of informal mobility systems to create truly resilient and equitable urban environments.

Keywords: Sustainable urban mobility, cultural adaptation, public transport, smart cities, citizen behavior change, participatory governance.

1. Introduction

Rapid population growth and urban concentration have led to unprecedented changes in global mobility dynamics. According to Spain's Ministry of Transport, Mobility, and Urban Agenda (2021), the traditional focus on infrastructure provision is evolving toward comprehensive planning that views mobility as a fundamental right capable of promoting social cohesion and economic growth. This paradigm shift highlights the need for transportation systems that go beyond operational efficiency to become pillars of sustainability, safety, and urban connectivity.

Sustainable urban mobility is defined as the set of strategies, policies, and transportation systems aimed at meeting the travel needs of the current population without compromising the capacity of future generations, minimizing environmental impact, promoting social equity, and ensuring economic viability (Greentech, 2025). This concept has taken on critical relevance in the 2020-2025 period, marked by a strong global push in which governments and companies have actively committed to strategies to reduce emissions, improve energy efficiency, and promote sustainable transport ecosystems (Intertraffic, 2025).

The concept of a smart city refers to urban environments that leverage information and communication technologies, particularly artificial intelligence, the Internet of Things, and big data analytics, to optimize resource management, improve the quality of life of their inhabitants, and promote sustainable development (Naifman, 2025). In the field of mobility, smart cities implement intelligent transport systems that enable proactive traffic management, demand anticipation, and improved user

experience through real-time information and personalized services.

Complementarily, sustainable cities are urban environments designed to balance the environmental, social, and economic dimensions of development, prioritizing the reduction of the carbon footprint, the conservation of natural resources, and the creation of livable and healthy spaces for their residents. UN-Habitat (2022) points out that the COVID-19 pandemic forced a fundamental reassessment of the unsustainable urban development models that prevailed before 2020, exposing systemic vulnerabilities and prompting cities to prioritize adaptability and sustainability as fundamental principles.

The term responsive city emerges as a conceptual evolution that transcends mere technological implementation to emphasize the responsiveness of urban systems to the needs, aspirations, and feedback of citizens. Digi (2023) states that responsive cities are built on the basis of citizen participation and co-creation, transforming residents from mere data providers into active collaborators in decision-making. This approach requires adaptable governance and flexible policy frameworks that keep pace with technological and social change.

Cultural adaptation in the context of urban mobility refers to the process by which citizens modify their perceptions, attitudes, values, and travel behaviors in response to changes in transportation systems and mobility policies. This process is neither linear nor uniform, but is mediated by generational, socioeconomic, territorial, and psychological factors that determine the speed and depth of adoption of new mobility practices (Ekpenyong et al, 2025).

This study focuses specifically on cities with populations of up to one million inhabitants, known as intermediate or medium-sized cities. Swisscontact (2023) identifies these urban centers as essential hubs for economic and social development, with considerable potential to drive growth and improve the quality of life of their residents through sustainable and comprehensive public transport systems. However, the needs and challenges of these cities differ substantially from those of megacities: they often face limitations in public transport infrastructure, greater dependence on informal transport and private vehicles, financial constraints, poor institutional quality, and a lack of comprehensive policy frameworks for sustainable urban mobility (Ekpenyong et al., 2025).

The rationale for this literature review lies in multiple gaps identified in the literature. First, although there are numerous studies on smart mobility in megacities such as Seoul, Singapore, or London, the direct transfer of these models to smaller urban contexts is often unfeasible due to differences in scale, cost, and urban structure (World Bank, 2022). Second, the period 2020-2025 has represented an unprecedented turning point: the COVID-19 pandemic acted as an unexpected catalyst that accelerated the reevaluation of policies and the integration of resilience into mobility planning (UN-Habitat, 2022). Third, there remains a significant gap between technological innovation and understanding of the processes of cultural adaptation among citizens, evidenced by the persistence of informal transportation systems even after formal modernization interventions (Rodríguez y Vergel-Tovar, 2023).

Additionally, the literature reveals that sociocultural attitudes toward private car ownership and resistance to change constitute fundamental barriers that mere technological implementation cannot overcome (Ekpenyong et al., 2025). This observation underscores the need for an interdisciplinary approach that integrates technological, social, cultural, and governance dimensions to holistically understand the processes of urban mobility transformation.

The objective of this research was to synthesize the state of knowledge on the prospective vision of cultural adaptation and changes in citizen behavior in response to the modernization of urban public transport in intermediate cities during the period 2020-2025, identifying emerging trends, driving factors, persistent barriers, and strategic recommendations for policymakers and urban planners.

2. Material and methods

This study was designed as a systematic descriptive-analytical literature review aimed at synthesizing the available scientific and technical knowledge on the modernization of urban public transport and cultural adaptation by citizens in cities with populations of up to one million inhabitants. The methodological design adopted an interdisciplinary approach that integrated perspectives from urban planning, social sciences, information technology, environmental studies, and public policy analysis, allowing for a holistic understanding of the complex interaction between technological innovation, citizen behavior, and governance dynamics (Ministry of Transport, Mobility, and Urban Agenda, 2021).

The period of analysis covered literature published between January 2020 and July 2025, a time frame justified by two fundamental reasons. First, the year 2020 marks the beginning of the COVID-19 pandemic, a disruptive event that acted as a catalyst for profound transformations in urban mobility

patterns and the reevaluation of transportation policies globally (UN-Habitat, 2022). Second, this five-year period represents a time of accelerated technological innovation and political commitment to sustainability, evidenced by initiatives such as the European Union's commitment to phase out sales of combustion vehicles by 2035 (Kuss, & Nicholas, 2023).

The search strategy was executed in indexed scientific databases including Scopus, Web of Science, and SciELO, supplemented by institutional repositories of international organizations such as UN-Habitat, the World Bank, the World Economic Forum, the International Association of Public Transport (UITP), the Inter-American Development Bank (IDB), and the European Parliament. Government portals and public policy documents from transport ministries in various countries were also consulted. The search terms, applied in Spanish and English, included combinations of the following descriptors: sustainable urban mobility, public transport, smart cities, intermediate cities, cultural adaptation, citizen behavior, Mobility as a Service (MaaS), vehicle electrification, citizen participation, urban governance, and transport resilience.

The inclusion criteria established that the documents must: (a) have been published between 2020 and 2025; (b) address topics related to public transport modernization, sustainable urban mobility, smart cities, or cultural adaptation in urban contexts; (c) present empirical evidence, theoretical analyses, or conceptual frameworks relevant to cities with populations of up to one million inhabitants or scalable principles applicable to these contexts; (d) be available in full text in Spanish, English, or Portuguese. Documents that exclusively addressed freight transport infrastructure, long-distance interurban mobility, or those focused on rural contexts without urban applicability were excluded.

The selection process was carried out in three phases. The initial phase consisted of identifying potential sources using search terms, obtaining a preliminary corpus of documents. The second phase involved reviewing titles and abstracts to assess thematic relevance according to the established criteria. The third phase comprised a complete reading of the selected documents and the systematic extraction of relevant information. The final corpus consisted of 48 sources, including peer-reviewed scientific articles, technical reports from international organizations, public policy documents, case studies, and sectoral reports.

The analysis of the information was structured using predefined thematic categories that emerged from both the previous literature and the inductive review process. The main categories included: (a) technological innovations in public transport, covering digitization, artificial intelligence, vehicle electrification, autonomous vehicles, and Mobility as a Service platforms; (b) cultural adaptation and changes in citizen behavior, including the evolution of travel preferences, drivers of adoption, and persistent barriers; (c) governance, participation, and inclusion, including citizen participation mechanisms, adaptive policy frameworks, and social equity; (d) case studies and lessons learned from successful and challenging modernization experiences; (e) forward-looking vision and emerging trends for post-2025 urban mobility.

For the comparative analysis, the narrative synthesis technique was used, identifying convergent patterns, conceptual divergences, and gaps in the literature. Particular attention was paid to identifying principles that are scalable and adaptable to different contexts.

The methodological limitations of the study include the publication bias inherent in literature reviews, the predominance of literature from developed contexts over emerging economies, and the rapid obsolescence of information in a field of rapid technological evolution. Additionally, the heterogeneity in the operational definitions of concepts such as “smart city” or “sustainable mobility” in the literature sometimes made direct comparability between studies difficult. However, these limitations were mitigated by the deliberate inclusion of sources from international organizations with a global perspective and case studies of Latin American and African cities facing challenges similar to those of the intermediate cities under analysis.

Categories of analysis in the literature review

The documentary corpus was systematically organized using a system of thematic categories that allowed for a coherent and comprehensive analysis. Table 1 presents the main categories, subcategories, associated descriptors, and the number of sources corresponding to each analytical dimension.

Table 1. Matrix of categories for organizing the literature review

Main Category	Subcategories	Search Descriptors	Sources (n)	Percentage (%)
1. Technological innovations in public transport	1.1. Digitalization and Artificial Intelligence	Intelligent traffic management systems, real-time information, generative AI, predictive maintenance, data analysis	8	16,67
	1.2. Vehicle electrification	Electric vehicles, electric fleets, charging infrastructure, battery technology, zero emissions	6	12,50
	1.3. Autonomous vehicles	Autonomous taxis, driverless buses, V2I communication, urban air mobility, sensors	4	8,33
	1.4. Mobility as a Service (MaaS)	Integrated digital platforms, multimodality, transportation apps, on-demand services	5	10,42
2. Cultural adaptation and citizen behavior	2.1. Evolution of travel preferences	Vehicle ownership, Generation Z, shared mobility, active modes, post-pandemic patterns	7	14,58
	2.2. Drivers of adoption	Convenience, cost-effectiveness, environmental awareness, accessibility, real-time information	6	12,50
	2.3. Barriers to change	Perception of service quality, car orientation, technological resistance, sociocultural attitudes	5	10,42
	2.4. Informal Transportation	Informal systems, complementarity, local needs, adaptation, integration	3	6,25
3. Governance, participation, and inclusion	3.1. Citizen Participation	Co-creation, digital consultations, advisory councils, citizen observatories, living labs	6	12,50
	3.2. Adaptive Governance	Flexible policies, regulatory frameworks, inter-institutional coordination, open data, decision-making	5	10,42
	3.3. Social Equity and Inclusion	Universal accessibility, gender perspective, vulnerable populations, social cohesion, right to mobility	7	14,58
4. Urban contexts and case studies	4.1. Megacities (Scalable Principles)	Seoul, Singapore, Helsinki, integrated systems, smart cards	4	8,33
	4.2. Intermediate Cities	Emerging cities, infrastructure constraints, vehicle dependency, specific contexts	5	10,42
	4.3. Implementation Lessons	Successes, challenges, unexpected outcomes, planning gaps, technology transfer	4	8,33
5. Prospective vision and emerging trends	5.1. Transportation 5.0	Technological convergence, digital twins, advanced AI, foundational models	4	8,33
	5.2. Resilience and sustainability	Climate change, green investments, urban adaptation, future disruptions	5	10,42
	5.3. Persistent challenges	Cultural inertia, institutional fragmentation, underfunding, social inequalities	4	8,33
6. Impact of the COVID-19 pandemic	6.1. Disruptions in mobility	Demand reduction, modal shifts, remote work, lockdowns	4	8,33
	6.2. New emerging patterns	New normal, flexible services, non-motorized transport, systemic resilience	3	6,25

Note: The total number of sources (n=48) does not correspond to the arithmetic sum of the subcategories because several documents were classified in multiple categories according to their multidimensional content.

Table 2 presents the distribution of sources according to their document type, including absolute frequencies and percentages.

Table 2. Distribution of sources according to document type (n=48)

Document Type	Sources (n)	Percentage (%)
Peer-reviewed scientific articles	18	37,50
Reports from international organizations	15	31,25
Public policy documents	8	16,67
Case studies and technical reports	7	14,58
Total	**48**	**100**

Table 3 complements the analysis with the geographical distribution of the sources consulted.

Table 3. Distribution of sources by geographical origin (n=48)

Geographic Origin	Sources (n)	Percentage (%)
Europe	16	33,33
International/Global	14	29,17
Latin America	9	18,75
Asia	6	12,50
North America	3	6,25
Total	**48**	**100**

Note: The "International/Global" category includes documents from organizations such as UN-Habitat, the World Bank, the World Economic Forum, and UITP that address comparative multinational perspectives.

4. Results

The results of the literature review are presented according to the six main categories of analysis, integrating the most relevant findings from the 48 sources consulted. Each category includes a critical analysis of the literature, identified empirical data, and implications for the modernization of public transport in intermediate cities.

4.1. Technological Innovations in Public Transport

The technological transformation of urban public transport during the period 2020-2025 is characterized by the convergence of multiple innovations that redefine traditional mobility paradigms. Analysis of the 23 sources corresponding to this category (47.92% of the corpus) reveals four fundamental technological dimensions that shape the current landscape of modernization.

4.1.1. Digitalization and Artificial Intelligence

Artificial Intelligence has established itself as a fundamental element for urban optimization, playing a decisive role in reducing traffic congestion, optimizing mobility flows, and facilitating predictive maintenance in urban services (Naifman, 2025). Its application allows cities to proactively anticipate problems, improving sustainability and safety in urban environments.

Real-time information systems are pillars of this transformation. Seoul's Transport Operations and Information Service (TOPIS) illustrates the effectiveness of integrating diverse data sources to provide real-time traffic information to both travelers and operators (World Bank, 2022). Recent research from the University of Twente shows that real-time public transport applications can significantly reduce vehicle kilometers traveled (VKT) and associated CO_2 emissions by inducing modal shifts from private cars to public transport (University of Twente, 2025).

The implementation of generative AI for passenger assistance represents a significant evolution in the user experience. In Singapore, innovation centers are

developing tools that include sign language translation and intelligent chatbots for travel inquiries, making public transport more accessible and user-friendly (World Economic Forum, 2025a). This strategic implementation transcends internal operational optimization, extending directly to the user experience through intuitive interfaces that encourage the adoption of public transport by overcoming psychological barriers related to perceived complexity, language barriers, or uncertainty.

4.1.2. Vehicle Electrification

Vehicle electrification is experiencing rapid growth, with projections indicating that there will be 85 million electric vehicles in circulation worldwide by the end of 2025 (Intertraffic, 2025). This widespread adoption is driven by substantial benefits: significant reductions in CO_2 emissions, lower maintenance costs compared to traditional combustion engines, and continuous innovations in battery technology that offer greater range and faster charging times (Greentech, 2025).

Political support is accelerating this transition, highlighting the European Union's commitment to phase out sales of new gasoline and diesel vehicles by 2035 (Kuss, & Nicholas, 2023). However, the literature consistently warns that the transition to electric fleets involves more than just vehicle procurement; it requires energy system planning, charging infrastructure, and optimized depot operations (Monitor Eurocities, 2025). This observation underscores a crucial causal relationship: technological innovation in vehicles cannot reach its full potential without simultaneous investment in the underlying physical and digital infrastructure.

4.1.3. Autonomous Vehicles and Urban Air Mobility

Advances in Artificial Intelligence are enabling the development of autonomous taxis and buses that promise to significantly reduce accidents, improve operational efficiency, and increase accessibility for people with reduced mobility (Intertraffic, 2025). These vehicles rely on sophisticated sensors and real-time data for safe navigation, designed to communicate with urban infrastructure through Vehicle-to-Infrastructure (V2I) systems to optimize traffic flow and safety (Li, Y., et. al., 2025).

The concept of urban air mobility, which encompasses flying taxis and drones, is transitioning from science fiction to practical implementation. Companies are actively testing autonomous aerial vehicles that could revolutionize short-distance urban travel by avoiding ground congestion (Intertraffic, 2025). However, these emerging technologies require adaptive regulatory frameworks and equity considerations to ensure they do not exacerbate existing urban inequalities.

4.1.4. Mobility as a Service (MaaS) and Digital Platforms

Mobility as a Service represents a paradigm shift in urban mobility, integrating various modes of transport—from public transport to bike sharing and on-demand services—into a single digital platform that simplifies the entire travel experience, including planning, booking, and payment (Naifman, 2025). The International Association of Public Transport (UITP) argues that the success of MaaS depends on its ability to genuinely respond to user needs and attract a critical mass, facilitating a significant shift towards sustainable modes (UITP, 2020).

Dijon, France, offers a tangible example with the launch of its DiviaMobilités app in 2025, a comprehensive MaaS solution that integrates multiple public transport options with booking, route planning, and real-time updates, with the aim of simplifying travel and actively promoting sustainable mobility options (Keolis, 2025). UITP (2020) explicitly states that “MaaS should be a tool to guide behavior towards more sustainable modes” (p. 4), elevating these platforms beyond mere technological convenience to become strategic instruments of urban governance.

The concept of Digital Twins is emerging as a growing trend, offering virtual replicas of urban environments that optimize infrastructure design, enable realistic scenario simulations, and facilitate more efficient planning of public spaces (Naifman, 2025).

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4.2. Cultural Adaptation and Citizen Behavior

The analysis of citizens' cultural adaptation to the modernization of public transport is a critical dimension that transcends technological implementation. The 21 sources corresponding to this category (43.75% of the corpus) reveal complex patterns of evolution in travel preferences, drivers of adoption, persistent barriers, and the particular dynamics of informal transport.

4.2.1. Evolution of Travel Preferences and Habits

A significant cultural shift is observed, characterized by a decline in traditional attachment to private car ownership, especially among younger generations. Generation Z increasingly prioritizes factors such as cost-effectiveness, environmental impact, and reduced urban congestion over the symbolic status associated with vehicle ownership (Intertraffic, 2025). This evolving preference is actively driving the growth and adoption of shared mobility services, constituting a profound cultural shift that emanates from specific demographic cohorts rather than merely technological facilitation of new options.

Recent studies by Taylor & Morris (2025) confirm that Millennials and Generation Z exhibit distinctive attitudes toward mobility, with a lower propensity to obtain driver's licenses and greater openness to multimodal alternatives (Taylor & Morris, 2025). This generational divide implies that cultural adaptation is not uniform across the population, requiring differentiated communication strategies and incentives according to demographic groups.

At the same time, there has been a shift toward public transportation and active modes. The case of Seoul demonstrates that deliberate public policy efforts can significantly reduce private car travel: by 2015, 66% of daily traffic was public transportation (World Bank, 2022). The use of shared bicycles and electric scooters is projected to increase by 50% in the near future (Greentech, 2025), evidencing a sustained trend toward micromobility.

Post-pandemic mobility patterns have also evolved significantly. While the COVID-19 pandemic initially caused a drastic reduction in demand for public transport, it also acted as a catalyst for new habits, including greater reliance on non-motorized transport and the need for adaptable services (UN-Habitat, 2021). As ridership recovers, lasting patterns are emerging, such as increased demand for flexible, all-day service options, influenced by the rise of hybrid and remote working models (ASCE, 2025).

4.2.2. Drivers of Adoption

The literature consistently identifies multiple factors driving the adoption of modernized public transportation. Convenience emerges as a primary driver, manifested in the proximity of services to home and workplace, the availability of direct routes, the perception of speed in travel, and safety (Redman et al., 2019). Real-time information provided by digital applications significantly improves the convenience and perceived attractiveness of public transport (University of Twente, 2025).

Cost-effectiveness is another decisive factor. Public transport is often perceived as a more affordable alternative to car ownership, especially when considering associated costs such as fuel, maintenance, and parking difficulties (Redman et al., 2019). The lower operating costs of electric vehicles also act as a financial incentive for operators and, indirectly, for users through potentially stable or lower fares (Greentech, 2025).

Growing global environmental awareness positions sustainability as a central strategic imperative in urban mobility (Intertraffic, 2025). The tangible benefits of modernized transportation, such as reduced CO_2 emissions and improved air quality, are significant motivators for its adoption (Greentech, 2025). However, analysis reveals a critical observation: studies by López-Carreiro, & Monzón (2025) found that “perception of climate change” has no significant predictive value in individual public transportation use. This suggests that while environmental awareness is a general driver, its direct influence on individual modal choice may be limited if tangible personal benefits are not sufficiently compelling.
Accessibility and inclusion are fundamental aspects. Modernized transportation systems are designed to offer accessible and equitable alternatives for all citizens, including people with reduced mobility (Naifman, 2025). The Inter-American Development Bank (2023)

4.2.3. Barriers to Change

Despite progress, significant barriers to public transport adoption remain, many rooted in perceptions of service quality. Redman et al., (2019) identifies the main barriers as: infrequent availability of vehicles, especially outside peak hours; discrepancies between scheduled and actual timetables; insufficient comfort inside vehicles and at stops; and cumbersome ticket purchasing processes. Users consistently express expectations for better intermodal connections and timetable compliance.

A deep cultural barrier is the entrenched “car orientation,” which significantly reduces the likelihood of using public transportation (López-Carreiro, & Monzón, 2025). Emotional attachment to

car ownership and its symbolic status are powerful deterrents to changing mobility behaviors (Ekpenyong et al., 2025). Historical urban planning that prioritized road infrastructure over alternative modes exacerbates this car-centric mindset.

Discussions about "public commitment and acceptance" for major changes (Kuss, & Nicholas, 2023) and concerns about "data privacy and security" in intelligent transportation systems (Business Research Insights, 2025) suggest potential public apprehension toward technologically advanced solutions that must be addressed through communication and trust-building strategies.

4.2.4. The Dynamics of Informal Transportation

In many contexts, particularly in Latin American cities, informal transportation systems persist and even thrive despite formal modernization efforts. This occurs because they effectively adapt to specific local needs, offering convenience, availability, and connectivity in areas or for travel purposes where formal systems are inadequate (Rodríguez y Vergel-Tovar, 2023).

The case of Transmicable in Bogotá offers a crucial lesson on the complexity of cultural integration. Despite the introduction of a formal cable car system, informal transport persisted and even adapted to complement the formal system, particularly in peripheral areas, by meeting specific local needs that the formal system did not adequately address (Rodríguez y Vergel-Tovar, 2023). This persistence highlights a critical challenge of cultural adaptation for formal planning, indicating a failure to fully understand and integrate existing, often deeply rooted, and informal mobility cultures. The strategic implication is clear: modernization interventions must integrate or learn from these systems rather than simply attempting to replace them.

4.3. Governance, Participation, and Inclusion in Mobility

The transformation toward smart, sustainable, and responsive cities requires governance frameworks that transcend technological implementation to actively incorporate citizen participation and ensure social equity. The 18 sources corresponding to this category (37.50% of the corpus) reveal the evolving role of citizens and persistent institutional challenges.

4.3.1. Citizen Participation and Co-creation

Citizen participation is crucial for the successful transformation to citizen-centered smart cities, ensuring that urban development is resilient, inclusive, and truly responsive to the needs and aspirations of the community (Naifman, 2025).

Active engagement promotes a more active democracy and allows citizens to report urban problems in real time, fostering a responsive urban environment.

Various mechanisms are being implemented to facilitate citizen participation, including digital voting tools, online consultations and surveys, direct communication applications with administrative bodies, and formal participation spaces such as advisory councils and citizen observatories (Naifman, 2025). The Citizen Participation Plan of the Colombian Ministry of Transport (2025) details mechanisms that go beyond simple feedback, seeking "more inclusive and representative management" through direct dialogue and shared decision-making.

Beyond mere consultation, the concept of co-creation emphasizes the participation of residents as active actors in the design and development process. IE Business School (2020) notes that this approach facilitates the acquisition of valuable and context-specific knowledge, significantly strengthening the basis for equitable urban development by ensuring that solutions are "for and with the people" (p. 23).

Mellouli & Komninos (2025) document the evolution of the citizen's role in smart cities: initial conceptualizations positioned citizens primarily as passive sources of data, while contemporary approaches recognize them as "active elements of the process" through terms such as co-creation and participatory design. The UITP Urban Mobility Innovation Index (2021) confirms this transition toward multidirectional and collaborative engagement where citizens are increasingly seen as partners in shaping urban mobility.

Despite the recognized benefits, fostering meaningful citizen participation faces obstacles documented by Mellouli, & (2025): challenges in ensuring broad representativeness across diverse demographics, experience gaps between citizens and technical planners, political interference, complex power dynamics, time constraints, limited resources, and the need to effectively leverage technology to bridge digital divides.

4.3.2. Adaptive Governance and Policy Frameworks

Urban mobility is recognized as a complex and multifaceted domain that requires highly adaptable solutions (UITP, 2021). Policy frameworks must be flexible and responsive to changing traveler needs, evolving social patterns, and unforeseen disruptions (Keolis, 2025). Smart governance leverages big data

and advanced technologies to address complex socioeconomic and spatial issues, with the availability of real-time measurements and open data crucial for informed decision-making and dynamic policy adjustments (University of Cambridge, 2023).

Effective transportation planning is intrinsically linked to broader urban development, requiring integrated investments in urban renewal, service infrastructure, and urban amenities (Swisscontact, 2023). This holistic approach ensures that mobility solutions support the overall growth of the city and its livability.

However, significant challenges remain in policy implementation. Ekpenyong et al. (2025) identifies: outdated legal frameworks, inadequate enforcement, lack of sustained political will, and poor coordination between different government and institutional bodies. Chronic underfunding remains a major impediment to the expansion, maintenance, and renewal of public transport fleets (Eurocities Monitor, 2025).

The literature repeatedly highlights the need for "adaptive governance," "flexible policies," and "agile and intelligent governance" (University of Cambridge, 2023; World Economic Forum, 2025b). This fundamental observation suggests that the success of technological solutions depends not only on their deployment, but also on the presence of a supportive and dynamic governance structure capable of continuously learning from data and citizen feedback, adjusting policy frameworks to keep pace with technological advances and evolving citizen behaviors.

4.3.3. Social Equity, Accessibility, and Inclusion

Smart cities seek to improve the quality of life for all residents, balancing environmental, social, and economic needs, with a strong emphasis on promoting inclusion, safety, and equity (Mellouli, &, 2025).

A key aspect of modernized transportation is its commitment to making mobility more inclusive and accessible for all, including vulnerable populations such as people with reduced mobility, children, and the elderly (Naifman, 2025).

Strengthening public transport systems generates significant documented social benefits: poverty reduction, increased urban mobility, stimulation of economic activity, and social integration of previously marginalized areas into the broader urban fabric (Aithor, 2025). Mobility planning must explicitly incorporate a gender perspective, recognizing that women often exhibit more sustainable mobility patterns and have different travel needs related to caregiving and safety, particularly during nighttime hours (Spanish Ministry of Transport, 2023).

Trencher & Karvonen (2025) argue that smart city initiatives should be conceptualized as social transitions toward inclusive development through technology. Their study of four smart cities demonstrates that success is measured not only by technological prowess or environmental impact, but by the ability to foster truly equitable, accessible, and socially cohesive urban environments. The concept of a "responsive city" implicitly requires that mobility solutions serve the diverse needs of all citizens, reflecting a new "social contract" for urban development (UN-Habitat, 2022).

4.4. Urban Contexts and Case Studies

The analysis of specific experiences in public transport modernization provides fundamental empirical evidence for understanding success factors and challenges. The 13 sources in this category (27.08% of the corpus) document cases of megacities with scalable principles, experiences of intermediate cities, and lessons learned from implementations with varying results.

4.4.1. Megacities: Scalable Principles

Although Seoul, South Korea, is a megacity, the principles of its Transport Operations and Information Service (TOPIS) are highly adaptable to smaller urban contexts. This system demonstrates highly effective data-driven planning, integrated intelligent transport systems (ITS), proactive demand management, and real-time information dissemination (World Bank, 2022). The widespread adoption of its smart card (T-money), which reached nearly 100% usage for subway and bus, highlights a successful cultural integration of a new payment system that also facilitates valuable data collection. The promotion of active mobility through extensive bike lanes and pedestrian areas illustrates a holistic approach to urban mobility.

Helsinki, Finland, stands out as a leader in sustainable mobility, attributed to a comprehensive strategy that includes financial incentives for electric vehicles, the establishment of car-free zones, the development of advanced cycling infrastructure, and a modern rail network (World Economic Forum, 2025a). Crucially, these efforts are complemented by significant investments in carbon-neutral energy sources, demonstrating a holistic approach to urban sustainability.

The World Economic Forum (2020) presents 25 case studies of smart cities on a global scale, identifying

cross-cutting principles of success: committed political leadership, multimodal data integration, active citizen participation, and adaptive regulatory frameworks. The underlying principles of data integration, user-centered design, and multimodal promotion are highly scalable, allowing smaller cities to extract and adapt strategic frameworks and underlying philosophies rather than attempting to replicate large-scale infrastructure projects.

4.4.2. Intermediate Cities: Specific Challenges

Swisscontact (2023) documents that intermediate cities are emerging as essential nodes for economic and social development, with considerable potential to improve quality of life through sustainable public transport systems. However, these cities face distinctive challenges: limitations in public transport infrastructure, greater dependence on informal modes and private cars, traffic congestion, environmental pollution, and safety concerns.

Ekpenyong et al. (2025) identifies specific barriers in emerging cities: financial constraints, poor institutional quality, lack of comprehensive policy frameworks for sustainable urban mobility, and limited political will. The observation that these cities struggle with limited public transport and heavy dependence on cars underscores that the "one million inhabitants" threshold encompasses a diversity of stages of urban development and socioeconomic realities.

The Barcelona Mobility Master Plan (ATM, 2020) offers an adaptable planning model for intermediate cities, emphasizing fare integration, intermodal coordination, and citizen participation as key pillars. Although Barcelona has over one million inhabitants, its metropolitan planning principles are applicable to smaller urban contexts seeking to integrate their mobility systems.

4.4.3. Implementation Lessons

The case of Transmicable in Bogotá provides a compelling example of an unanticipated outcome. Despite the introduction of a formal cable car system, informal transport not only persisted but adapted to complement the formal system (Rodríguez y Vergel-Tovar, 2023). Informal services continued to meet specific local needs—better travel times, connectivity to underserved areas, convenience—that the formal system did not adequately address. This experience reveals a profound lesson: top-down planning, if not sufficiently "responsive" to local realities, often fails to take into account organic and culturally rooted mobility solutions that arise from specific community needs.

The European Parliament report (2020) on COVID-19 and urban mobility documents how the pandemic caused significant disruptions, leading to supply chain problems, a drastic reduction in demand, and delays in planned investments for smart transportation projects. However, it also accelerated the adoption of innovative solutions and the reassessment of mobility priorities.

REAL CORP's (2025) analysis of urban equity and cultural inclusivity in cosmopolitan cities shows that modernization interventions can have different impacts on different population groups, highlighting the need for equity assessments prior to the implementation of new systems.

4.5. Prospective Vision and Emerging Trends

The analysis of emerging trends and the prospective vision for urban mobility beyond 2025 allows us to identify the technological and social development trajectories that will shape the future of public transport. The 13 sources corresponding to this category (27.08% of the corpus) reveal the convergence towards integrated paradigms and the persistent challenges that must be addressed.

4.5.1. Transportation 5.0 and Technological Convergence

The future vision of urban mobility is taking shape as "Transportation 5.0," a comprehensive paradigm that merges electrification, shared mobility (MaaS), advanced data-driven decision-making (AI), and smart infrastructure (Li, Y., et. al., 2025). This holistic approach seeks to significantly reduce environmental impact, increase passenger convenience, and generally improve the efficiency and accessibility of transportation networks.

Cutting-edge AI, foundational models, and large language models (LLMs) are poised to revolutionize Intelligent Transportation Systems, improving traffic management, optimizing autonomous vehicle operations, and contributing to the development of more sophisticated smart cities (Business Research Insights, 2025). The concept of Digital Twins will become increasingly common, offering virtual replicas of urban environments that will optimize infrastructure design, enable realistic scenario simulations, and facilitate more efficient planning (Naifman, 2025).

This forward-looking vision does not simply represent the addition of more technology, but rather a deeper integration where the digital realm goes beyond informing physical infrastructure to actively shaping, optimizing, and adapting it in real time. This convergence will lead to urban environments that are hypersensitive to dynamic conditions and citizen

needs, blurring the traditional lines between planning, operation, and adaptation.

4.5.2. Urban Resilience and Sustainability

Future urban development will increasingly prioritize resilience, emphasizing green investments, responsive urban planning, and adaptive governance systems to effectively address the growing challenges of climate change and prepare for future disruptions (UN-Habitat, 2022).

Roggema, R. (2021) documents the concept of "Adaptive Urbanism and Resilient Communities," which proposes transforming streets to address climate change through green infrastructure, active mobility, and multifunctional public spaces.

A critical area of focus will be optimizing first- and last-mile travel, which is essential for improving access to broader mobility systems, alleviating congestion, boosting local economies, and enhancing overall quality of life (World Economic Forum, 2025b). Emerging alternatives such as micromobility, ride sharing, and on-demand public transportation are gaining significant traction globally.

The Inter-American Court of Human Rights (2025) has issued guidance on the right to a healthy environment and its relationship to sustainable mobility, establishing legal frameworks that link transportation planning to human rights and environmental protection obligations.

4.5.3. Persistent Challenges

Despite the rapid pace of technological advances, deeply ingrained sociocultural attitudes toward private car ownership remain a significant and persistent barrier (Ekpenyong et al., 2025). Future policies must proactively address this cultural inertia through a combination of targeted incentives, comprehensive educational campaigns, and the provision of highly attractive and robust alternative mobility options.

Financial shortfalls, fragmented governance structures, lack of sustained political commitment, and absence of effective interagency coordination continue to hamper progress, particularly in emerging and intermediate cities (Ekpenyong et al., 2025). Addressing these systemic issues will require sustained effort and innovative financing models.

A critical ongoing challenge is ensuring that rapid advances in technology and infrastructure do not inadvertently exacerbate existing social inequalities. Wang & Chen (2025) emphasize that innovations must be intentionally designed and implemented to improve universal accessibility and promote social equity for all citizens, especially vulnerable groups.

The literature reveals a fundamental observation: even with the advent of advanced concepts such as Transportation 5.0 and sophisticated AI integration, human behavior remains the most complex and least predictable variable in the sustainable urban mobility equation. Technology can facilitate, enable, and optimize, but it cannot force cultural adaptation; the latter requires a nuanced, citizen-centered, and sustained approach over time.

4.6. Impact of the COVID-19 Pandemic on Urban Mobility

The COVID-19 pandemic was an unprecedented disruptive event that fundamentally transformed urban mobility patterns and accelerated processes of change that would otherwise have taken decades. The seven sources in this category (14.58% of the corpus) document both the immediate disruptions and the emerging patterns that shape the "new normal" of mobility.

4.6.1. Immediate Disruptions in Mobility Systems

The pandemic initially caused a drastic decline in public transport use due to lockdowns and fear of contagion (World Bank Blogs, 2020). The European Parliament (2020) documents reductions of up to 90% in passenger numbers during the strictest lockdown periods, causing severe financial crises for public transport operators that depended on fare revenue.

Business Research Insights (2025) reports that the pandemic caused significant disruptions in the smart transportation market, leading to supply chain problems, a drastic reduction in demand for various transportation services, and subsequently delays or reductions in planned investments for smart transportation projects, including autonomous vehicles and intelligent traffic management systems.

However, UN-Habitat (2022) argues that the crisis also highlighted the critical need for resilient, coordinated, flexible, and dynamic transportation systems. The pandemic forced a fundamental reassessment of the unsustainable urban development models that prevailed before 2020, exposing systemic vulnerabilities and prompting cities to prioritize adaptability and sustainability as fundamental and proactive principles.

4.6.2. Emerging New Patterns and the "New Normal"

UN-Habitat (2021) documents that the pandemic acted as a catalyst for new mobility habits, including

greater reliance on non-motorized transport and the need for adaptable public services. A significant increase in cycling and walking was observed, particularly in cities that implemented temporary infrastructure for active modes.

The European Parliament (2020) identified the emergence of a "new normal" characterized by: (a) increased demand for flexible, round-the-clock service options, influenced by the rise of hybrid and remote working models; (b) high expectations for hygiene and distancing on public transport; (c) a preference for individual or shared modes of transport with small groups; and (d) greater adoption of digital tools for trip planning and payment.

ASCE (2025) confirms that, as passenger numbers recover, these new patterns show signs of permanence. Travel patterns have become fragmented, with less pronounced peaks in demand and a more even distribution throughout the day, which has significant implications for service planning and resource allocation.

The pandemic accelerated transformations that would likely have taken years under normal conditions. World Bank Blogs (2020) argues that Latin American cities, in particular, were forced to rapidly adapt their urban transport models, implementing innovative measures that would otherwise have faced institutional and political resistance. This forced acceleration offers valuable lessons about the adaptability of urban systems and citizens when circumstances demand it.

5. Conclusions and discussions

The technological transformation of urban public transport during the period 2020-2025 reveals a convergence of interrelated innovations that are reshaping traditional mobility paradigms. A significant finding is the interdependence between technological innovation and supporting infrastructure. Li et al. (2025) warn that the transition to electric fleets requires comprehensive planning of energy systems, charging infrastructure, and optimized depot operations. MaaS platforms are emerging as instruments of urban governance; the International Association of Public Transport (2020) states that "MaaS should be a tool to guide behavior toward more sustainable modes" (p. 4).

The case of DiviaMobilités in Dijon (Keolis North America, 2025) demonstrates how multimodal integration can promote sustainable mobility options. However, global projections contrast with the limitations of intermediate cities, where financial constraints and institutional weakness hinder technological adoption (Ekpenyong et al., 2025). The success of emerging technologies critically depends on simultaneous investments in infrastructure, adaptive regulatory frameworks, and user-centered design.

Analysis of cultural adaptation reveals complexities that transcend linear explanations. Taylor and Morris (2025) document that Generation Z exhibits a notable decline in attachment to car ownership, prioritizing affordability and environmental impact. However, López-Carreiro and Monzón (2025) found that perceptions of climate change lack significant predictive value in individual modal choice, evidencing a disconnect between widespread awareness and individual action. Barriers persist: Redman et al. (2019) identify negative perceptions of service quality as significant deterrents, while Ekpenyong et al. (2025) document "car orientation" as a deep cultural barrier. The case of Transmicable in Bogotá (Rodríguez & Vergel-Tovar, 2023) reveals that informal transport persisted, complementing the formal system and satisfying local needs that the latter did not address. Cultural adaptation is the most complex factor in modernization; behavioral change requires multidimensional strategies that articulate tangible personal benefits with social contributions, segmented according to generational characteristics.

Urban governance shows significant evolution in the conceptualization of the citizen's role. Naifman (2025) states that citizen participation is crucial for citizen-centered smart cities. Mellouli and Komninos (2025) document the transition from passive data sources to "active elements of the planning process." IE Business School (2020) argues that co-creation guarantees solutions "for and with the people." The University of Cambridge (2023) maintains that policy frameworks must be flexible and responsive to changing needs. The United Nations Human Settlements Program (2022) emphasizes that smart cities must balance environmental, social, and economic needs with an emphasis on inclusion and equity. Trencher and Karvonen (2022) argue that success is measured by the ability to foster truly equitable environments. Effective governance requires adaptive structures that respond dynamically to technological and social changes, positioning social equity as a central criterion for success.

Case studies provide empirical evidence on determinants of success. The World Bank (2022) documents how Seoul demonstrates the effectiveness of data-driven planning and integrated systems; the T-money card achieved nearly 100% usage, demonstrating successful cultural integration. Helsinki exemplifies a holistic approach by combining incentives for electric vehicles, car-free zones, and cycling infrastructure (World Economic

Forum, 2025a). However, Swisscontact (2023) documents that intermediate cities face distinctive challenges: infrastructure limitations, dependence on informal modes, and financial constraints. The World Economic Forum (2020) identifies cross-cutting principles for success: committed political leadership, multimodal data integration, and active citizen participation. Intermediate cities should focus on adapting transferable strategic principles to their specific contexts, prioritizing context-sensitive innovation over direct technology transfer.

The forward-looking vision reveals technological convergence and growing integration between the digital and physical realms. Li et al. (2025) define "Transportation 5.0" as the fusion of electrification, shared mobility, artificial intelligence, and smart infrastructure. Naifman (2025) documents how Digital Twins will enable infrastructure design optimization and scenario simulations. The World Economic Forum (2025b) identifies the optimization of first- and last-mile travel as a critical area. The United Nations Human Settlements Program (2022) argues that future development will prioritize resilience and green investments. However, Ekpenyong et al. (2025) warn that sociocultural attitudes toward the automobile remain significant barriers. Wang and Chen (2025) emphasize that innovations must be designed to improve universal accessibility, avoiding exacerbating inequalities. The development trajectory must confront persistent challenges related to cultural inertia, institutional constraints, and risks of deepening existing exclusions.

The COVID-19 pandemic was a disruptive event that transformed mobility patterns and accelerated processes of change. The European Parliament (2020) documents reductions of up to 90% in traffic during lockdowns. However, the United Nations Human Settlements Program (2022) argues that the crisis highlighted the need for resilient and flexible systems. Emerging patterns show permanence: the American Society of Civil Engineers (2025) confirms greater demand for flexible options influenced by hybrid work. Experience shows that rapid transformation is possible when there is contextual pressure and political will, offering lessons on the adaptability of urban systems.

Finally, the modernization of urban public transport transcends the technical exercise to become a profound social and cultural process. Success depends on articulating technological innovation, understanding cultural adaptation, citizen participation, and responsive governance in an integrated approach.

Citizen cultural adaptation represents the most complex variable in modernization. Behavioral changes cannot be forced through the provision of technological alternatives; they require strategies that articulate tangible personal benefits with social and environmental contributions.

Intermediate cities face distinct challenges that require adaptive and specific solutions, focused on scalable principles rather than the direct transfer of models from megacities.
Adaptive governance is a fundamental requirement. Institutional frameworks must evolve into dynamic structures capable of learning from data and citizen feedback, adjusting policies to the pace of technological change.

Social equity must be positioned as a central criterion for success. Technological advances must be designed to reduce existing inequalities, ensuring universal accessibility and attention to vulnerable populations.

The forward-looking vision points toward a convergence of digital and physical urbanism, where the primacy of human behavior remains crucial. Technology can facilitate and optimize, but it cannot replace the citizen-centered approach required for the cultural transformation toward sustainable urban mobility.

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