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Article

# Urban Circularity and Knowledge Territories in Latin America: Governance and Social Participation in Sustainable Mobility

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## Abstract

The intensification of urbanization and the environmental crisis highlight the need for new paradigms of sustainable urban development, in which mobility plays a central role. This article analyzes sustainable urban mobility initiatives in Latin American knowledge territories through a comparative framework that integrates Knowledge-Based Urban Development (KBUD) and urban circularity principles. Grounded in the Fourth-Generation Knowledge Territories (TC4) perspective, the study focuses on governance models and social participation as drivers of transformative mobility practices. Methodologically, it adopts a qualitative and exploratory case study approach, combining primary data from field visits with secondary sources such as legislation, institutional documents, and technical reports. Despite the proliferation of science parks and innovation districts in Latin America, little is known about how governance and social participation shape sustainable mobility initiatives in these contexts, particularly when analyzed through the combined lenses of KBUD and urban circularity. The comparative analysis reveals varying degrees of openness and limitations in urban mobility governance across the three territories selected (Distritotec-Mexico, Parque Patricios-Argentina, e Porto Digital-Brazil). The findings reveal distinct governance configurations and degrees of alignment with circular mobility principles. Distritotec stands out for its multistakeholder governance and community-led mobility initiatives, reflecting efforts to operationalize the quintuple helix model. Parque Patricios shows fragmented integration between infrastructure improvements and participatory planning, while Porto Digital presents limited articulation between innovation policies and sustainable mobility, with centralized governance and low public engagement. Persistent challenges observed throughout the cases include the weak institutionalization of citizen participation, insufficient strategies to disincentivize private car use, and a lack of data governance mechanisms.

**Keywords:** sustainable urban mobility; knowledge territories; Latin America; urban circularity

## 1. Introduction

The intensification of urbanization and the growing environmental crisis have fostered the emergence of new paradigms for sustainable urban development, among which the Knowledge-Based Urban Development (KBUD) model stands out. KBUD articulates knowledge as a core element for driving economic growth, sociocultural advancement, and environmental responsibility, promoting urban sustainability through vitality, equity, quality of life, and shared prosperity [1].

In this context, Knowledge Territories (KT), which include science and technology parks, innovation districts and university campuses, play a strategic role in promoting urban circularity. These areas can operate as urban living laboratories for the co-creation, experimentation, and diffusion of circular solutions, integrating knowledge, innovation, and the active participation of diverse stakeholders [2]. Their evolution mirrors the increasing complexity of innovation models, transitioning from linear academia-industry relations to the quintuple helix, which incorporates government, civil society, and the environment as key innovation agents [3–5].

Although KT encompasses a wide range of urban dimensions - including housing, public space, energy, and security - this paper focuses specifically on urban mobility, since it is a key enabler for implementing Science and Technology Parks (STP) and Innovation Districts (ID), functioning as a transversal condition that integrates sociocultural diversity, economic vitality, spatial connectivity, and institutional governance within KBUD. Accessibility, connectivity, amenities, and high-quality environments are closely linked to a territory's innovation capacity and its ability to attract and retain knowledge workers as well as investments [6,7].

The integration of circular economy principles into KBUD consolidates an approach that challenges the linear “extract-produce-dispose” model by fostering urban systems based on regeneration, reuse, and resource optimization [8]. This transition demands systemic transformations in governance, public policy, and participatory planning, requiring KT to embed themselves in the broader urban fabric and contribute to regional development beyond their physical boundaries [9].

However, these models are not without criticism, mainly in the Global South, their implementation often encounters structural barriers: weak institutional coordination, policy discontinuity, dependency on fiscal incentives, and limited integration among key actors [5,10,11]. Furthermore, without robust social safeguards, KTs may contribute to gentrification and exclusionary dynamics [12,13].

Within this framework, sustainable urban mobility, adopted by this paper as a guiding concept, emerges as a foundational component of both circularity and knowledge-based development, enhancing spatial integration, environmental performance and also conditions the economic competitiveness and social inclusion capacity of innovation ecosystems. The use of private vehicles, which is common in urban transport, generates considerable negative impacts. These include environmental degradation, low energy efficiency, excessive land use for parking and road expansion, and increased traffic congestion. The reliance on private motorized vehicles also affects public health through air and noise pollution, traffic collision, and greenhouse gas emissions. Such consequences run counter to the principles of sustainable mobility and development. Therefore, to promote more sustainable transport, it is desirable to develop systems that integrate active mobility with public transportation - both in terms of infrastructure and services, while encouraging the reduction or elimination of private vehicle use [14].

KBUD is understood as a potential solution to current and future growth challenges. Fourth-Generation Knowledge Territories (TC4) [15] adopts an “interactive or feedback-based” innovation model, which emphasizes local community participation and environmental preservation, considering both its ecological relevance and its crucial importance to innovative firms within the KBUD framework [4]. This interactive model stands in contrast to the linear “science push” and “market pull” models characteristic of the first and second generations of STPs, which framed innovation as a process between academia and industry. In the first case, universities seek to create economic opportunities for themselves by pushing knowledge created within their boundaries to companies. In the second, industry entreated academia to produce solutions to their existing knowledge gaps [9].

With the collapse of these linear innovation paradigms and the emergence of new technologies such as artificial intelligence, nanotechnology, and biotechnology, along with the risks they entail and the escalating climate crisis, public and private higher education institutions have been compelled to redefine or redesign their roles in response to contemporary social challenges. In alignment with KBUD principles and in contrast to linear processes, theories, and practices, the

second concept examined in literature appears under the designations of “Circular Economy of Cities”, “Urban Circularity”, and the “Doughnut Economy”. These terms essentially refer to cities that adopt the principles of circular economy. Although they clearly share synergies, each term presents its own particularities (Figure 1).

	<b>Circular Economy in Cities</b>	<b>Urban Circularity:</b>	<b>Doughnut Economy</b>
<i>Scope / Focus</i>	materials and waste management within the urban context	encompasses all urban systems and their integration, and has broader scope	systemic, balancing social and ecological needs / human development and planetary boundaries
<i>Aims to Implement</i>	<i>...specific practices of recycling and reuse</i>	<i>...systemic transformation in urban management</i>	<i>...policies and practices that balance human needs with environmental sustainability</i>

Source: the authors based on [8,16].

**Figure 1.** Principles of the Circular Economy in Urban Contexts: Circular Economy for Cities, Urban Circularity, and the Doughnut Economy.

The Circular Economy for Cities applies circular economy principles to urban contexts, emphasizing the reuse, repair, refurbishment, and recycling of materials and products to create a closed-loop system that minimizes waste and resource consumption [16]. Urban Circularity is a broader concept that encompasses not only resource management but also how cities are designed and inhabited, aiming to foster sustainable and resilient urban environments that maximize human well-being. Embedded in the 2030 Agenda and the New Urban Agenda of the UN-Habitat III conference, urban circularity frames the circular economy as a development model that promotes sustainability through resource optimization and the adoption of cleaner technologies.

The Doughnut Economic Framework, in turn, builds upon the Sustainable Development Goals (SDGs) and seeks to reimagine our economy for the 21st century, aiming to meet social needs within environmentally safe and socially just boundaries. This framework offers a more holistic vision, striving to balance human well-being with planetary boundaries. Its innovation lies in the integration of social domains reflecting human development needs, which form the foundation of the doughnut model, alongside the Earth’s biophysical limits [17]. A city that adopts this model uses the principles of the circular economy as one of its core strategies to remain within both ecological ceilings and social foundations.

The implementation of circular economy principles in urban settings extends beyond technical considerations, involving a systemic transformation of society and a restructuring of economic and governance systems [18]. This has profound implications for how cities are planned, demanding an equilibrium between urban growth and sustainability, and promoting more efficient resource use and consumption reduction.

In this regard, innovation within both KBUD and Urban Circularity calls for a systemic approach, with cities fostering co-creation, co-design, and co-implementation processes involving multiple stakeholders, including government, the private sector, civil society, and local communities. Previous research has predominantly compared cases of KT in Europe, North America, and parts of Asia, most analyses remain at the meso (regional) scale and focus on innovation, or economic

development. Yet, studies adopting a micro-level perspective remain scarce, particularly those examining the object and its proximate environment, as well as the localized dynamics that shape this micro-universe — especially in the Global South and within the lens of sustainable urban mobility.

This article examines sustainable urban mobility initiatives in Latin American KT through a comparative framework that integrates the principles of KBUD and urban circularity. To understand how these dimensions support (or constrain) the transition toward more inclusive and sustainable urban futures, it focuses on governance and social participation from the perspective of TC4, which adapts KBUD concepts to the Brazilian and, more broadly, to the Latin American reality of extreme socioeconomic inequalities. The research question is: to what extent do KT in Latin America integrate governance and social participation to advance sustainable and circular urban mobility?

After this introduction, Section 2 develops the theoretical foundation, discussing KBUD and how it relates to urban circularity, followed by the overview of the case studies. Section 3 presents the methodological approach adopted in the study. Section 4 provides the empirical analysis of the three cases. Finally, Section 5 offers the concluding remarks.

## 2. Theoretical Background and Case Studies Overview

This section outlines the theoretical framework based on KBUD and urban circularity, and subsequently presents an overview of the three case studies - distritotec, Parque Patricios, and Porto Digital.

### 2.1. Knowledge Territories from the Perspective of Urban Circularity

In the context of KBUD, urban mobility becomes increasingly relevant as institutions such as corporations, universities, research centers, and housing developments establish themselves in a given region. This process typically coincides with population growth and trip generation, thereby demanding expanded transport infrastructure and affecting local traffic patterns. The resulting impacts vary significantly, depending on urban planning policies, investments in public transit and active mobility, sustainable mobility strategies, and the overall efficiency of the existing transportation system.

Within the framework of urban circularity, cities are expected to be accessible to all through safe and sustainable public transport, aiming to reduce private motor vehicle dependence and to promote ecological alternatives [19]. Consequently, there is an emphasis on fostering more sustainable and efficient transportation systems, the adoption of low-emission mobility modes, and the integration of active mobility with public transit networks [20]. These measures can be supported by the use of Information and Communication Technologies (ICTs) to discourage private vehicle use [21].

Moreover, urban planning should prioritize the development of infrastructure that facilitates sustainable mobility and implement land use patterns that promote compact and densely populated urban environments, thereby minimizing travel needs (Schlesier, 2024). While urban circularity emphasizes the integration of circular economy principles into urban systems, KBUD positions knowledge as a catalyst for economic growth and innovation. These frameworks are mutually reinforcing, offering complementary strategies for sustainable urban transformation and supporting the consolidation of TC4.

KBUD is structured around four key dimensions: sociocultural, economic, spatial, and institutional. The sociocultural dimension focuses on building a knowledge society by fostering the production, circulation, and information governance, while promoting social equity by valuing human capital and cultural diversity. The economic domain treats endogenous knowledge as a strategic resource that drives innovation and informs financial decision-making in productive processes. The spatial dimension aims to preserve and enhance both natural and urban environments, linking the growth of urban areas to knowledge clusters through sustainable initiatives. The institutional dimension underscores the democratization and humanization of

knowledge, encouraging collective learning and civic vision. KBUD should be guided by principles such as institutional leadership, good governance, strategic planning, and socio-political equity [1].

The feedback-based innovation model requires close interaction with local communities and environmental stewardship, which are fundamental for KBUD. These elements are not only socially and ecologically significant but also serve as catalysts for innovation and sustainable economic development [3,21,22]. Although co-creation within feedback-oriented models remains a considerable practical challenge, it is one of several pathways for community engagement in TC4. Additionally, there is potential for inclusive governance arrangements that promote the active participation of civil society representatives in decision-making processes. Public involvement in policy development, project evaluation, and regular consultation mechanisms is essential. Furthermore, urban spaces in innovation districts should be designed to encourage public use and foster serendipitous encounters among diverse groups through inclusive urban planning and a vibrant events calendar [22–24].

In this regard, the literature on urban circularity highlights the importance of addressing the city as a whole, encompassing both local and global perspectives [25]. The necessary transformation toward a “circular city” entails an iterative process of co-creative innovation and systemic change. This requires a reactive stance and also a proactive vision and the mobilization of key stakeholders, rooted in collaborative and participatory governance, engaging citizens, public authorities, private organizations, and knowledge institutions in shaping the urban future. Social participation is thus fundamental for operationalizing the circular economy in urban contexts, emphasizing the involvement of citizens in urban planning decisions [26]. This can be achieved through public consultations, discussion forums, and other participatory mechanisms, ensuring that urban development policies respond to citizens’ real needs and promoting a more inclusive and equitable society [25].

Urban circularity has been explored in several domains, including urban planning [27] and mobility [14,20]. This conceptual and practical framework, when applied to urban mobility planning, may support the development of transportation systems that are more equitable, sustainable, and efficient, and that meet people’s needs while respecting planetary boundaries. Addressing such complex urban challenges demands new governance arrangements, based on the collaboration and coordination of multiple actors. As such, multilevel governance structures are necessary to ensure the alignment of strategies, policies, and public needs [27].

Governance plays a crucial role in translating theory into practice, particularly given the complexity of contemporary society. Its importance is underscored in various theoretical approaches. While the Doughnut Model literature focuses primarily on global governance systems, the KBUD literature emphasizes “good governance,” founded on principles of participation, rule of law, transparency, and accountability [28–32].

This study draws on perspectives from public administration and political science, incorporating public governance literature to offer a multilevel understanding of the roles played by actors and institutions in public policy. Theoretical frameworks such as networked and collaborative governance provide coherence across different contexts.

In a broad sense, governance in this study is defined as a complex and challenging decision-making process involving power relations that extend beyond the state. Literature suggests that governance practices are often shaped by internationally driven agendas (particularly by institutions like the World Bank) and should be built on the pillars of participation, rule of law, transparency, and accountability. However, implementation varies significantly across contexts, depending largely on institutional capacity and the state’s role [28–32].

This distinction is evident when comparing national and local governance levels. At the national scale, there tends to be greater distance from the population, making it necessary to rely on robust mechanisms for collecting and transmitting public input, perceptions, and delegations. Conversely, local governance institutions are often better positioned to engage communities and develop more integrated policies [32]. Nevertheless, persistent gaps remain, such as limited institutional and

organizational capacity and a lack of policy integration mechanisms. These challenges are especially relevant to the implementation of both urban circularity and KBUD, as they require integrated responses to nonlinear changes, tipping points, complex interactions, and feedback processes.

## 2.2. Overview of the Case Studies

Porto Digital, established in 2000, was created as a public policy initiative aimed at fostering the development of the information and communication technology (ICT) sector in Pernambuco [33]. This policy also sought to attract ICT talent and revitalize the historic Bairro do Recife, an area that incorporates architectural elements from various periods of Brazilian history, ranging from colonial to industrial times. Inspired by the theoretical perspective of the Quadruple Helix, the most advanced innovation model at the time, Porto Digital's governance is centralized under a Social Organization (Organização Social – OS) called Núcleo de Gestão do Porto Digital (NGPD). This organization comprises a specialized technical team and an administrative board of 19 members, including representatives from the municipal government (Recife City Hall), the State Government of Pernambuco, Porto Digital associates, business associations, the Federal University of Pernambuco, as well as renowned researchers and experts in ICT and culture.

Following a similar model nearly a decade later, Parque Patricios was established in 2008 with the objective of attracting ICT-focused enterprises. Located in one of the central areas of Buenos Aires, Argentina's capital city, Parque Patricios offers tax incentives and research scholarships to promote ICT-related activities. Unlike the case of Porto Digital, Parque Patricios displays a simpler governance structure, primarily centralized within the local government, with no formal involvement of external actors in strategic decision-making. Nevertheless, it was strategically positioned near higher education institutions and pre-existing ICT firms.

The distritotec initiative is the result of a process initiated during the 2010s, when crime rates reached alarming levels in Monterrey, the capital city of Nuevo León (Mexico), more specifically in Instituto Tecnológico y de Estudios Superiores de Monterrey's (ITESM) surrounding area. The murder of a university student led to an enrollment decline and a significant local population decrease. In response, ITESM began coordinating a reurbanization initiative in collaboration with local residents, municipal and state governments, and the business community. This district, characterized here as an example of the Quadruple Helix model, is self-described as an "urban community seeking to transform lives through the power of connection" [34].

Governed through a polycentric structure, distritotec features a resident council, a commission composed of ITESM representatives, private sector agents, innovation and urban development specialists, and a management committee responsible for supervising a public fund dedicated to supporting government-led projects within the district. These stakeholders are currently engaged in efforts to ensure the district's sustainable urban development, aligning their strategies with the Quintuple Helix framework.

## 3. Methodology

This study adopts a qualitative and exploratory case study approach, aimed at comparing governance models and sustainable urban mobility practices in KT in Latin America. The research design involves the integration of primary data (through field visits) and secondary sources, including institutional documents, legislation, and technical reports. Table 1 outlines the methodological steps followed in the study.

**Table 1.** Methodological Steps.

Step	Description	Type of Data	Source
A	Mapping of third- and fourth-generation knowledge territories located in Latin America	Secondary data	Anprotec, GIID, IASP, Inova Data BR
B	Selection of case studies: Parque Patricios (Buenos Aires, Argentina), Porto Digital (Recife, Brazil), and distritotec (Monterrey, Mexico)	Secondary data	Institutional websites, scientific and policy documents
C	Collection of data from the selected cases	Primary and secondary data	Technical missions with field visits and interviews (2024–2025). Review of institutional reports, legislation, scientific and policy documents
D	Identification of governance models and sustainable urban mobility initiatives	Secondary data + empirical observation	Local legislation, technical reports, on-site observation
E	Comparative analysis	Analytical framework	Indicators [24] and five analytical axes (Social Participation; Multilevel Governance; Modal Integration and Connectivity; Social Inclusion; Territorial Impact)

Source: the authors.

In the first stage, the identification and mapping of KT were based on the following databases: the National Association of Entities Promoting Innovative Ventures (Anprotec); the Global Institute on Innovation Districts (GIID); the International Association of Science Parks and Areas of Innovation (IASP); and Inova Data BR, a platform for integration of Brazilian science parks.

The inclusion criteria for case selection were: (i) location in Latin America; (ii) countries with democratic political regimes; and (iii) the presence of formal or potential university participation in governance. Based on these criteria, the following cases were selected: the Technological District (DT)

of Parque Patricios (Buenos Aires, Argentina), Porto Digital (Recife, Brazil), and distritotec<sup>1</sup> (Monterrey, Mexico).

In the second stage, we mapped governance models and urban mobility initiatives implemented within each KT. This was accomplished using information from institutional websites, legislation, and technical reports (secondary data), as well as field visits (primary data).

In order to analyze governance models related to urban mobility and to identify best practices, we applied the set of measures [24], based on their study of the cases 22@ Barcelona, Parc de l'Alba, Paris-Saclay, and Sophia Antipolis, located in Spain and France. These KTs are frequently cited in the specialized literature as representative cases of KBUD. They illustrate the transition from traditional science parks to more integrated and sustainability-oriented models, and have become benchmarks in the adoption of the quintuple helix approach to innovation. This model expands previous frameworks by incorporating not only universities, government, and the productive sector but also civil society and the environment as key components of the innovation ecosystem.

It is important to note that previous research employed the theoretical approaches of KBUD and urban circularity as interpretive frameworks to analyze governance and mobility practices in these cases, rather than assuming their comprehensive implementation [24]. Following the same approach, our study uses these frameworks to evaluate initiatives in Latin American KT without assuming their full realization.

These territories provide valuable input for the implementation of best practices in urban mobility, and these measures are categorized as follows (Table 2):

**Table 2.** Analytical categories and measures related to best practices.

Category	Measures Related to Best Practices
<b>Active mobility (Walking + Cycling)</b>	Promotion of walking and cycling
<b>Public and Road Safety</b>	Reduction of traffic injuries and urban violence
<b>Public Mass Transit</b>	Expansion, route creation, and financing mechanisms
<b>On-Demand Transport</b>	Flexible mobility services combined with ICTs
<b>Mobility Management</b>	Strategies to reduce vehicle traffic / restrictions on individual transport demand

Source: The authors.

Finally, the comparative analysis of urban mobility in the three selected cases was organized around five analytical dimensions: social participation and inclusion, multilevel governance, modal integration and connectivity, territorial impact, and spatial equity. The framework was developed by the authors on the basis of previous research on KBUD, urban circularity, and sustainable mobility [1,17,24,35]. Building on these contributions, we devised an evaluative tool inspired by Likert-type scales to enable a systematic comparison of governance and mobility practices across the cases. The five dimensions were aligned with the four theoretical domains of KBUD - economic, sociocultural, spatial, and institutional- and adapted to address mobility-related challenges specific to Latin American KT. Each dimension was assessed on a 1 to 5 ordinal scale, reflecting the observed degree of implementation, inclusiveness, and systemic articulation (Table 3).

<sup>1</sup> According to its branding, "distritotec" is written in lowercase to convey principles of horizontality, equity, and governance [34].

**Table 3.** Index scale and interpretive criteria.

Index	Meaning
5	Highly structured, inclusive, and multiscale governance or mobility system
4	Advanced model with strong institutional coordination, though with some gaps
3	Intermediate structure with relevant initiatives, but limited in scope or inclusiveness
2	Incipient structure with weak articulation or low societal engagement
1	Absence or critical weakness in mechanisms or observed outcomes

Source: The authors.

The index values were assigned based on a combination of secondary and primary data, enabling a standardized context evaluation across the three cases.

#### 4. Findings

Table 4 provides an overview of the three selected KT, highlighting their origins, institutional arrangements, and demographic and spatial characteristics.

**Table 4.** Cases key features.

Case	DT Parque			
	distritotec	Patricios	Porto Digital	
<b>Year of Establishment</b>	2012	2008	2000	
	TC Generation	3rd Generation	3rd Generation	
<b>Theoretical Model</b>	Innovation Model (Helix)	Quintuple Helix	Triple Helix	Quadruple Helix
	Country	Mexico	Argentina	Brazil
<b>Territory</b>	City	Monterrey	Buenos Aires	Recife
	Area (ha)	452	328	149
<b>Population (TC area)</b>	26,000	37,000	9,000	

Source: Authors' compilation.

After presenting the main characteristics of the three cases, the results are structured into four analytical subsections. Subsection 4.1 examines how the domains of KBUD are translated into mobility strategies, highlighting convergences with principles of sustainability and urban circularity. Subsection 4.2 explores social participation and governance constraints in mobility policies, emphasizing the extent to which the quadruple helix model is effectively incorporated. Subsection 4.3 discusses the scalability and territorial impact of mobility initiatives. Finally, subsection 4.4 addresses modal integration and equity in urban mobility.

#### 4.1. KBUD and Urban Mobility Strategies

Table 5 summarizes the relationship between the KBUD domains and urban mobility strategies in innovation districts:

**Table 5.** Urban Mobility in Knowledge Territories and the Domains of KBUD.

KBUD Domain	Pillar	Urban Mobility Implications in Knowledge Territories
<b>Economic Development</b>	Economy	Mobility has a direct impact on economic prosperity, as it facilitates interaction and collaboration among territorial agents and connects people to jobs, commerce, and essential services. Investments in efficient public transport systems and infrastructure enable the population to access training and employment opportunities, secure supply chains, and support the distribution of goods, thereby stimulating economic growth. Mobility planning aimed at reducing travel distances also contributes to lowering transport costs in terms of time and energy. This, in turn, fosters the creative economy by improving access to cultural venues and innovation hubs, while also encouraging local commerce and economic activity
<b>Sociocultural Development</b>	Society	Social equity refers to the ability to provide accessible urban mobility (both physically and financially) to the entire population, taking into account economic, cultural, racial, age, gender, and accessibility differences. It also aims to promote sustainable development and enhance quality of life. Social equity is further reflected in the creation of attractive, safe, and accessible public spaces, such as parks, squares, and recreational areas, as well as in the promotion of community gathering spaces
<b>Spatial Development</b>	Urban and Environment	Promotion of urban compactness aims to limit the area occupied by urban infrastructure and reduce residents' daily travel distances, thereby decreasing reliance on individual motorized transport. It also involves expanding and improving access to active mobility networks connected to public transport systems, in order to encourage the adoption of environmentally responsible modes of transportation
<b>Institutional Development</b>	Governance	A set of policies, role assignments, responsibilities, and processes that enable mobility within the KBUD framework, encompassing the KT's governance. This also includes local mobility governance, involving operators, concessionaires, public sector entities (such as municipal departments and technical teams), and participatory processes. These elements are fundamental for promoting innovation and development within KT Source: The authors, based on [35].

While Table 5 presents the KBUD domains and their implications for mobility in knowledge territories, Table 6 groups the observed practices into five functional categories that can be considered a way of operationalizing those domains [24]. Specifically, though not exclusively, active mobility reflects spatial and sociocultural concerns; public and road safety connects sociocultural equity and institutional stewardship; public mass transit expresses economic efficiency and spatial integration; on-demand transport links economic adaptability to spatial connectivity; and mobility management translates institutional governance and economic instruments into demand regulation.

**Table 6.** Best practices related to sustainable urban mobility in the studied Knowledge Territories.

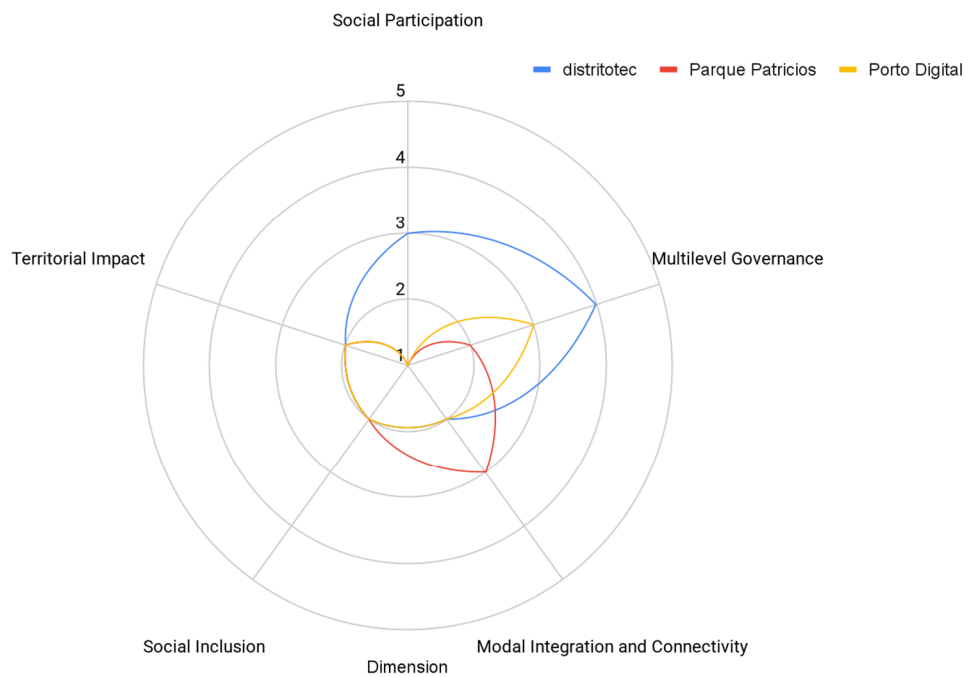
Category	Best practices in Knowledge territories (Stuchi, Alves e Serafim, 2024)	Identified Sustainable Mobility Initiatives		
		distritote c	Parque Patricios	Porto Digital
Active mobility (Walking + Cycling)	Campaigns to encourage the use of active modes	2	3	2
	Pedestrian-only streets	1	3	2
	Wayfinding strategies / marked walking paths	2	3	2
	Wide sidewalks (over 4 meters wide)	3	1	1
	Landscaping and tree coverage	3	3	2
	The district prioritizes pedestrian movement throughout	1	1	1
	Use of privately owned public spaces	3	1	2
	Cycle networks		3	2
	Cycle networks with 30km/h zones	1	3	2
	Bicycle-sharing systems	3	3	3
	Dockless bicycle-sharing systems	1	1	1
	Bicycle infrastructure such as parkings, lifts and maintenance and repair centers	2	1	1
Public and Road Safety	Last mile infrastructure around subway stations	1	2	1
	Electric bike sharing services (in partnership with startups)	1	1	2
	Active cyclist social media networks	1	1	3
	Calming traffic measures	3	3	3
	Residential areas with a maximum speed of 10 km/h	1	1	1
	Street hierarchy	1	3	2
	Connected public open spaces systems	3	3	3
Public Mass Transit	Pedestrian-oriented lighting (on and around sidewalks and crossings)	1	3	1
	Gender perspective integration into urban planning and design	1	1	2
	Integration between transport modes	2	3	
	New stations, lines and/or expansion of pre-existing lines	2	3	2
	Free intra-community buses to complement	3	1	1

	regular bus routes			
	Real time transit information through apps	3	3	3
	Bus lanes	1	3	1
	Integrated transit fare systems	1	2	1
	Clean energy-based public transit	1	2	1
	ODT options to complement existing public transit	3	3	3
<b>On-Demand Transport (ODT)</b>	On-demand bus services operating by zone, with last minute reservations	3	1	1
	On-demand bus services door-to-door buses for persons with disabilities	1	1	1
	Autonomous, electric and shared mobility (autonomous prototypes)	1	1	1
	Regulation of parking lots and garages	1	1	1
	Routing car traffic onto larger roads	1	1	1
	Implementation of mass transport lines and stations and general mobility systems improvement	1	3	2
	Rapid Transit and Cycling Networks	1	1	1
<b>Mobility Management</b>	Information and communication technologies	3	3	3
	Parking inventory for demand analysis	2	1	1
	Smart/ automated parking management	1	1	1
	Incentive parking management and coordination with local parking policy to promote modal shift towards public transport	3	1	1
	Aiming to reduce parking spaces to 1 for every 5 or, at most, 3 residences	1	1	1
	Reserved parking for car and ride sharing services	3	1	1

Source: The authors, based [24], complemented by institutional documents, legislation, scientific papers, technical reports, and primary fieldwork (2024–2025). Scores correspond to 3 = existing, 2 = under implementation, 1 = non-existent.

These distinct cases demonstrate best practices in sustainable urban mobility within KT. The different practices identified are summarized in Table 6, which categorizes them using the following score: (3) existing, (2) under implementation, (1) non-existent.

The categories summarized in Table 6 serve as the empirical basis for the comparative assessment developed in Sections 4.2-4.4, structured around the five analytical dimensions (assessed on a 1 to 5 ordinal scale) defined in the methodology and synthesized comparatively in Figure 2.



**Index Meaning**

- 5 Highly structured, inclusive, and multiscalar governance or mobility system
- 4 Advanced model with strong institutional coordination, though with some gaps
- 3 Intermediate structure with relevant initiatives, but limited in scope or inclusiveness
- 2 Incipient structure with weak articulation or low societal engagement
- 1 Absence or critical weakness in mechanisms or observed outcomes

Source: The authors.

**Figure 2.** Overview of Sustainable Urban Mobility Practices in Knowledge Territories.

KBUD Domain	Analytical Dimension	distritotec	Parque Patricios	Porto Digital
Sociocultural	Social Participation	(3): it features a formal governance body ( <i>Consejo de Vecinos</i> ) and a pioneering participatory structure aligned with KT principles; however, its role	(1): lacks effective participatory forums related to the KT; governance model is highly centralized	(1): lacks effective participatory forums related to the KT (although the establishment of a Thematic Mobility Chamber is foreseen within the framework of the Municipal Road



		remains purely consultative and its representation is limited to only 15 out of the 24 neighborhoods within the district		Safety Plan, it has not yet been implemented
	Social Inclusion	(2): vulnerable communities (Campana, Altamira) remain marginalized in terms of both access and distribution of benefits	(2): urban regeneration efforts primarily benefit institutional actors and private companies, without effectively incorporating the surrounding population	(2): measures do not reach peripheral neighborhoods
Institutional	Multilevel Governance	(4): quadruple helix model partially implemented, but ITESM remains dominant	(2): governed by law and governmental centralization	(3): governance model based on a Social Organization ( <i>Núcleo de Gestão do Porto Digital</i> ), with an administrative board that includes government, university, private sector, and experts. However, it shows low levels of public engagement
Spatial	Modal Integration and Connectivity	(2): local actions are fragmented (complete streets), scarcity of cycling infrastructure, limited integration with metropolitan public transport, and internal modes of	(3): metrobus Sur, metro line H, and cycling infrastructure, but with limited focus on distributive justice	(2): isolated active mobility initiatives; limited intermodal integration

transport are  
restrictive

Economic	Territorial Impact	(2): effects are concentrated surrounding the campus	(2): unequal distribution of improvements; impact concentrated in the north sector	(2): territorially limited impact
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#### 4.2. Multilevel Governance and Social Participation

This subsection examines multilevel governance and social participation in mobility policies. The comparative analysis mobilizes different KBUD domains and practice categories from Tables 5 and 6, with governance issues often intersecting institutional, sociocultural, economic, and spatial dimensions. The intensity of these interconnections varies across the three cases, depending on the degrees of openness to social participation and constraints to urban mobility governance across the three territories, highlighting the limited effective incorporation of the quadruple helix principles.

The case of *distritotec* presents an innovative example of participatory institutional governance in the Latin American context, by formally incorporating a neighborhood council - *Consejo de Vecinos* - as a deliberative body in territorial governance. This initiative reflects an effort to align with the quadruple helix model, involving representatives from the university, public authorities, the private sector, and civil society. However, participation remains limited to a consultative role and is constrained by the dominant influence of ITESM in the territory's strategic management. Moreover, only 15 out of the 24 neighborhoods officially encompassed by the district's boundaries have active council representation. In the case of neighboring socially vulnerable communities, such as *Campana* and *Altamira*, although not formally integrated into the institutional perimeter of *distritotec*, studies indicate that they comprise a significant portion of the local labor force and are directly affected by the dynamics of urban transformation. These circumstances underscore the need for greater inclusion of these communities in territorial planning and participatory processes [13,36]. Thus, although the governance arrangement represents progress compared to other innovation districts, its effectiveness depends on overcoming power asymmetries and enhancing participatory mechanisms [37].

Governance in *Parque Patricios Technology District* is marked by the local government's strong leadership, particularly following the enactment of Law 2972/2008 and the symbolic and administrative relocation of Buenos Aires' Head of Government to the neighborhood as a territorial revitalization landmark [38]. Although the district is embedded within a broader urban planning framework, linked to the Urban Environmental Plan - *Plan Urbano Ambiental* - and the activities of *Comuna 4*, effective instances of social participation remain limited. There is no evidence of deliberative forums that structurally and continuously incorporate local residents into the district's decision-making processes. This reflects a governance model centered on investment attraction and urban upgrading, with low permeability to the demands and perspectives of historically established communities in the area [10,39].

In the case of *Porto Digital*, the private sector has a leading role in its governance through the *Porto Digital Management Nucleus* (NGPD - *Núcleo de Gestão do Porto Digital*), a private non-profit organization, typified as a Social Organization, and Science and Technology Institution, by local and regional governments. NGPD is financially self-sustained and can, thus, operate independently from local governments, which is understood as its main advantage in promoting interaction between the

public, academia and companies [40]. It has a team of over 100 employees and an administrative board with 19 representatives: 7 from internal and external companies; 3 from local secondary and higher education institutions, 3 appointed by Recife's and Olinda's city governments; 4 appointed by Pernambuco State Government, and 2 elected civil society members with notable professional capacities in the fields of Architecture, Urbanism and Culture [40–42]. The Innovation Cluster was implemented in the aftermath of a regional plan to promote economic competitiveness in Brazil's Northeastern Region - *Iniciativa pelo Nordeste* - that aimed at fostering economic growth and competitiveness in Brazil's poorest region through clustering policies and incentives for its main industries, e.g., grain, tropical fruits and tourism. Information technology was added to the program with the aim of diversifying the local economy [40,43].

#### 4.3. Scalability and Territorial Impact

Based on the KBUD domains and practice categories presented in Section 4.1, the analysis reveals the limited scalability of urban mobility best practices across the three territories. In the case of *distritotec*, urban transformations have primarily focused on the university campus and its immediate surroundings, with notable improvements in road infrastructure and public space activation. These interventions, mainly led by ITESM in collaboration with the municipal government and private actors, indicate a territorial development strategy oriented toward planned densification and urban revitalization. However, the diffusion of these effects beyond the campus' contiguous areas remains limited. A significant portion of communities within the district, including peripheral neighborhoods such as Campana and Altamira, continue to face structural challenges related to mobility, basic infrastructure, and access to urban services. Although the growth in residential population and economic activity suggests a degree of territorial dynamism, there is insufficient evidence that such changes are equitably distributed across the territory [13,34].

In *Parque Patricios*, the impacts are unevenly distributed throughout the territory. The multiscale analysis [44] shows that land value appreciation and changes in land use are concentrated in the northern sector of the district, closer to the city center and benefitting from pre-existing infrastructure, while southern areas remain marked by low investment and urban decline. This selective urban renewal undermines the scalability of the model, which appears effective only in already consolidated parts of the district.

The strategic plan for the central area developed by Recife City Hall entitled "*Centro do Recife Na Rota do Futuro*" [45] presents the "*Centro em Movimento*" program, consisting of pillars to promote safe walkability, including the *Porto Digital* location, as well as the development of cycling and public transport infrastructure in the region. However, these guidelines have not yet been effectively implemented and private sector investments remain confined to the immediate surroundings of the park, with limited integration into adjacent neighborhoods where residents continue to face significant mobility constraints. The revitalization of downtown Recife has achieved economic and symbolic consolidation, positioning the area as a nationally recognized innovation hub. Moreover, although the ongoing *Novo Cais* road requalification project was neither conceived within nor anchored by the institutional actors of *Porto Digital*, its proximity to the *Bairro do Recife* and its potential effects on urban mobility and spatial configuration cannot be overlooked. The *Novo Cais* project, proposed as a strategy for urban integration and historical valorization, is located in a territory historically shaped by socio-spatial disputes, most notably, the urban conflict led by the *Ocupe Estelita*<sup>2</sup> movement, a grassroots mobilization that opposed the *Novo Recife* development, a high-end real estate project promoted by a consortium of construction companies.

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<sup>2</sup> In 2014 the "*Occupy Estelita movement*" brought many people onto the streets in opposition to the *New Recife* project. The movement is recognized as one of the main right to the city social movements in Brazil.

These patterns demonstrate that, despite the catalytic potential of the analyzed KT, urban mobility policies remain spatially concentrated. This territorial focus limits their capacity to drive structural transformations in the broader urban fabric.

#### 4.4. Modal Integration and Equity in Urban Mobility Access

Empirical evidence reveals differences among the analyzed KT in their capacity to promote modal integration and ensure equitable access to urban mobility. The assessment articulates all KBUD domains and practice categories (from Tables 5 and 6, respectively). While spatial concerns and sociocultural equity often receive greater emphasis, institutional arrangements and economic instruments also influence how integration and equitable access are achieved across the territories.

In *distritotec*, despite the implementation of 4 km of complete streets and localized efforts to encourage active mobility, the territory remains predominantly structured around private motorized transport [46]. Internal transportation systems such as *ExpresoTec* and *CircuitoTec*, though operationally efficient, are limited to ITESM students, faculty, and staff. *ExpresoTec* routes show minimal integration with the broader public transit network, prioritizing university-affiliated residential zones [47]. Additionally, service hours are synchronized with academic schedules, creating temporal gaps that restrict accessibility for non-university populations [46].

In *Parque Patricios*, substantial investments in urban mobility infrastructure, including the extension of Metro Line H, the introduction of the *Metrobús Sur*, and the expansion of the cycling network, have improved connectivity with central and consolidated urban areas, fostering intermodality and enhancing public transport efficiency. However, these accessibility gains have disproportionately benefited new users, particularly employees of ICT firms and government institutions. The long-standing and vulnerable resident populations have seen limited benefits, as most interventions have been concentrated in the northern section of the district, which already possessed superior infrastructure, while southern neighborhoods continue to suffer from deficient connectivity transport services.

In the case of *Porto Digital*, the implementation of active mobility measures, such as sidewalk expansion, street redesign, and pilot complete street projects, suggests incremental progress, though still geographically limited. Weak integration with the public transportation systems serving peripheral neighborhoods undermines the effectiveness of these interventions for the many workers and students who commute to the city center. The absence of a robust intermodal strategy that integrates public transit with active mobility modes (walking and cycling) compromises the systemic viability of sustainable mobility solutions. The ongoing *Novo Cais* project proposes road requalification improvements, primarily focused on expanding roadways to improve motorized traffic flow. In addition, given the history of evictions and land disputes in the *Cais José Estelita* area, the inclusive character of the intervention remains uncertain and potentially limited.

In light of the above, derived from the conceptual framework of KBUD (Table 5) and best practices related to sustainable urban mobility in the KT (Table 6) five analytical dimensions are used in the comparative assessment of the three innovation districts: Social Participation; Social Inclusion; Multilevel Governance; Modal Integration and Connectivity; and Territorial Impact (Figure 2).

These findings illustrate the need to strengthen mobility governance mechanisms, especially in third-generation KTs that still operate under linear or top-down governance logics. Practices such as investment in shared infrastructure, application of ICTs, and institutionalized participatory mechanisms remain unevenly implemented. The results resonate with international cases of KT, e.g., 22@ Barcelona, *Parc de l'Alba*, *Paris-Saclay*, *Sophia Antipolis*, where sustainable mobility is promoted, but car dependence and governance fragmentation persist [24]. However, in Latin America these challenges are exacerbated by structural inequalities and weaker institutional capacities, which limits the consolidation of integrated and participatory mobility strategies. In line with the *Doughnut* framework, achieving sustainable mobility requires not only reducing environmental footprints (e.g., emissions, land consumption) but also addressing structural

inequalities in urban access and mobility rights [14]. A comprehensive governance strategy is thus essential to bridge gaps between technical planning and social inclusion.

## 5. Discussion

The transition toward urban circularity entails deep transformations in institutional structures, territorial configurations, and sociotechnical systems. When analyzed through the lens of KBUD, sustainable mobility emerges, beyond a technical domain, as a central mechanism for enabling inclusive, regenerative, and innovation-oriented territories. Mobility, thus, becomes a transversal axis connecting the environmental, economic, social, and spatial dimensions of urban transformation [35].

Drawing on the analytical framework developed in previous research [24], this study assessed mobility practices across three Latin American KT - *distritotec*, *Parque Patricios*, and *Porto Digital* - considering their integration of active mobility public mass transportation; accessibility; public and road safety; digital tools, and governance mechanisms.

The findings reveal different configurations and trajectories for the three KT. *Distritotec* stands out for its plural governance, rooted in the involvement of multiple stakeholders including universities, local government, residents, and the private sector. The implementation of walkable streets, wayfinding systems, and community-led initiatives reflects an effort to embed sustainable mobility within the territory's urban fabric and to align it with principles of the quintuple helix.

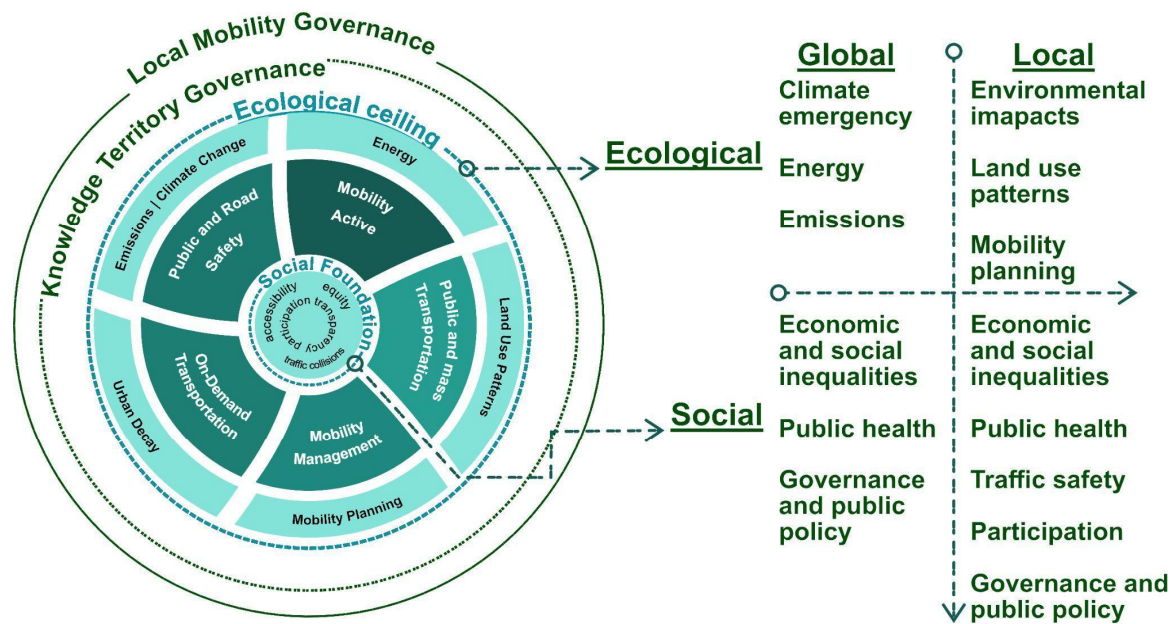
*Parque Patricios*, although centrally located and supported by metropolitan investment, demonstrates a more fragmented picture. While improvements in public transport infrastructure and bicycle lanes have been observed, the governance model remains primarily state-led, limiting the institutionalization of participatory mechanisms. Furthermore, integration between planning efforts and the surrounding communities has yet to be consolidated.

*Porto Digital*, despite being one of the earliest cases and home to a consolidated ecosystem of innovation, shows a limited articulation between knowledge production and sustainable mobility. The territory has yet to internalize mobility as a structuring dimension of urban circularity. Most of the mobility-related measures mapped through the lens proposed in [24] are either absent or underdeveloped, and governance remains heavily centralized in a single organizational structure, with limited channels for public engagement.

While the literature suggests that local governance institutions are generally better positioned to engage communities and formulate integrated policies, the cases analyzed here demonstrate that this potential is only realized when there is explicit recognition that community participation is a constitutive part of the territorial development process [32]. This finding resonates with the collaborative governance literature, indicating that it is not the institutional scale itself that ensures engagement, but rather the capacity of governance arrangements to recognize the community as an active subject in the process of urban transformation.

These observations reinforce the argument that sustainable mobility is not achieved solely through infrastructure provision or isolated pilot projects. Rather, it requires a governance model capable of fostering cross-sectoral collaboration, ensuring accountability, and actively involving citizens in planning and monitoring processes [14]. This implies expanding the institutional capacity to integrate different domains of policy and knowledge, as well as creating enabling environments for participatory experimentation and innovation [29,30].

To further situate the evidence, the analysis is interpreted through the Doughnut framework (Figure 3), which has been adapted to sustainable urban mobility.



Source: the authors, based on [17,24].

**Figure 3.** Sustainable Urban Mobility Represented within the Doughnut Framework.

Through this framework, sustainable mobility practices are situated within ecological ceilings and social foundations, exposing contributions and persistent gaps across the three territories. It underscores that continued car dependence, fragmented governance, and weak participatory mechanisms constrain the realization of sustainable mobility and, at the same time, hinder the alignment of KT with the broader goals of urban circularity.

## 6. Conclusion

This study examined sustainable urban mobility in three Latin American KT through a comparative case-study design that combined fieldwork with secondary sources. We adopt sustainable urban mobility as a governance-driven socio-technical transition that simultaneously reduces environmental externalities—such as greenhouse-gas emissions and local air pollution—and expands safe, affordable, and timely access to urban opportunities, especially for historically marginalized groups. Our stance is framed by two complementary lenses: KBUD, which foregrounds institutions, knowledge infrastructures, and learning; and urban circularity, informed by the Doughnut framework, which requires staying within ecological ceilings while meeting social foundations. The research draws on perspectives from the fields of public administration, public governance, and political science to understand how governance models and social participation affect the development and implementation of public policies related to KBUD, focusing on transformative mobility practices.

Empirically, the analysis shows uneven progress on measures typically associated with durable sustainable urban mobility transitions. Disincentives of private car use remain weak, reflecting a broader challenge in operationalizing circular principles at the local level. Parking regulation, demand management strategies, and digital integration remain insufficiently explored, even though they are essential components of a transition toward low-carbon and inclusive urban systems. Such measures must be complemented by data governance, open access to information, and the creation of urban living labs capable of generating actionable knowledge and iterative learning.

In line with the Doughnut framework, mobility systems must mitigate environmental pressures and also guarantee equitable access to urban opportunities, particularly for historically marginalized

groups. The operationalization of this agenda, however, requires confronting institutional inertia, bureaucratic fragmentation, and uneven distribution of technical and financial resources.

The contribution of this study is threefold. Conceptually, it specifies how sustainable urban mobility can be operationalized within KBUD and circular-city logics by linking environmental targets to governance capabilities and equity outcomes. Diagnostically, it identifies concrete policy gaps—parking management, demand management, and platform interoperability—whose absence, more than a lack of visionary planning, underpins implementation bottlenecks. Practically, it highlights feasible governance levers at KT scale, including institutionalized urban living labs, open-data policies with common standards, and co-production arrangements that connect citizen input to iterative policy updates. These findings imply that aligning KBUD with urban circularity requires moving beyond pilots and narrative commitments to reconfigure everyday rules and incentives: adopting integrated parking and pricing regimes tied to improvements in public and active mobility; mandating data sharing and interoperability among operators; and embedding inclusive participation in statutory procedures such as budgeting and performance audits.

## 7. Limitations and Future Research Directions

This research presents limitations related to the analysis based on a small set of cases which may limit the depth of contextual understanding. In addition, the use of a self-constructed evaluative index (1–5 scale), while useful for systematizing comparisons, inevitably involves interpretive judgment by the researchers, introducing potential subjectivity in value attribution and limiting replicability in other contexts. The analytical measures also draw on European benchmarks—such as 22@ Barcelona, Parc de l'Alba, Paris-Saclay, and Sophia Antipolis—that, although widely recognized in the literature, may not fully capture regional specificities of Latin American contexts, including informality and institutional fragilities.

Future research should expand the comparative universe to build a governance typology for sustainable urban mobility under KBUD; develop and test indicators and metrics capable of capturing the co-benefits of mobility systems in circular cities, such as improved air quality, spatial equity, and innovation spillovers; investigate the dynamics of citizen engagement and the role of digital tools in co-producing mobility solutions remains a promising avenue; trace causal effects of specific instruments—parking pricing, low-traffic zones, integrated fares—on mode share and access for vulnerable groups using mixed methods; and examine how open data, APIs, and civic-tech platforms shape participation quality and implementation fidelity amid digital inequalities in Global South contexts

Overall, progress toward sustainable urban mobility in Latin American KT depends less on new rhetoric than on redistributing power and accountability across agencies and operators, institutionalizing inclusive governance and data practices, and coupling credible disincentives for car use with integrated and equitable alternatives.

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