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Smart City Development under EU Mobility Regulations: Linking Transport Constraints, Green Infrastructure and 3P (Public-Private-People) nexus

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Abstract

European cities face increasing constraints related to traffic congestion, emissions, and spatial pressure, which affect both logistics efficiency and quality of life. In response, the New EU Urban Mobility Framework (2021) and the Greening Freight Transport Package (2023) promote more integrated approaches to sustainable mobility, green logistics, and environmental resilience. Against this background, the article analyses how transport systems, urban green spaces (UGS), and Public-Private-People (3P) nexus are combined in practice to support more sustainable and adaptive forms of urban development. The study is based on qualitative research using semi-structured interviews with urban experts from the public sector, private logistics operators, and community organisations in Barcelona and Singapore. The two cases represent contrasting governance models: Barcelona's participatory approach, which links mobility restrictions with the reconfiguration of public space, and Singapore's highly centralised model, in which green infrastructure is embedded in long-term transport and logistics planning. The results show that while the European regulatory framework provides a clear strategic direction, its effectiveness depends on local governance arrangements and implementation capacities. Respondents highlighted that UGS often support not only environmental and recreational functions but also everyday mobility and neighbourhood-scale accessibility. At the same time, integration generates coordination challenges related to spatial trade-offs, institutional fragmentation, and operational constraints. The findings indicate that policy goals are broadly transferable, whereas governance mechanisms and implementation paths remain strongly context-dependent. The article contributes to debates on smart city development by showing that the integration of transport regulation, green infrastructure, and the 3P nexus is shaped less by individual policy instruments than by the capacity to embed them within coherent and context-sensitive governance frameworks.

Keywords: Urban Logistics; Green Logistics; Smart Cities; Urban Green Spaces (UGS); Sustainable Mobility; 3P nexus; Sustainable Management

1 Introduction

Contemporary cities face growing pressure related to mobility and the environment, including congestion, conflicts over street space and transport externalities. In car-dominated cities, streets primarily serve as capacity infrastructure, which in the long term weakens social relations and the quality of the living environment (Appleyard, 1981; Newman & Kenworthy, 2015; Brdulak & Brdulak, 2017). This "car dependency" perpetuates traffic demand and amplifies the negative impacts of transport at local and metropolitan scales (Banister, 2008; Newman & Kenworthy, 2015). Mobility-related environmental pressure includes emissions as well as health and well-being stressors. Climate change further increases the vulnerability of mobility and infrastructure systems. Resilience research highlights the need to strengthen the adaptive and transformative capacities of cities (Holling, 1973; Folke et al., 2010).

Sustainable mobility and green infrastructure increasingly form a combined set of interventions in urban space. In this study, 'smart city development' is conceptualised as the institutional capacity of urban governance to synthesise mobility regulations, green infrastructure, and social agency within a unified adaptive framework (Brdulak, in press). While 'smartness' provides the data-driven and regulatory infrastructure for this integration, 'urban resilience' is viewed as the resulting property of the system to learn, adapt, and transform under uncertainty

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(Brdulak, in press; Folke et al., 2010). Sustainable mobility shifts the focus from maximising capacity towards accessibility (Banister, 2008; Cervero, 2013), while high-quality public spaces remain a prerequisite for behavioural change (Gehl, 2010; Carmona, 2019). This triad is operationalised through the Public-Private–People (3P) nexus, where 'smartness' is measured by the quality of institutional learning and trust-based cooperation, enabling cities to transform regulatory pressures into opportunities for social-ecological renewal (Brdulak, in press; Kabisch et al., 2017).

The article places these challenges in the European political and regulatory context, where EU frameworks reinforce the transition towards low-carbon mobility. This corresponds to a shift away from car-based planning (Banister, 2008; Newman & Kenworthy, 2015) and supports practices improving the quality of urban life (Gehl, 2010; Carmona, 2019). However, a critical research gap persists in understanding how relational governance mechanisms within the 3P nexus bridge the tension between strategic mobility goals and the operational maintenance of green infrastructure (Brdulak, in press). While existing literature often privileges infrastructural robustness (Banister, 2008; Cervero, 2013), this study identifies resilience as a co-produced outcome of multi-actor negotiations under severe spatial and regulatory constraints (Brdulak, in press; Ostrom, 2009).

The aim of this article is to identify and compare governance mechanisms that support urban resilience through the integration of mobility and green infrastructure, analysed in relation to the European political and regulatory framework in urban mobility. Particular attention is paid to cross-sectoral cooperation within the 3P nexus. The selection of Barcelona and Singapore follows a logic of analytical complementarity (Flyvbjerg, 2006), contrasting a decentralised European deliberative system with a centrally coordinated model. Singapore is included not as an EU-emulating entity, but as a global benchmark for environmental integration under extreme density. This juxtaposition provides an essential 'analytical contrast' for EU frameworks, allowing us to test whether universal sustainability goals can be effectively scaled and implemented through fundamentally different institutional pathways (Banister, 2008; Cervero, 2013; Barter, 2004; Phang, 2018).

The article addresses three research questions:

RQ1: What institutions, policies and implementation mechanisms shape urban resilience through the integration of mobility and green infrastructure in Barcelona and Singapore?

RQ2: How does cooperation in the Public-Private-People (3P nexus) affect the effectiveness and sustainability of mobility and green infrastructure measures?

RQ3: Which elements of the solutions used in Barcelona and Singapore show potential for transfer to other urban contexts, and which are strongly dependent on institutional and cultural conditions?

The article also contributes to the theoretical discussion on urban resilience by showing that the integration of mobility and green infrastructure depends on governance configuration rather than on individual instruments alone. It treats resilience as a governance-dependent process and uses the comparison of Barcelona and Singapore to identify contrasting pathways of resilience-building in urban mobility.

These questions combine a theoretical perspective with empirical analysis and focus on the implications for the development of smart cities, understood as the ability of cities to integrate mobility, environmental and social policies in the face of growing regulatory constraints (Brdulak, in press).

2 EU regulatory and institutional framework

The EU framework for mobility, climate and urban development does not function as a uniform regulatory code for cities, but rather as an architecture of principles, objectives and instruments of indirect influence. It relies mainly on 'soft' mechanisms that set priorities, condition funding and support planning. Its strength lies in steering transformation, while implementation depends on national and local conditions, including institutional capacity, political costs and public acceptance.

A consistent element of this architecture is the overarching mandate of decarbonisation and the reduction of environmental pressure. The European Green Deal (COM/2019/640) prioritises climate objectives and strengthens the legitimacy of measures that reduce car traffic (European Commission, 2019). However, implementation may trigger resistance when transition costs are perceived as unevenly distributed.

A second key principle is the shift from a capacity-oriented paradigm towards accessibility. The Sustainable and Smart Mobility Strategy (COM/2020/789) promotes demand management, multimodality and emission reduction (European Commission, 2020). This corresponds to the paradigm shift described in the literature, in which cities are planned as systems of accessibility rather than maximising car traffic (Banister, 2008; Newman & Kenworthy, 2015). In practice, climate objectives may conflict with economic and logistical pressures, resulting in selective use of transformation instruments.

A third element of the EU framework is sector integration, in which urban mobility is linked to health, safety and the quality of public space. The New EU Urban Mobility Framework (COM/2021/811) supports integrated planning and strengthens implementation tools such as SUMPs (European Commission, 2021). This shifts the mobility debate towards quality of life and public space, where behaviour change depends on streets being safe,

comfortable and attractive for active mobility (Gehl, 2010; Carmona, 2019). As a "soft" framework, UMF does not remove implementation barriers, and effectiveness depends on the capacity of cities to consistently reallocate space and maintain policies over time.

Urban logistics is a particularly difficult component of the transition. The Greening Freight Transport Package (2023) reinforces freight decarbonisation and promotes intermodal solutions (European Commission, 2023). For cities, the last mile becomes both a strategic area of intervention and a source of conflict related to access, delivery organisation and operating costs. Research on sustainable mobility indicates that the day-to-day operation of the system often determines public acceptance and the durability of reforms (Banister, 2008; Cervero, 2013; Iwan et al., 2024). A purely technological approach to freight decarbonisation, without organisational adaptation, may shift transition costs to small businesses and local services.

Another element of the EU framework is its normative dimension. The New Leipzig Charter (2020) promotes integrated urban development and frames the reallocation of street space in terms of fairness, accessibility and quality of life (European Union, 2020). These objectives may generate tensions if implementation mechanisms do not address distributional effects.

The institutional dimension is also relevant. The Urban Agenda for the EU and the European Urban Initiative create channels for multi-level cooperation and knowledge transfer, strengthening implementation capacities and supporting the diffusion of practices (European Commission, 2016, 2022). Their effectiveness depends on local institutional resources and political continuity.

A summary of key EU instruments and their importance for mobility-UGS-governance is presented in Table 1.

Table 1. EU instruments and their significance for mobility - UGS and governance

Document/instrument	Impact status	Framework 'principle'	Mechanism of influence on cities	Significance for mobility-UGS-governance
European Green Deal (2019)	strategic mandate	decarbonisation + environmental pressure	political priorities, justification for intervention	legitimises measures to reduce traffic/emissions, but does not resolve distributional dilemmas
SSMS (2020)	sectoral strategy	modal shift + multimodality + incentives	transport transformation agenda	reinforces the paradigm shift in mobility (accessibility > capacity)
UMF (2021)	urban framework	sector integration	SUMP, integration with planning/health/safety	enables the combination of mobility with street quality and (indirectly) with greenery
Greening Freight (2023)	freight package	decarbonisation of logistics	intermodality, efficiency, system tools	strengthens the "last mile" as a test of consistency and acceptance of reforms
New Leipzig Charter (2020)	urban development standard	common good + fairness	framework of legitimacy and objectives	supports the reallocation of street space and pro-UGS arguments
Urban Agenda / EUI (2016/2022)	cooperation infrastructure	multi-level governance + learning	partnerships, implementation capacity	channel for scaling solutions and reducing the implementation gap

Source: own work

They are complemented by implementation tools, in particular ELTIS (European Local Transport Information Service) and SUMP guidelines, which promote standardised and iterative implementation of mobility policies (Rupprecht Consult, 2019). The OECD perspective and initiatives such as the EU Mission: Climate-Neutral and Smart Cities emphasise systemic resilience and policy coordination (Matsumoto & Ledesma Bohorquez, 2023; OECD, 2024; European Commission, n.d.). The comparison of Barcelona and Singapore assesses how this EU policy architecture operates across governance models and its relevance for integrating mobility and green infrastructure.

3 Theoretical framework

Contemporary cities are increasingly analysed as socio-ecological systems in which social, institutional, economic and environmental processes remain interlinked. Decisions on mobility, infrastructure and spatial development influence ecological processes, which in turn shape living conditions and governance constraints (Holling, 1973; Folke et al., 2010; Pickett et al., 2011). This perspective emphasises uncertainty and non-linear responses, where interventions may have delayed or indirect effects (Meerow et al., 2016).

In this framework, 'smart city development' is operationalised as the systemic capacity for urban resilience, understood as a property of the whole system rather than isolated technical performance. Drawing upon socio-ecological systems (SES) theory, resilience is defined as a dynamic and relational process encompassing three interdependent capacities (Holling, 1973; Folke et al., 2010): absorptive (sustaining functionality), adaptive (adjusting structures within existing paradigms), and transformative (fundamental reorganisation). For the mobility sector, this necessitates a shift from rigid engineering robustness towards institutional flexibility (Meerow et al., 2016), where green infrastructure acts as a vital interface mediating between tangible ecological assets and the intangible social learning required for adaptive governance (Pickett et al., 2011).

While green infrastructure supports climate adaptation (Kabisch et al., 2017), its effectiveness is contingent upon governance arrangements that structure cross-sectoral coordination (Ostrom, 2009). However, a distinct research gap persists in understanding how relational governance within the 3P nexus - recognising 'People' as equal co-creators and custodians of public value (Brdulak, in press) - bridges the operational tension between mobility restrictions and the expansion of greenery. Rooted in co-production, this perspective is essential for overcoming the 'wicked problems' of urban logistics, where top-down regulations frequently encounter implementation gaps due to a lack of social legitimacy and shared responsibility.

4 Research methods

The article applies a qualitative approach based on two case studies: Barcelona and Singapore (Yin, 2018). The selection of Barcelona and Singapore follows a logic of analytical complementarity (Flyvbjerg, 2006). While Barcelona represents the European deliberative-networked model, Singapore is included as a global benchmark and an 'analytical contrast' for EU frameworks, allowing for testing whether universal sustainability goals can be effectively implemented through fundamentally different institutional pathways (Brdulak, in press). The study is exploratory-analytical and focuses on reconstructing decision-making processes, institutional practices and cross-sectoral cooperation in green infrastructure management and its integration with urban mobility and spatial planning (Flyvbjerg, 2006).

The research was conducted in three stages. First, desk research was carried out, including an analysis of strategic and planning documents (Bowen, 2009). Second, in-depth qualitative interviews were conducted with experts representing three sectors (Public-Private-People) (Kvale & Brinkmann, 2009). Twelve interviews were conducted in Barcelona and 13 in Singapore, involving representatives of public administration, planning units, expert circles, non-governmental organisations and the private sector. Third, the empirical findings were complemented with a targeted review of scientific literature and selected secondary sources, including institutional reports.

The qualitative design limits generalisation, as the analysis is based on two case studies embedded in their institutional and cultural contexts (Flyvbjerg, 2006).

The interviews were structured around nine core analytical categories: institutional structures, policy integration, financing, participation, urban green spaces, spatial projects, innovation, social justice, and adaptive learning (Brdulak, in press).

5 Results: Case studies

To establish the context for the following analysis, Table 2 provides a comparative summary of the two cities, illustrating the 'analytical contrast' between the high-density European model and the centrally managed city-state.

Table 2. Comparative profile of Barcelona and Singapore (2024-2025 data)

Attribute	Barcelona	Singapore
Total Area	101 km²	~730 km²
Population	1.6 million	5.9 million
Population Density	~15,800 inhabitants/km²	~8,100 inhabitants/km²
Green Space Accessibility	Within 300 metres of every dwelling	90% of households within a 10-minute walk of a park
Global Resilience Ranking	High ecological innovation (Eurocities)	5th globally (FM Global Resilience Index)
Governance Model	Participatory, decentralised co-governance	Centrally coordinated, technocratic

Source: own work

5.1 Barcelona - a case study

Barcelona has long faced strong mobility pressure due to high density and intensive street use. Interviewees described mobility as closely linked to quality of life, accessibility of public space and everyday urban practices. They emphasised that transport restrictions often preceded broader spatial interventions, including street redesign, improved walking and cycling conditions and the introduction of greenery.

- Transport and mobility as an area of regulatory restrictions in Barcelona

Interviewees described transport restrictions as a permanent element of Barcelona's functioning, reflecting spatial and environmental constraints rather than symbolic policy. Further increases in car capacity were considered infeasible without worsening living conditions. Restrictions on car mobility were frequently justified by neighbourhood-level experiences of noise, air pollution and safety problems. Mobility was framed as part of everyday urban life, consistent with approaches treating streets as social spaces rather than traffic corridors (Gehl, 2010; Appleyard, 1981).

Interviewees noted that regulations shifted the focus from traffic management towards accessibility management. Parking and transit restrictions were treated as prerequisites for pedestrian- and cycling-oriented redesign. This sequence corresponds to literature on compact cities and sustainable mobility (Banister, 2008; Newman & Kenworthy, 2015). At the same time, interviewees stressed that restrictions were not socially neutral and could provoke resistance where daily commutes or economic activity were affected (interviews, Barcelona, 2025).

- Integration of mobility with green infrastructure in Barcelona

The integration of mobility and green infrastructure was described as a consequence of earlier transport decisions. Interviewees emphasised that street greenery became feasible only after car traffic was reduced and street functions were redefined. In practice, this enabled the transformation of streets into multifunctional spaces, with expanded pedestrian areas and new greenery, especially in densely built neighbourhoods with limited access to larger green areas.

Green infrastructure was also described as supporting the new mobility organisation by reinforcing lower speeds and pedestrian and cycling priority. This corresponds to approaches framing streets as multifunctional spaces combining transport, social and environmental objectives (Gehl, 2010; Carmona, 2019).

However, interviewees emphasised that integrating mobility and greenery entailed additional costs and constraints, including maintenance, conflicts with underground infrastructure and the need for technical access. In some locations, conflicts also emerged with space users who perceived greenery as limiting accessibility or economic activity (interviews in Barcelona, 2025). At the same time, respondents noted that greenery improved comfort in public space and helped build acceptance for transport restrictions, supporting the continuity of street transformation.

- Organisation of mobility and urban logistics in Barcelona

Transport restrictions required adjustments in the daily organisation of mobility and last-mile logistics. Interviewees described this as a gradual regulation of car traffic, combined with a shift from transit functions towards neighbourhood-oriented street use. This affected deliveries through changes in delivery times, restrictions on heavy vehicle access and increased use of smaller vehicles in dense areas.

Urban logistics was also described as an area where tensions emerged quickly. Interviewees noted that trade and services often perceived new traffic rules as an operational burden, which led to frequent adjustments and testing of alternative solutions rather than implementing a single target model (interviews Barcelona, 2025; Kiba-Janiak et al., 2024). Walking and cycling gained importance as functional modes in a high-density context, supporting proximity-based mobility patterns (Banister, 2008; Cervero, 2013). Overall, respondents presented logistics and mobility organisation as continuous adaptation to local conditions (interviews Barcelona, 2025).

- Governance and the 3P nexus in the field of mobility in Barcelona

Interviewees described mobility governance in Barcelona as cooperation among multiple actors, where municipal initiatives were modified in response to residents' reactions and the private sector's capacity to adapt. This reflects network governance, in which coordination, trust and learning during implementation are central (Ansell & Gash, 2008; Emerson & Nabatchi, 2015; interviews Barcelona, 2025).

The public sector was described as responsible for organising the process and protecting the public interest, including consistency across districts and municipal services, and managing tensions between environmental and social goals and daily operations (Bryson, Crosby, & Stone, 2015; interviews Barcelona, 2025). The private sector

appeared primarily as an implementation participant, with recurring friction where regulations affected delivery costs, customer access or investment conditions (Hodge & Greve, 2017; Siemiatycki, 2013; interviews Barcelona, 2025).

The role of 'people' was strongly present but ambiguous. Interviewees emphasised that limited social acceptance could quickly undermine implementation, while participation more often shaped the direction and limits of change than operational parameters (Fung, 2015; Ansell & Gash, 2008; interviews Barcelona, 2025). Barcelona was also characterised by pilots and gradual adjustments, which reduced political risk and enabled responses to resistance or side effects (Ostrom, 1996; Bovaird, 2007; Osborne, 2010; interviews Barcelona, 2025). At the same time, interviewees described 3P mechanisms as viable but fragile: participation and social monitoring could strengthen trust, yet conflicts of interest in development projects remained difficult to resolve (Mueller et al., 2020; interviews Barcelona, 2025).

- Implications for urban resilience (resilience-in-action) - Barcelona

The Barcelona case suggests that resilience in mobility emerged primarily through implementation practice rather than as an explicit policy objective. Interviewees described resilience as the city's capacity to respond to tensions and adjust solutions during implementation, consistent with approaches framing resilience as an adaptive and learning-oriented process (Folke, 2006; Davoudi et al., 2012; interviews Barcelona, 2025).

Resilience was mainly reflected in a shift from absorptive responses towards adaptive adjustment. Restrictions initially introduced to address traffic pressure and environmental impacts later supported more durable changes in street organisation, logistics and public space. Interviewees emphasised that testing and modifying measures, rather than implementing a single rigid model, was critical, aligning with adaptive resilience perspectives that prioritise institutional flexibility (Meerow et al., 2016; Chelleri et al., 2015).

Transformative elements were less frequent and selective, mainly involving a lasting redefinition of streets and the relationship between mobility and public space. Interviewees noted that change was uneven and dependent on local conditions, consistent with observations of fragmented urban transformation (Chelleri et al., 2015; Davoudi, 2018).

From a governance perspective, resilience was supported by decentralised decision-making and multi-actor involvement. The 3P arrangement did not remove conflicts but provided a framework for exposing and managing them. The ability to deepen change depended on stable relationships and resources across administration, private actors and residents (Folke et al., 2010; Meerow et al., 2016). Overall, Barcelona showed high adaptive capacity in mobility, but limited capacity for uniform transformation across the city, with uneven distribution of costs and benefits.

5.2 Singapore - a case study

Singapore is a high-density city where limited space and intensive infrastructure use make mobility a resource requiring strict management. Interviewees described mobility primarily as a condition for system efficiency and reliability rather than an area of ongoing public controversy. The case analysis focuses on how a strong transport regulatory framework shapes urban space and links mobility, green infrastructure and long-term planning in a centrally coordinated governance model.

- Transport and mobility as an area of regulatory restrictions in Singapore

Interviewees described mobility restrictions as part of a long-term city management approach that is applied consistently. Regulations on road traffic, vehicle ownership and infrastructure use were presented as systemic and proactive rather than reactive. Key reference points were limited space and the need to avoid infrastructure overload while maintaining the city's role as an economic and logistical hub. Transport decisions were embedded in long-term planning and monitored on an ongoing basis, reflecting demand management approaches in Asian cities and city-states (Barter, 2004; Phang, 2018).

Interviews also suggested that extensive regulation remained socially acceptable when it translated into predictability and system efficiency. Restrictions on car ownership and usage costs were described as part of an implicit contract between the state and city users, with public objectives clearly prioritised over individual preferences (interviews in Singapore, 2025).

- Integrating mobility with green infrastructure in Singapore

Interviewees described the integration of mobility and green infrastructure as planned from the outset rather than emerging from local interventions. Transport and environmental solutions were designed in parallel, and greenery was treated as an integral component of urban infrastructure. The transport network was linked to green

and water-related infrastructure along corridors and surrounding spaces, supporting comfort and environmental stability (Newman & Kenworthy, 2015).

Respondents emphasised that greenery primarily supported the predictability and efficiency of the mobility system through clearly defined functions. At the same time, the scope for local modifications was described as limited, as solutions were designed to be consistent and stable (interviews in Singapore, 2025).

- Organisation of mobility and urban logistics in Singapore

In Singapore, mobility and logistics were described as strictly regulated and integrated with spatial planning. Interviewees emphasised that transport efficiency is a prerequisite for the city's role as an economic and logistics hub. Road traffic, public transport and delivery logistics were designed in a coordinated manner, with emphasis on demand management and congestion reduction (Barter, 2004; Phang, 2018).

Urban logistics operated within a clearly defined framework regulating delivery routes and delivery times, which supported predictability and reduced conflicts with other modes. Interviewees noted limited street- or neighbourhood-level experimentation: solutions were implemented city-wide and standardised, prioritising system stability over local flexibility (Rodrigue, 2024).

- Governance and the 3P nexus in the field of mobility in Singapore

Mobility governance in Singapore was described as highly centralised and based on long-term planning, with public institutions playing the dominant role in design, coordination and enforcement. This model prioritised stability and predictability and corresponds to hierarchical governance approaches observed in city-states (Phang, 2018).

The private sector mainly played an executive role within a defined regulatory framework. Cooperation with the administration was primarily contractual and operational rather than based on co-decision-making, resulting in stable but asymmetrical relations (Hodge & Greve, 2017; Siemiatycki, 2013). The role of "people" appeared mainly through system use: interviewees linked social acceptance to efficiency and predictability rather than participatory co-management, with participation described as informational or consultative (Fung, 2015; Healey, 1997). Overall, the 3P nexus was described as orderly but narrow, enabling rapid implementation while limiting bottom-up adaptation, which influenced resilience building in mobility.

- Implications for urban resilience (resilience-in-action) - Singapore

In Singapore, interviewees rarely used the term 'resilience' and instead referred to system stability, reliability and the avoidance of disruptions under spatial pressure and high mobility demand (interviews in Singapore, 2025). Resilience in mobility was described as an outcome of consistent planning and strong institutional coordination.

Interviewees emphasised absorptive mechanisms: demand regulation, standardised solutions and continuous monitoring designed to minimise congestion risks. This corresponds to infrastructure-oriented resilience approaches prioritising continuity of operation and rapid response to disruptions (Ahern, 2011; Meerow et al., 2016). Adaptive capacity was described mainly as technical and organisational adjustments implemented within established rules and procedures, resulting in planned and controlled adaptation (Davoudi et al., 2012; Chelleri et al., 2015). The transformative dimension was less visible, as the system was designed to limit the need for profound reconfiguration of mobility practices and space use.

From a governance perspective, resilience was closely linked to central decision-making, with public institutions enabling consistent implementation and private and social actors playing complementary roles. Overall, the Singapore case illustrates a resilience pattern based on systemic stability and high absorption capacity, providing a reference point for comparison with Barcelona in the discussion of governance mechanisms and transferability.

6 Discussion

An analysis of Barcelona and Singapore indicates that resilience in urban mobility is shaped primarily by governance arrangements rather than by individual transport instruments. In Barcelona, resilience was built through adaptive implementation, including negotiated restrictions, testing and gradual adjustment of measures. In this model, the 3P nexus functioned as a learning and coordination mechanism for responding to social and spatial tensions, consistent with resilience approaches emphasising adaptation under uncertainty (Davoudi et al., 2012; Meerow et al., 2016). It also aligns with findings that deliberative governance can support policy legitimacy while generating high coordination costs and uneven spatial effects (Ansell & Gash, 2008; Healey, 1997).

Singapore reflects a different pathway based on central planning and regulatory control. Interviewees described the 3P nexus as narrower, with public institutions playing the dominant role in managing mobility demand and maintaining system stability. Resilience was linked mainly to absorption and prevention, with adaptation occurring

within established procedures. This corresponds to research associating centralised governance with efficiency and predictability under high system pressure (Ahern, 2011; Chelleri et al., 2015). The comparison suggests that there is no single model of resilient mobility; effectiveness depends on the compatibility between regulatory objectives, governance mechanisms and local institutional context, which is central to assessing transferability.

The comparison also contributes theoretically by showing that resilience in urban mobility is governance-contingent. Barcelona represents an adaptive-negotiated pathway of resilience-building, whereas Singapore represents a coordinated-regulatory pathway. This suggests that resilience is shaped not only by absorptive, adaptive or transformative capacity, but also by the governance arrangements through which these capacities are produced and maintained. The findings further refine the 3P nexus by showing that its contribution to resilience depends on the fit between participation, coordination and implementation capacity.

From an EU perspective, the key policy direction is a shift from capacity-oriented planning towards accessibility and integrated approaches linking mobility with public space and quality of life (European Commission, 2019, 2020, 2021). Barcelona illustrates how restrictions and street-space reallocation can operationalise this logic at neighbourhood level (Gehl, 2010; Appleyard, 1981; interviews Barcelona, 2025).

Barcelona adds a strong micro-scale dimension to the EU framework, where mobility and greenery are integrated through street transformation into multifunctional spaces combining environmental functions and traffic organisation (Carmona, 2019; interviews Barcelona, 2025).

In Singapore, alignment with EU logic relates mainly to reducing transport pressure and maintaining system efficiency under limited space. Interviewees described this as pursued through long-term demand management, strong regulatory instruments and consistent enforcement, supported by a social contract that accepts restrictions (interviews Singapore, 2025). This creates different conditions for legitimisation mechanisms: in Barcelona they rely more on public debate and negotiation, while in Singapore they are linked to system predictability and trust in institutions (interviews Barcelona, 2025; interviews Singapore, 2025).

Urban logistics is a domain where both cases connect strongly with EU priorities. The Greening Freight Transport Package highlights the last mile as a critical component of transformation, as deliveries and services quickly reveal distributional and operational costs of reorganising access and space (European Commission, 2023). Interviews from Barcelona confirm that trade and services often perceive new traffic rules as an operational burden, leading to iterative adjustments rather than a single target model (interviews Barcelona, 2025). Singapore indicates that last-mile logistics can be governed within a stable regulatory framework when enforcement capacity is high (Barter, 2004; Phang, 2018; interviews Singapore, 2025).

From an OECD perspective, both cases illustrate different pathways to systemic resilience. Barcelona reflects resilience through learning and iterative adjustment under tension, whereas Singapore reflects resilience through long-term planning and regulatory coordination (Matsumoto & Ledesma Bohorquez, 2023; OECD, 2024; interviews Barcelona, 2025; interviews Singapore, 2025).

The comparison clarifies transferability. Policy objectives consistent with EU and OECD frameworks remain broadly transferable, including the shift from capacity to accessibility, addressing the last mile and integrating mobility with public space and green infrastructure (European Commission, 2019, 2020, 2021, 2023; Matsumoto & Ledesma Bohorquez, 2023; OECD, 2024). Implementation mechanisms are strongly contextual: Barcelona highlights negotiated, learning-based governance, while Singapore highlights regulatory consistency and demand management embedded in long-term planning (Barter, 2004; Phang, 2018; interviews Barcelona, 2025; interviews Singapore, 2025). Transfer should therefore focus on design principles rather than direct replication of instruments.

7 Recommendations for urban policy

Synthesising the findings from the comparative analysis of Barcelona and Singapore, it is proposed that smart city development under EU mobility regulations be conceptualised as a relational governance capability rather than a standalone spatial or technological intervention. The evidence suggests that for cities to effectively navigate the operational tension between increasing transport constraints and the mandate for expanded green infrastructure, they must move beyond technical delivery toward the systematic strengthening of ‘social infrastructure’. This involves prioritising permanent deliberative structures within the 3P nexus to manage distributional conflicts at the earliest stages of planning, thereby ensuring that street-space reallocation remains socially legitimate and that institutional success is measured by trust-based cooperation.

In tandem with the strategic transition from transport capacity toward accessibility, municipal authorities are advised to treat greenery not as a discretionary amenity, but as critical urban infrastructure. Such a shift requires the implementation of integrated, multi-sectoral budgets analogous to those of transport or water systems, ensuring that green-blue networks provide consistent ecosystem services despite severe spatial pressure. Given that urban logistics and the Greening Freight Transport Package serve as primary ‘stress tests’ for reform durability, it is recommended that delivery operations and last-mile access be structurally integrated into the initial design phase

of green infrastructure developments to prevent operational frictions from undermining legitimacy across administrative cycles.

With a view to achieving EU sustainability goals while managing local uncertainty, the sequencing of reforms should follow a 'safe-to-fail' logic, incorporating iterative piloting to build social acceptance before city-wide scaling. Ultimately, policy transfer between cities should focus on reconstructing the trust-based relationships and co-production logics inherent to the 3P nexus, ensuring that resilience becomes a collective competence - an expression of a community's capacity to learn and act effectively despite the constraints of contemporary urban environments.

8 Conclusions

The study shows that the EU framework functions as a guiding architecture for urban mobility, shifting policy focus from maximising capacity towards accessibility, reduced environmental and health pressures, and improved public space quality. The findings confirm that mobility under regulatory constraints should be analysed together with green infrastructure development and governance arrangements.

RQ1: In both cases, the integration of transport restrictions with street greening proved to be a practical test of policy coherence. It revealed cities' ability to translate climate and quality-of-life objectives into concrete street-space allocation decisions and to maintain interventions over time.

RQ2: The sustainability of reforms depends on governance capacity, including cross-sector coordination, conflict management around access, parking and urban logistics, and the legitimacy of restrictions. Barcelona illustrates an iterative pathway based on learning and negotiated trade-offs, while Singapore illustrates long-term regulatory consistency and high enforceability (interviews Barcelona, 2025; interviews Singapore, 2025). This highlights the role of relationships within the Public-Private-People (3P) nexus in shaping resilience outcomes.

The analysis further shows that resilient mobility does not result from a single set of instruments but from the alignment of regulatory tools, mobility organisation and 3P cooperation. In this sense, the 3P nexus provides a useful framework for examining tensions between system efficiency, distributional effects and environmental objectives.

RQ3: Transferability concerns policy design principles-integrating mobility with public space quality and green infrastructure and managing trade-offs rather than direct replication of legitimacy and enforcement mechanisms, which remain strongly context-dependent.

The article's main theoretical contribution lies in conceptualizing resilience in urban mobility as governance-dependent rather than instrument-specific. By comparing Barcelona and Singapore, the study identifies two contrasting but coherent pathways of resilience-building: an adaptive-negotiated pathway and a coordinated-regulatory pathway. This highlights that the integration of mobility and green infrastructure is shaped by institutional configuration, implementation capacity and the role of the 3P nexus, rather than by a single transferable model of intervention.

Overall, smart city development under mobility regulation relies on coherent integration of mobility, environmental and social policies, with resilience understood as a governance process rather than a technical outcome of individual transport measures.

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