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# The Transition Pathways to Sustainable Urban Mobility: Could They Be Extended to Megacities?

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**Abstract:** Population concentration in urban areas has placed cities at the forefront of the global struggle to achieve the Sustainable Development Goals. Within cities, current mobility patterns are responsible for a significant proportion of environmental emissions. As a result, cities across the world are seeking to develop transitions towards new and greener mobility systems. This paper analyses the different pathways that explain the readiness, or otherwise negation, of cities in achieving sustainable mobility. Based on a sample of 65 cities from all over the world, and with the application of Set-Theoretic Multi-Method Research and Necessary Conditions Analysis, it is demonstrated that there are necessary conditions for the achievement of sustainable mobility, as well as different terms that explain its achievement and its denial. Moreover, the analysis confirms that both the necessary conditions for sustainable mobility and one of the terms explaining its denial reflect the existence of causal mechanisms. The paper confirms the necessity for an analysis of the transitions towards sustainable mobility to take into account the characteristics of the context. Furthermore, it is not possible to explain the behaviour of megacities on the basis of generalised statements.

**Keywords:** sustainable mobility; megacities; transition pathways; SMMR; QCA



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## 1. Introduction

The processes of globalisation, industrialisation, and urbanisation impact the environmental, economic and social aspects of urban life [1–4]. In light of the necessity and potential for a transition towards a sustainable and resilient development model, cities occupy a pivotal position in the sustainable transition processes [5]. Urban cities are the first to experience the consequences of climate change, and are at the forefront of the struggle for sustainable development and sustainable transitions [6,7]. In light of these considerations, a radical transition is urgently required, involving a shift towards mobility that minimises ecological impacts and ensures the responsible use of resources in order to achieve the Sustainable Development Goals [2,6,8,9].

The primary objective of these transitions is to create cities where mobility is not dependent on non-renewable energy consumption. This implies overcoming the dominance of car-based regimes or systems [10]. Sustainable mobility can be defined as the achievement of a widespread high level of physical mobility and the use of transport technologies that limit carbon dioxide emissions to levels consistent with the Sustainable Development Goals [11]. Therefore, the purpose of this paper is to identify the conditions that determine whether cities are ready to implement sustainable mobility solutions.

The socio-technical systems approach is recommended for the analysis of urban mobility systems because they co-evolve in a context of changes in other systems that increase the inherent complexity of managing transitions [8,9,12]. From a socio-technical perspective, the evolution of technology and economy, and the actions of key players, interact to create dynamics that lead to tipping points [13]. Nevertheless, the majority of research on transitions is conducted on a single system, with the understanding that the analysis of interactions between multiple systems is of paramount importance [8]. In this context, it is crucial to understand the interrelationship between different conditions in order to grasp the transition processes of mobility [14]. Consequently, the first research gap addressed in this paper is to examine how different interplays between actors within the mobility regime identify and pursue different pathways toward sustainable urban mobility.

It is well documented that megacities are significant contributors to $CO_2$ emissions [15,16] and that they face a number of additional challenges in comparison to other urban areas. These include issues related to pollution, transport, waste management, employment, public service delivery and governance [17]. Consequently, it is vital that we consider how we can manage the future of megacities in a way that ensures a more efficient use of resources, in order to achieve sustainability [18,19]. However, it is important to recognise that megacities differ in terms of the sustainability challenges they face, as well as in the ways in which they address these challenges [17]. In developing cities, conventional interpretations of socio-technical regimes are inadequate due to the complexity of their service sectors and the highly unequal distribution of infrastructure [19]. Megacities are currently facing significant sustainability challenges in their mobility systems, which require transformative changes [19,20]. The transition to more sustainable forms of mobility in developing megacities presents challenges for planning systems that require in-depth analysis [21–23]. However, there is a paucity of research on the role of key actors in facilitating sustainable transitions within them [7]. Given the existence of disparate pathways between megacities in the same geographical areas and countries, it is insufficient to attribute the observed differences in their growth pathways to factors such as overpopulation, uncontrolled migration, or governance failures. These factors need further analysis. This paper addresses the second research gap, namely the identification of any differences in the transitions towards sustainable urban mobility by developing megacities.

The application of configurational methodologies, such as Qualitative Comparative Analysis (QCA), to address sustainability issues has become a widely adopted approach. These methodologies facilitate a deeper understanding of phenomena by examining configurations [24]. This is accompanied by an increasing acknowledgment of the significance of causal and process-tracing mechanisms in explaining socio-technical transitions [25]. Consequently, the work will apply Set-Theoretic Multi-Method Research (SMMR), which involves the application of QCA followed by process tracing. While sustainability challenges are global in nature, transitions research focuses on the local level, where innovations and interactions between policy actors, firms, consumers and organisations are situated [12]. Therefore, as a sample, 65 cities are taken from the Urban Mobility Readiness Index, 2023 edition [26].

The Theoretical Framework is then presented, with a focus on the explanation of transition pathways from the Multi-Level Perspective and on megacities. This is followed by a justification of the propositions presented in the following section. The model, the data and the method of analysis are then presented. This is followed by the results and their discussion. The paper ends with the conclusions, which cover implications, limitations and future lines of research.

## 2. Theoretical Framework

### *2.1. Multi-Level Perspective and Transition Pathways*

Transformations in urban mobility systems are shaped by a range of global processes, including urbanisation, rising demand for mobility, climate change and sustainability. It is, therefore, possible to examine innovations in mobility through the lens of socio-technical transitions, which encompass changes in a number of different areas, including infrastructure, industrial networks, business models, policies and mobility behaviour [27]. The

Multi-Level Perspective (MLP) is a frequently employed model for the analysis of socio-technical transitions. This approach interprets such transitions through an examination of the interplay between interrelated processes and developments at three analytical levels: niche, regime and landscape [18,27–29]. Niches refer to the level at which novelty and innovation occur, characterised by experimentation, instability and low performance; in niches, actors can develop new approaches in relative isolation from external pressures [27,28]. The regime consists of a network of central actors who control the configuration of the dominant system and have an interest in stabilising the status quo [28] and reflects the basic functioning of the system in the face of pressures from the exogenous landscape and the niche [19]. The landscape refers to the exogenous environment in which slow developments of change occur, representing the external forces that challenge the status quo maintained by the regime [27,28].

MLP conceptualises transitions as regime shifts that occur through interaction processes at three levels. Firstly, niche innovations develop gradually, awaiting their momentum. Secondly, niche innovations and landscape changes exert pressure on the system and the regime. Thirdly, regime destabilisation creates windows of opportunity for niche innovations, which diffuse and disrupt the existing system [27,28]. The MLP conceptualises socio-technical transitions as the consequence of multi-level interactions between radical niche-level innovations and path-dependent systems that are stabilised through multiple lock-in mechanisms [13].

Social regimes are the dominant cultures, structures and practices within a social system. Over time behavioural routines and business practices develop within such systems [30,31]. Transitions are complex, long-term, future-oriented, abstract, global and unique change processes [1,31,32]. In order for such transitions to occur it is necessary to alter the structure of the system [33]. Transition management posits that regime actors are most likely to attempt to enhance their position and reinforce the existing regime [6]. Indeed, elements of the system are incrementally reproduced, maintained and improved by incumbent actors [30]. Thus, the emergence of urban transitions depends on the existence of an enabling environment for regime destabilisation [19]. Consequently, while regimes may be dynamically stable over time (decades), they periodically undergo phases of shock and non-linear systemic changes [31].

The urban mobility regime encompasses not only the different modes of transportation, institutions and infrastructures, but also the cultures and practices associated with the conceptualisation, organisation, governance, and understanding of mobility [6]. Mobility systems are thus stabilised by the alignment between technologies, policies, user patterns, infrastructures and cultural discourses that have been created and reinforced over the past few decades [30]. The transition to a different mode of mobility needs not only technological alterations, behavioural changes, traffic management, spatial planning and infrastructure development [14,16], but also modifications to the cultural meanings attached to everyday life practices [34]. Social regimes tend to prioritise system optimisation over innovation, largely due to prevailing habits, competencies, investments, regulations and norms [33]. This approach offers stability and creates a sense of path dependency [31]. Nevertheless, new pathways can emerge from new or existing resources related to a given social phenomenon.

From a multi-level perspective, a transition pathway derives from the interaction between the activities and structures of internal regime dynamics, the dynamics of the wider landscape and promising niches. These dynamics destabilise the existing regime and contribute to the emergence of a new one [35]. Transition pathways describe the manner in which technological innovations mature and are developed by different social actors, and how they contribute to the shift of the current regime towards desired ones or heal its ruptures [29,35,36]. Geels and Schot [29] propose a typology of transition pathways, influenced by social processes [36], based on multilevel interactions [1]: The Reproduction Pathway is characterised by a lack of pressure from the landscape, with stable interactions between niche actors and regimes [1,14,29,36]. The Transformation Pathway is defined by landscape developments that exert pressure on the regime, which gradually adjusts when niche innovations are absent [14,29,36], and this results in a gradual change of direction in the trajectory of the regime [1]. Regime actors could respond by redirecting innovation pathways, and a new regime could emerge [27] De-alignment and Re-alignment Pathways occur in systems dominated by their focus on infrastructure and dependence on policy interventions [36], and when landscape-level change is large and sudden it can cause regime actors to lose confidence leading to regime dealignment and erosion [29]. When niche innovations are underdeveloped, it creates space for multiple niche innovations to coexist and compete [36]; when faced with a dominant niche innovation, a new regime realignment occurs [27,37]. The Technological Substitution Pathway is characterised by high landscape pressure in the face of a developed niche innovation emerging and replacing the existing regime [1,29], with new niche actors competing to dominate the new regime [37]. With the Reconfiguration Pathway, niche innovations are initially adopted into the regime with adjustments to its basic architecture [29], involving alliances between existing and new entrants [27,36].

### *2.2. Transition Pathways in Megacities*

Megacities are cities with a population of over 10 million that exert a significant influence on the economic, technological, and socio-cultural dynamics of their surrounding environment. Such cities frequently serve as a catalyst for change within their respective countries [7,38]. Megacities represent a significant driver of environmental change, both in terms of resource consumption and as a reflection of the adverse effects of urbanisation [18]. The emergence of such megacities can be attributed to three key factors: demographic transition, resulting from population growth and a reduction in the size of the housing stock; migration from rural areas; and geographic expansion through the annexation of urban areas and the development of new urban areas [39]. Megacities are defined by a high-density central area surrounded by densely populated nodes [40]; reflecting spontaneous growth and informal urbanisation [41].

Megacities, especially those in emerging economies, face challenges such as meeting basic human needs in the face of rapid urbanisation, sustainable growth and reducing the vulnerability of the poorest [39]. Therefore, polycentric spatial planning in megacities is emerging as an alternative approach to monocentric urban planning, which is ineffective in limiting emissions. In this sense, the 15 min city, which provides essential amenities within a 15 min walk, is a formula for reducing commuting and car use in megacities such as Paris, Toronto and Shanghai [15].

The process of metropolitan urbanisation is characterised by three distinct modes of growth: infill, which encompasses the construction of building additions surrounding existing built-up areas; edge expansion, which represents a unidirectional expansion of new buildings on the periphery of an existing urban area; and peripheral or leapfrog growth, which is detached from previous urbanised layouts [42]. In their application to megacities, they enable the identification of different transition pathways. The most commonly employed pathway is oscillating/ping pong, which refers to the cyclical process of infill, edge expansion and leapfrog development. This pathway has seen continued growth in the dominance of edge expansion, with periods of infill and periphery modes. The second most common pathway is the transition towards densification, which is the most sustainable in terms of land use. This pathway develops from a dominance of edge expansion to an increasing dominance of infill, which is evidenced by the transition to sprawl, whereby the growth of infill gives way to edge expansion. This is followed by the extensive sprawl pathway, which sees edge expansion give way to an increasing dominance of low-density peripheral growth. Finally, the transition to sprawl pathway is characterised by a shift from edge expansion to an increasing dominance of low-density peripheral growth [18].

The development of megacities is characterised by a number of factors that contribute to political and economic instability. These include high pressure for economic development, weak institutional structures, informal political decision-making processes and fragmented governance structures, multiple jurisdictions and governance mechanisms involving actors at different levels and scales, ambivalent transport and land use policies, lack of public recognition of sustainability, as well as severe socio-economic gaps leading to spatial segregation [7,21,22,38,43]. The majority of megacities are situated in emerging markets, predominantly in Asia and Africa. These regions are characterised by high economic growth and the emergence of a middle class, accompanied by shifts in consumption and urbanisation patterns. Consequently, the development of adequate infrastructure and transport planning has not always kept pace with the increase in vehicle ownership. However, it is important to acknowledge the diversity of megacities [39,41], given that developing megacities differ in scale and population density, as well as in their environmental and resource pressures [7].

## 3. Justification of the Propositions

Transit-oriented development is an effective strategy for achieving sustainable mobility. This strategy seeks to integrate the use of spaces and transport systems, facilitating the development of a compact city and a walker-friendly environment around different transport modes [44,45]. Urban public transport systems play a crucial role in the pursuit of sustainable development [2,3,46]. One way of achieving sustainable mobility is to strengthen public transport, which can be achieved through the expansion of conventional services and the introduction of new services and uses [9]. In accordance with a conventional pattern of transport planning, the majority of cities rely on public transport systems and supporting infrastructure [6,31,47,48]. Urban mobility systems are based on a combination of public and private transport options [6,31,49]. In the field of sustainable transport, there is a concerted effort on the part of both the public and private sectors to coordinate their activities in order to achieve sustainability goals [50]. Finally, a key area of such sustainability investment is the development of emerging technologies for urban mobility solutions [40].

In sustainable mobility, there is a growing emphasis on the integration of measures to limit car travel with advances in public transport systems and improvements to infrastructure for walking and cycling. The concept of integrated transport emphasises the combination of different modes of transport so that individuals can organise their own travel plans [3]. This multimodality is a key driver of urban mobility transitions and reinforces the attractiveness of the different modes of transport that compose it [49]. In this sense, the development of public transport within a service network is conceived as a combination of transport modes that form a convenient, comfortable, healthy and egalitarian multimodal system accompanied by the necessary infrastructure [47]. Consequently, the establishment of a sustainable urban environment can be attained through the advancement of public transportation, the minimisation of individual motorised transportation modes, and the promotion of novel collective transportation formats [11,46,51]. Consequently, the following propositions are put forward:

**Proposition 1a:** *Certain conditions pertaining to the mobility system of cities interact with the explanation of the readiness for the implementation of sustainable mobility.*

**Proposition 1b:** *Certain conditions pertaining to the mobility system of cities interact with the explanation for the readiness for the implementation of sustainable mobility.*

In megacities, public transport is the dominant mode of transportation, with stakeholders concerned with increasing and improving its variety [20]. Passenger transport in many megacities relies on public transport provided by both the public and private sectors [50]. Consequently, in megacities where the public transport system is adequate and easily accessible, the necessity for parking is relatively low. However, in the context of inadequate public transportation, private vehicles are often the preferred mode of transportation, leading to a significant increase in the demand for parking. This situation presents a significant challenge for fast-growing megacities, particularly in relation to parking [52].

Mobility is becoming increasingly important in megacities due to fragmented demand, the presence of an informal sector, land scarcity, uncontrolled urban sprawl and congestion [39]. The urban mobility regime in developing cities reflects a set of rules, regulatory environment, institutional arrangements and governance practices that may differ from those in developed cities [21]. It is challenging to comprehend the potential for destabilisation of the mobility regime in megacities, as it suggests an opportunity for the emergence of new niches that could reshape urban systems [7]. The focus on regime change in the transition literature to solve sustainability-related problems reflects a Western bias in relying on niches as the source of change [20], as well as the perspective of developed countries [41]. It is, therefore, proposed that the emergence of urban transitions towards sustainable mobility in megacities is contingent upon the existence of environments that facilitate regime destabilisation [7]. However, conflicting priorities among its key actors sometimes result in insufficient efforts to destabilise the mobility regime [7].

The implementation of mega urban transport projects and the integration of space use and transport can be regarded as a necessary but not sufficient measure to achieve the social goals pursued by megacities [44]. The successful introduction of sustainable mobility in developing countries requires a transition in different dimensions, including infrastructure, technologies, policies, regulations, culture and social meanings [22]. Consequently, the transition towards sustainable urban mobility in developing megacities needs an in-depth comprehension of the dynamics of change and stability associated with transition processes [21,38]. Furthermore, disparities in the implementation of transit-oriented development were discerned between megacities [45]. The following propositions are, therefore, presented:

**Proposition 2a:** *The conditions linked to the mobility system of cities interact in explaining the readiness for the implementation of sustainable mobility differently in the case of developing megacities.*

**Proposition 2b:** *The conditions linked to the mobility system of cities interact in explaining the negation of the readiness for the implementation of sustainable mobility differently in the case of developing megacities.*

## 4. Data, Model, and Method of Analysis

In order to facilitate the work of public managers, assessment tools such as indices and indicators are created. Such tools assist those responsible for the management of megacities in developing conditions that are conducive to sustainability [17]. The data required for measurement are derived from the Urban Mobility Readiness Index of 2023 [26], this index has been employed in several previous works [5,53,54]. The 2023 Index provides in-depth analysis of 65 geographically diverse cities across six regions (North America, Latin America, Europe, Middle East, Asia Pacific and Africa). They range from sprawling megacities such as Tokyo and Delhi to more compact ones such as Oslo and Washington DC. Or fast-growing metropolises such as Nairobi [26].

In constructing the index, each KPI that constitutes a dimension was given a weight based on its relevance. Additional weight is given to factors that capture the city's ability to become a future leader. The weighting of the KPIs was based on the Index development team's discussions with managers and sector specialists. In addition, convex optimisation techniques were used to understand the weighting structure needed to compare cities [26]. The index's city profile provides access to a city's score on each indicator, as well as its relative position compared to other cities.

The proposed model is based on the Multilevel Perspective on Socio-Technical Transitions (Figure 1). In the present case, the innovations are the level of implementation of sustainable mobility (measured through the Sustainable Mobility Score, SUM), the explanatory conditions at the landscape level (infrastructure, INF), and the explanatory conditions at regime level public transport (PUB), market attractiveness (MAT) and system efficiency (SEF) are also considered.


**Figure 1.** Model tested.

- Sustainable Mobility Score (SUM) "captures the extent to which the city is investing in and driving structural changes in pursuit of cleaner, healthier, and more risk-conscious mobility systems" (based on 16 KPIs drawn from the UMR Index: air quality; car-free zones; car ownership moderation; climate-related losses; cycling adoption; cycling infrastructure; direct EV incentivisation; disaster-risk informed development; electric charging station density; electric vehicle market share in sales; government investment in charging stations; noise and light pollution restraint; public transit utilisation; rail network; strength of multimodal network; walkability).
- Public Transit (PUB) "measures cities on public transit density, efficiency, and utilisation rate and the extent to which they can adapt to address competition from emerging mobility services".
- Infrastructure (INF) "measures if the city developed robust infrastructure and expanded connectivity to support future mobility" (micromobility enablement, public transit accessibility, regional connectivity, international connectivity, and quality of infrastructure).
- Market Attractiveness (MAT) "values if the city engages the private sector and secure diverse investments to build out mobility" (public transit offering, smart mobility activation, mobility headquarters, public funding availability).
- Systems Efficiency (SEF) "evaluates the municipal government coordinate and enhance the city's mobility network through things like traffic management systems or investment in e-charging stations" (demand and transport planning, modal mix optimisation, operational efficiency, risk preparedness, service continuity).

In order to reinforce causal claims, it is necessary to combine different approaches, as no single approach is sufficient. The configurational and process-tracing approaches emphasise the importance of differentiating between causal and non-causal conditions. They concentrate on potential determination, identifying probable conditions or occurrences, and are attentive to the necessity and sufficiency of causes in triggering or facilitating an effect or outcome [55]. Therefore, this paper employs Set-Theoretic Multi-Method Research (SMMR), which involves first applying Qualitative Comparative Analysis (QCA), and then developing process tracing to the solutions obtained. The application of both methods is feasible since both are based on set theory and assess the degree to which cases belong to different conditions and outcomes. The utilisation of QCA serves to circumvent certain constraints inherent to regression-based techniques, such as the emphasis on the isolation of discrete effects. In this way, QCA focuses on analysing the interaction between different conditions to explain the presence of an outcome. Previous applications of this method include the analysis of indices linked to urban sustainability [56]. Moreover, QCA circumvents the issue of multicollinearity by assuming a high degree of association between the conditions under analysis [57]. The conditions identified through QCA reflect the scope conditions that characterise the cases that present the outcome under study [58]. In order to identify necessary conditions in degree, Necessary Condition Analysis (NCA) will be employed [59]. Through process tracing, the existence of causal mechanisms that explain the presence of the result is identified. Process tracing can be developed with either a descriptive or causal design. The former aims to complete the model used, whereas the latter focuses on the identification of mechanisms that explain the existence of the outcome under study [58].

The RStudio packages SetMethods and NCA were employed for the data analysis.

## 5. Results

The data were calibrated using the 95th and 5th percentiles as the points of total inclusion and total exclusion, while the mean was used to establish the point of maximum ambiguity, a calibration with less demanding percentiles (such as 75th, 50th and 25th) would have decreased the variance of raw data [57]. Cases with a membership of 0.5 in any of the conditions were added 0.01 to avoid them acting as ambiguous cases.

### *5.1. Identification of the Necessary Conditions*

Firstly, the existence of atomic necessary conditions for SUM and ~SUM with QCA was identified. In order for a condition to be considered necessary, it must exceed a Cons.Nec of 0.9, a Cov.Nec of 0.6 and a RoN away from 0.5.

As illustrated in Table 1, MAT (Cons.Nec = 0.916, Cov.Nec = 0.740, RoN = 0.748), SEF (Cons.Nec = 0.922, Cov.Nec = 0.812, RoN = 0.832) and PUB (Cons.Nec = 0.924, Cov.Nec = 0.818, RoN = 0.838) are necessary for SUM. In contrast, no condition is necessary for ~SUM. To identify the necessary conditions in greater detail, NCA was applied. According to NCA, a condition is necessary if it has an effect size greater than 0.1 and a *p*-value less than 0.05.

**Table 1.** Analysis of the atomic necessary conditions SUM/~SUM.

| Condition | Cons.Nec | Cov.Nec | RoN |
|---|---|---|---|
| INF | 0.896/0.488 | 0.752/0.489 | 0.772/0.622 |
| MAT | 0.917/0.493 | 0.740/0.475 | 0.748/0.594 |
| SEF | 0.922/0.438 | 0.812/0.460 | 0.832/0.633 |
| PUB | 0.924/0.455 | 0.818/0.480 | 0.838/0.645 |
| ~INF | 0.391/0.753 | 0.390/0.897 | 0.661/0.920 |
| ~MAT | 0.349/0.730 | 0.366/0.913 | 0.672/0.937 |
| ~SEF | 0.387/0.822 | 0.366/0.927 | 0.629/0.936 |
| ~PUB | 0.413/0.828 | 0.389/0.929 | 0.635/0.937 |

As can be seen in Table 2, the variables INF, MAT, SEF and PUB are necessary in degree for SUM in corner 1: INF (size effect = 0.292, *p*-value = 0.001), MAT (size effect = 0.307, *p*-value = 0.000), SEF (size effect = 0.293, *p*-value = 0.000) and PUB (size effect = 0.395, *p*-value = 0.000). Furthermore, in degree of corner 4, INF (size effect = 0.252, *p*-value = 0.000), MAT (size effect = 0.186, *p*-value = 0.002), SEF (size effect = 0.307, *p*-value = 0.000) and PUB (size effect = 0.273, *p*-value = 0.000) are also necessary. Figure 2 presents a graphical representation of the necessary conditions as determined by NCA. The horizontal axis represents the corresponding condition, while the vertical axis depicts the result. The objective of such a graph is to identify the line that differentiates the space with cases from the space with (almost) no cases.

**Table 2.** Identification of necessary conditions with NCA (effect size and *p*-value).

| Condition | Corner1 | Corner2 | Corner3 | Corner4 |
|---|---|---|---|---|
| INF | 0.292 (0.001) | 0.001 | 0.000 | 0.252 (0.000) |
| MAT | 0.307 (0.000) | 0.016 | 0.000 | 0.186 (0.002) |
| SEF | 0.293 (0.000) | 0.000 | 0.000 | 0.307 (0.000) |
| PUB | 0.395 (0.000) | 0.002 | 0.000 | 0.273 (0.000) |

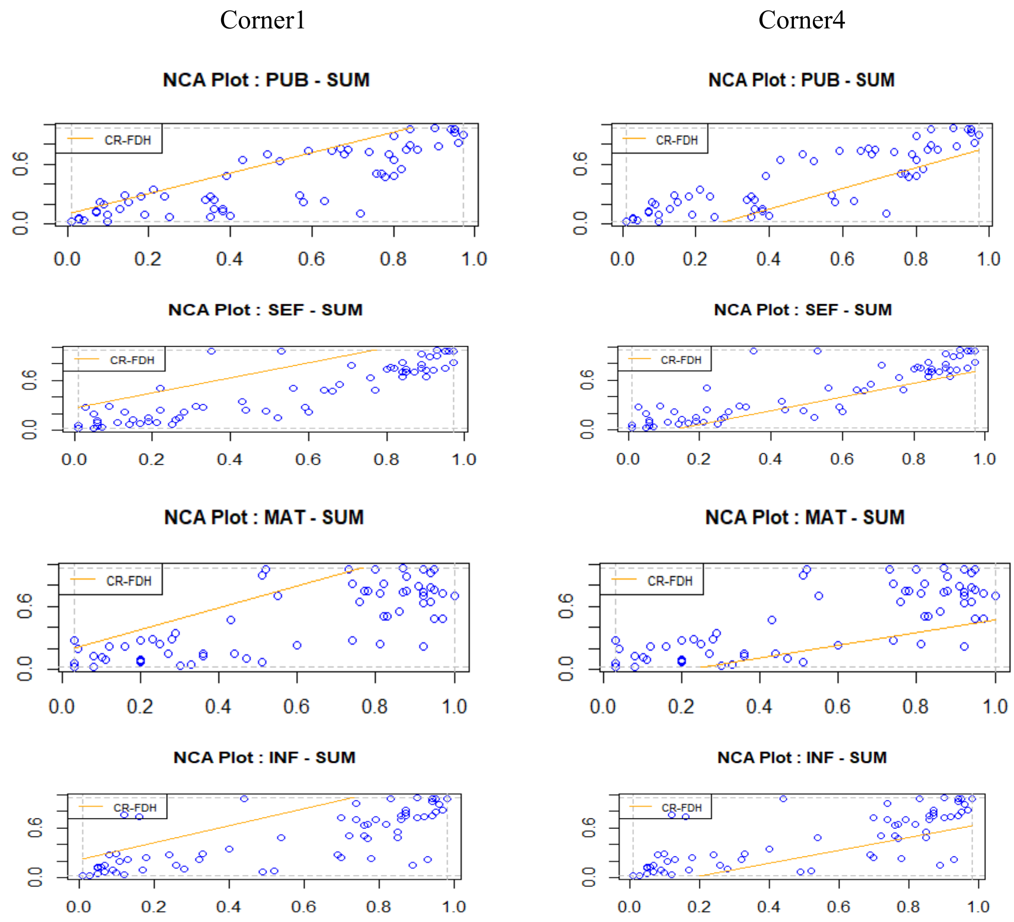


**Figure 2.** Graphical representation of the necessary conditions NCA.

On the basis of the above, it is argued that PUB, SEF and MAT are necessary conditions for SUM.

Next, we sought to determine whether the presence of the necessary conditions makes the presence of the mechanism possible [58]. In order to identify the causal mechanisms reflected in the necessary conditions, deviant relevant cases were identified. Their analysis allowed to identify omitted conjuncts, supported by the comparison of deviant relevant cases with typical cases. The most deviant relevant cases were identified for MAT Dubai (NecCond = 0.92, Outcome = 0.22, Best = 0.38), SEF Chicago (NecCond = 0.77, Outcome = 0.48, Best = 0.94), and PUB Kuala Lumpur (NecCond = 0.72, Outcome = 0.10, Best = 0.66).

The best comparisons between deviant relevant and typical cases for each condition were then identified as MAT Helsinki (TYP)-Dubai (DREL) (Best = 0.43, MostTyp = TRUE, MostDREL = TRUE), SEF Helsinki (TYP)-Chicago (DREL) (Best = 0.99, MostTyp = TRUE, MostDREL = TRUE), PUB Dublin (TYP)-Kuala Lumpur (DREL) (Best = 0.71, MostTyp = TRUE, MostDREL = TRUE).

The comparison between deviant consistency cases and typical cases allows us to identify the following pairs: SEF Istanbul (DCONS)-Amsterdan (TYP) (TT_INF = 1, TT_MAT = 1, TT_PUB = 1, Best = 0.38, MostTyp = FALSE, MostDCONS = TRUE), PUB Toronto (DCONS)-New York (TYP) (TT_INF = 1, TT_MAT = 1, TT_PUB = 1, Best = 0.63, MostTyp = FALSE, MostDCONS = TRUE).

The inference is enhanced when a typical case is matched with the appropriate iir case, enabling the assessment of causal properties [58]. The pairs identified for each condition are as follows: MAT Helsinki (TYP)-Manama (IIR) (UniqCov = TRUE, GlobUncov = TRUE, Best = 0.16, MostTyp = TRUE), SEF Helsinki (TYP)-Manama (IIR) (UniqCov = TRUE, GlobUncov = TRUE, Best = 0.20, MostTyp = TRUE), PUB Dublin (TYP)-Jeddah (IIR) (UniqCov = TRUE, GlobUncov = TRUE, Best = 0.18, MostTyp = TRUE).

Pairs of typical cases are then presented in order to establish whether the mechanism can be extrapolated across all typical cases of the condition. The comparison between two typical cases assesses the regularity of the mechanism [58]. In the case of MAT Helsinki (TYP1)-Vancouver (TYP2) (UniqCov = both, Best = 0.66, MostTyp = typ1), SEF Helsinki (TYP1)-Milan (TYP2) (UniqCov = both, Best = 0.27, MostTyp = typ1) and PUB Dublin (TYP1)-Barcelona (TYP2) (UniqCov = both, Best = 0.60, MostTyp = typ1).

Finally, the analysis considered the outliers identified through NCA. The difference between the original effect and the effect in the case of removing the outlier was analysed, both in absolute terms and relative terms. If we focus on the ceiling outliers, we observe that Istanbul for MAT and SEF and Rome for PUB are the outliers whose elimination would result in a greater relative increase in the effect [59].

### 5.2. Identification of Sufficient Conditions

In order to establish sufficient conditions according to QCA, the conservative solution was chosen because it does not incorporate logical remainders. The truth table from which it is extracted requested a consistency of 0.85 and one case per configuration.

The solution for SUM resulted in INF*SEF*PUB + INF*MAT*PUB + SEF*MAT*PUB -> SUM, which has optimal parameters (inclS = 0.869, PRI = 0.781, covU = 0.880) (Table 3). The solution is simplified to PUB*(INF*SEF + INF*MAT + SEF*MAT).

**Table 3.** Conservative solution SUM.

| Term | inclS | PRI | covS | covU | Cases |
|---|---|---|---|---|---|
| INF*SEF*PUB | 0.912 | 0.848 | 0.810 | 0.019 | Warsaw, Hong Kong, Zurich, Vancouver, Tokyo, Copenhagen, Barcelona, Singapore, Milan, Sydney, Madrid, Oslo, Seoul, Munich, London, Dubai, Boston, Washington D.C., Amsterdam, New York, Stockholm, Paris, Helsinki, Chicago, Berlin, San Francisco |
| INF*MAT*PUB | 0.882 | 0.797 | 0.813 | 0.022 | Istanbul, Melbourne, Moscow; Hong Kong, Zurich, Vancouver, Tokyo, Copenhagen, Barcelona, Singapore, Milan, Sydney, Madrid, Oslo, Seoul, Munich, London, Dubai, Boston, Washington D.C., Amsterdam, New York, Stockholm, Paris, Helsinki, Chicago, Berlin, San Francisco |
| SEF*MAT*PUB | 0.916 | 0.853 | 0.840 | 0.048 | Dublin, Beijing, Shanghai; Hong Kong, Zurich, Vancouver, Tokyo, Copenhagen, Barcelona, Singapore, Milan, Sydney, Madrid, Oslo, Seoul, Munich, London, Dubai, Boston, Washington D.C., Amsterdam, New York, Stockholm, Paris, Helsinki, Chicago, Berlin, San Francisco |
| M1 | 0.869 | 0.781 | 0.880 | | |

The solution is composed of three terms: INF*SEF*PUB (inclS = 0.912, PRI = 0.848, covS = 0.810; covU = 0.019); INF*MAT*PUB (inclS = 0.882, PRI = 0.797, covU = 0.813, covU = 0.022); SEF*MAT*PUB (inclS = 0.916, PRI = 0.853, covS = 0.840; covU = 0.048).

In the case of ~SUM (Table 4), the solution was INF*~PUB + ~SEF*~PUB + ~INF*~SEF*~MAT + INF*~SEF*~MAT->~SUM. The solution has optimal parameters (inclS = 0.918, PRI = 0.871, covU = 0.866). The solution can be simplified as ~PUB*(INF + ~SEF) + ~SEF*(~INF*~MAT + INF*MAT).

The solution is comprised of four terms: INF*~PUB (inclS = 0.931, PRI = 0.800, covS = 0.395; covU = 0.081); ~SEF*~PUB (inclS = 0.979, PRI = 0.968, covU = 0.730, covU = 0.028); ~INF*~SEF*~MAT (inclS = 0.975, PRI = 0.963, covS = 0.631; covU = 0.021); INF*~SEF*MAT (inclS = 0.898, PRI = 0.662, covS = 0.318; covU = 0.033). Figure 3 presents the graphical representation of the solutions.

**Table 4.** Conservative solution ~SUM.

| Term | inclS | PRI | covS | covU | Cases |
|---|---|---|---|---|---|
| INF*~PUB | 0.931 | 0.800 | 0.395 | 0.081 | Jakarta, Dallas, Atlanta, AbuDhabi, Montreal, Houston, Toronto, Los Angeles |
| ~SEF*~PUB | 0.979 | 0.968 | 0.730 | 0.028 | Nairobi, Quito, Manama, Casablanca, Lagos, Manila, Monterrey, Lima, Johannesburg, Capetown, MexicoCity, Mumbai, Cairo, Sao Paulo, Bogota, Santiago, Rio de Janeiro, Rome, Jeddah, Riyadh, Delhi, Bangkok, Doha, Jakarta, Dallas |
| ~INF*~SEF*~MAT | 0.975 | 0.963 | 0.631 | 0.021 | Nairobi, Quito, Manama, Casablanca, Lagos, Manila, Monterrey, Lima, Johannesburg, Capetown, MexicoCity, Mumbai, Cairo, Sao Paulo, Bogota, Santiago, Rio de Janeiro, Rome, Jeddah, Riyadh, Delhi, Bangkok; BuenosAires, Kuala Lumpur |
| INF*~SEF*MAT | 0.898 | 0.662 | 0.318 | 0.033 | Dallas, Istanbul, Melbourne, Moscow |
| M1 | 0.918 | 0.871 | 0.866 | | |

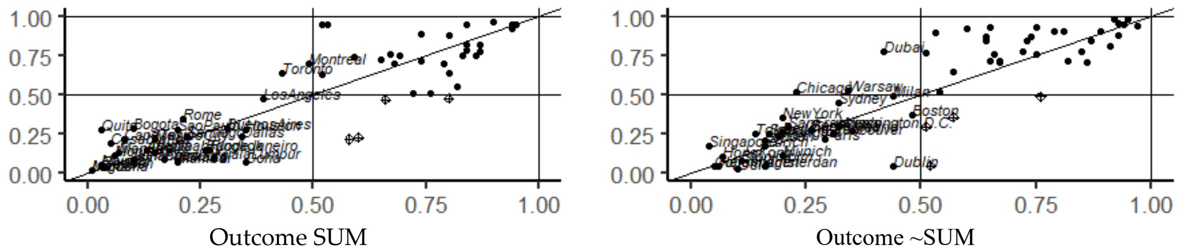


**Figure 3.** A graphical representation of the solutions.

To confirm the robustness of the results, different analyses were carried out, starting with an analysis according to the geographical area to which the cities belong. This showed that there are no differences according to distance either for the SUM solution (INF*SEF*PUB = 0.074, INF*MAT*PUB = 0.092, SEF*MAT*PUB = 0.071), nor for ~SUM (INF*~PUB = 0.023, ~SEF*~PUB = 0.008, ~INF*~SEF*~MAT = 0.026, INF*~SEF*~MAT = 0.05).

Subsequently, a cluster analysis was conducted to ascertain whether the city in question belongs to the megacity category. As illustrated in Table 5, the close proximity of the three terms (INF*SEF*PUB = 0.005; INF*MAT*PUB = 0.002; SEF*MAT*PUB = 0.003), indicates that there are no discernible differences between the outcomes for megacities (1) and no megacities (0). This homogeneity of the results can be seen in the similar consistencies and coverage of the clusters in different terms with respect to the pooled data.

**Table 5.** Cluster analysis SUM megacities.

| | INF*SEF*PUB | INF*MAT*PUB | SEF*MAT*PUB |
|---|---|---|---|
| Consistencies | | | |
| Pooled | 0.912 | 0.882 | 0.916 |
| Between 0 (41) | 0.909 | 0.883 | 0.918 |
| Between 1 (24) | 0.923 | 0.878 | 0.910 |
| Distances | | | |
| From Between to Pooled | 0.005 | 0.002 | 0.003 |
| Coverages | | | |
| Pooled | 0.810 | 0.813 | 0.840 |
| Between 0 (41) | 0.873 | 0.849 | 0.854 |
| Between 1 (24) | 0.672 | 0.735 | 0.808 |

A comparable situation is observed in the case of the ~SUM explanation, where no differences are evident between the different clusters (Table 6).

**Table 6.** Cluster analysis ~SUM megacities.

| | INF*~PUB | ~SEF*~PUB | ~INF*~SEF*~MAT | INF*~SEF*MAT |
|---|---|---|---|---|
| Consistencies | | | | |
| Pooled | 0.931 | 0.979 | 0.975 | 0.898 |
| Between 0 (41) | 0.908 | 0.978 | 0.966 | 0.944 |
| Between 1 (24) | 0.993 | 0.980 | 0.984 | 0.810 |
| Distances | | | | |
| From Between to Pooled | 0.031 | 0.001 | 0.006 | 0.054 |
| Coverages | | | | |
| Pooled | 0.395 | 0.730 | 0.631 | 0.318 |
| Between 0 (41) | 0.481 | 0.697 | 0.556 | 0.378 |
| Between 1 (24) | 0.276 | 0.775 | 0.735 | 0.234 |

The analysis was then conducted using the GDP per capita of the cities as a variable to establish the clusters, with a threshold of USD 12,000 per capita employed to determine whether a high level was reached.

As illustrated in Tables 7 and 8, there are no differences in the explanations according to the GDP per capita of the cities.

**Table 7.** Cluster analysis SUM GDP.

| | INF*SEF*PUB | INF*MAT*PUB | SEF*MAT*PUB |
|---|---|---|---|
| Consistencies | | | |
| Pooled | 0.912 | 0.882 | 0.916 |
| Between 0 (12) | 0.978 | 0.921 | 0.857 |
| Between 1 (53) | 0.910 | 0.880 | 0.918 |
| Distances | | | |
| From Between to Pooled | 0.026 | 0.016 | 0.024 |
| Coverages | | | |
| Pooled | 0.810 | 0.813 | 0.840 |
| Between 0 (12) | 0.478 | 0.500 | 0.516 |
| Between 1 (53) | 0.833 | 0.834 | 0.862 |

**Table 8.** Cluster analysis ~SUM GDP.

| | INF*~PUB | ~SEF*~PUB | ~INF*~SEF*~MAT | INF*~SEF*MAT |
|---|---|---|---|---|
| Consistencies | | | | |
| Pooled | 0.931 | 0.979 | 0.975 | 0.898 |
| Between 0 (12) | 1.000 | 0.959 | 0.981 | 1.000 |
| Between 1 (53) | 0.924 | 0.990 | 0.970 | 0.889 |
| Distances | | | | |
| From Between to Pooled | 0.028 | 0.011 | 0.004 | 0.041 |
| Coverages | | | | |
| Pooled | 0.395 | 0.730 | 0.631 | 0.318 |
| Between 0 (12) | 0.144 | 0.882 | 0.904 | 0.104 |
| Between 1 (53) | 0.496 | 0.669 | 0.521 | 0.404 |

### *5.3. Identification of Causal Mechanisms*

The existence of causal mechanisms with sufficient conditions was analysed. None were identified in the terms explaining SUM, but a causal mechanism was identified in the first term of the ~SUM solution. Firstly, the typical cases identified are presented in Table 9.

**Table 9.** Identification of typical cases.

| Case | FC | Out | CC_Min | Term | Rank | CleanCorr | FC<=Y | UniqCov | Best | MostTypFC | MostTypTerm |
|---|---|---|---|---|---|---|---|---|---|---|---|
| FC INF | | | | | | | | | | | |
| Jakarta | 0.52 | 0.92 | 0.60 | 0.52 | 1 | FALSE | TRUE | FALSE | 1.28 | FALSE | FALSE |
| Houston | 0.69 | 0.72 | 0.65 | 0.65 | 2 | TRUE | TRUE | TRUE | 0.41 | TRUE | FALSE |
| Dallas | 0.70 | 0.76 | 0.66 | 0.66 | 2 | TRUE | TRUE | FALSE | 0.46 | FALSE | FALSE |
| FC ~PUB | | | | | | | | | | | |
| Houston | 0.65 | 0.72 | 0.69 | 0.65 | 1 | FALSE | TRUE | TRUE | 0.49 | TRUE | FALSE |
| Dallas | 0.66 | 0.76 | 0.70 | 0.66 | 1 | FALSE | TRUE | FALSE | 0.54 | FALSE | FALSE |
| Jakarta | 0.60 | 0.92 | 0.52 | 0.52 | 2 | TRUE | TRUE | FALSE | 1.12 | FALSE | FALSE |

As illustrated in Table 10, a comparison between a typical case and an iir case reveals the existence of a mechanism that is responsible for the generation of the result.

**Table 10.** A comparison between a typical case and an iir case.

| TYP | IIR | PairRank | CleanCorr | FC<=Y | UniqCov | GlobUncov | Best | MostTypFC | MostTypTerm |
|---|---|---|---|---|---|---|---|---|---|
| FC INF | | | | | | | | | |
| Jakarta | Beijing | 3 | iir | both | FALSE | TRUE | 2.07 | FALSE | FALSE |
| Jakarta | Shanghai | 3 | iir | both | FALSE | TRUE | 2.11 | FALSE | FALSE |
| Jakarta | Dublin | 4 | none | typ | FALSE | TRUE | 2.79 | FALSE | FALSE |
| Houston | Beijing | 5 | both | both | TRUE | TRUE | 1.41 | TRUE | TRUE |
| Houston | Shanghai | 5 | both | both | TRUE | TRUE | 1.45 | TRUE | TRUE |
| FC ~PUB | | | | | | | | | |
| Houston | HongKong | 1 | iir | both | TRUE | TRUE | 1.04 | TRUE | TRUE |
| Houston | Copenhagen | 1 | iir | both | TRUE | TRUE | 1.16 | TRUE | TRUE |
| Houston | Stockholm | 1 | iir | both | TRUE | TRUE | 1.18 | TRUE | TRUE |
| Houston | Singapore | 1 | iir | both | TRUE | TRUE | 1.31 | TRUE | TRUE |
| Houston | Barcelona | 1 | iir | both | TRUE | TRUE | 1.34 | TRUE | TRUE |

Of the pairs identified in the aforementioned table, the Houston–Beijing comparison is the most advantageous and is regarded as the optimal representation of the comparison indicated in the FC INF and the Houston–Hong Kong pair for the FC~PUB.

Finally, through the comparison of two typical cases (Table 11), it can be demonstrated that the mechanism is extrapolable to all the typical cases that are explained by the term.

**Table 11.** A comparison between two typical cases.

| TYP1 | TYP2 | PairRank | CleanCorr | FC<=Y | UniqCov | Best | MostTypFC | MostTypTerm |
|---|---|---|---|---|---|---|---|---|
| FC INF | | | | | | | | |
| Houston | Jakarta | 3 | typ1 | both | typ1 | 1.94 | typ1 | typ1 |
| Dallas | Jakarta | 3 | typ1 | both | none | 1.96 | none | none |
| Houston | Dallas | 4 | both | both | typ1 | 1.24 | typ1 | typ1 |
| FC ~PUB | | | | | | | | |
| Houston | Dallas | 1 | none | both | typ1 | 1.40 | typ1 | typ1 |
| Houston | Jakarta | 2 | typ2 | both | typ1 | 2.10 | typ1 | typ1 |
| Dallas | Jakarta | 2 | typ2 | both | none | 2.12 | none | none |

In FC INF, the optimal typical pair of cases is Houston–Jakarta, while in FC~PUB, the optimal typical pair of cases is Houston–Dallas.

## 6. Discussion of Results

The results demonstrate that PUB, SEF and MAT are necessary conditions for SUM, while there are no necessary conditions for ~SUM. This confirms the crucial role of public transport for sustainable mobility [3,49]. Moreover, the role of MAT confirms that investment in technological innovations in mobility is a key factor in implementing urban mobility solutions [40]. Furthermore, the research indicates that the implementation of shared transport solutions is essential in order to offer mobility alternatives [49]. Finally, the necessity of SEF reinforces the role of transport planning [47,48].

To deepen the within-case analysis linked to the necessary conditions, deviant relevant cases were identified. The most representative cases were Dubai for MAT, Chicago for SEF and Kuala Lumpur for PUB. To facilitate their analysis, pairs of cases (typical-deviant relevance) were systematically identified for these conditions. Thus, for MAT it is Helsinki–Dubai, for SEF Helsinki–Chicago and for PUB Dublin–Kuala Lumpur. The city of Dubai is characterised by different factors that have the potential to undermine its sustainability. These include its high population density, the way in which land is used, the range of mobility options available to residents, the quality of mobility networks and the design of streets [60]. In contrast, the Malaysian capital, Kuala Lumpur, has made significant investments to improve its mobility. However, it has also identified a number of barriers to the use of sustainable mobility services, including their lower efficiency and high price [61]. Previous policies developed in mobility infrastructure in Kuala Lumpur encouraged vehicular rather than pedestrian movement, which has induced a car dependency and car culture that is in conflict with the country's current sustainable development initiatives [62]. The limitation of both cities in achieving high levels of SUM is confirmed when compared to Helsinki and its traditional commitment to smart mobility [63]. The limitations of both cities in achieving high levels of SUM are confirmed when compared to Helsinki and its long-standing commitment to smart mobility [63].

Finally, deviant consistency cases were identified, with Istanbul and Moscow in the case of SEF, and Montreal and Toronto in the case of PUB. The case of Istanbul, which is the case highlighted in the analysis of the outliers with NCA for MAT and SEF conditions, is particularly noteworthy. Indeed, rules, regulation and uncertainty of mobility system partners are among the main barriers to the adoption of mobility innovations in Istanbul [64]. In fact, Istanbul is an illustrative example of a megacity where attempts have been made to destabilise the mobility regime through infrastructure development [7]. Consequently, the conditions necessary for SUM were identified, and they also facilitate the presence of the causal mechanism that determines SUM.

If the focus is on the combinations of conditions that explain SUM, we recall that these result in PUB*(INF*SEF + INF*MAT + SEF*MAT). Thus, the different terms explaining the presence of SUM imply the combination of PUB with other conditions. Firstly, it can be related to a relevant role on the part of local authorities reflected in INF*SEF. Secondly, a conjunction between the relevance of new mobility solutions (through MAT), and the relevant role of local authorities (either as a result of the coordination reflected in SEF or the creation of infrastructures implied by INF) is posited. The combination of the terms PUB and MAT indicates that urban mobility is based on a mix of public and private mobility options [6,31,49]. In any case, the central role of public transport in achieving sustainable mobility is confirmed [2,3]. Likewise, the term SEF*MAT*PUB explains Shanghai, an example that the emergence of urban transitions towards sustainable mobility requires environments that facilitate regime destabilisation [7]. In contrast to other cities, such as Beijing, less transit-oriented development is identified in suburban areas of Shanghai. Consequently, the initial development of the metro network has failed to respond to subsequent urban development [45].

The combinations of terms that explain ~SUM are ~PUB*(INF + ~SEF) + ~SEF*(~INF*~MAT + INF*MAT). In this case, we are faced with two options for ~SUM to occur. One possible explanation is that it may begin with ~PUB. However, it is noteworthy that it can be coupled with the existence of INF, indicating that cities with a high level of infrastructure are not highly ready for the implementation of sustainable mobility due to the lack of robust public transport (~PUB). For instance, Shanghai, a city renowned for its exemplary public transport system in China, has been unable to meet the mounting demands it faces. The insufficient growth in public transport has created a window of opportunity for the development of shared transport [7]. In the other combination, ~PUB is coupled with a lack of high coordination by local authorities (~SEF). The second group of options comprises cities that share a lack of high coordination (~SEF), coupled with the simultaneous presence of infrastructure (INF) and investments in new mobility formulas (MAT). Alternatively, this could be expressed as the negation of both (~INF*~MAT). The terms explaining ~SUM reflect approaches to the impact of prioritising the role of the public sector in achieving sustainable mobility [6] since ~PUB appears in two of the terms explaining ~SUM and ~SEF in the other two. Even if cities possess robust infrastructures, they may still be implicated in the explanations of ~SUM.

Consequently, Proposition 1a and 1b are accepted. Therefore, the combination of the conditions considered at the landscape and regime level explains the readiness of cities to implement sustainable mobility solutions or their negation.

It is also notable that a causal mechanism was identified in the INF*~PUB term within the ~SUM explanation. In the case of INF, the typical cases are Jakarta and Houston, while the irrelevant case is Beijing. In Jakarta, there has been increased investment to improve public transport infrastructure, suggesting that understanding spatial behaviour and socio-cultural innovation should be prioritised to ensure a well-functioning mobility system. Nevertheless, Jakarta is confronted with significant challenges in attaining a transition to sustainable mobility [4]. The rapid development of mobility infrastructure in Jakarta is underway through the incorporation of a variety of public transport and integrated mobility solutions, including mass rapid transit, light rail and commuter lines, as well as more integrated road-based public transport. However, the number of private car users has also increased due to economic growth [65]. In the case of ~PUB, the typical cases are Houston and Hong Kong, while the irrelevant case is Dallas. In Houston, although the Houston Metro offers light rail service, its route coverage is limited [66]. In contrast, Dallas has the longest light rail network in the United States [67]. The results indicate that INF*~PUB overcomes the role of scope conditions to trigger the causal mechanism that determines ~SUM.

The explanation of the behaviour of megacities is disparate. Therefore, the different terms that explain SUM include megacities with a high GPD (Seoul, London, Paris, New York, Istanbul, Moscow, Tokyo, or Beijing). The solutions align with the megacities' commitment to infrastructure megaprojects [44]. The megacities explained in the ~SUM solution concentrate on two of the terms: ~SEF*~PUB and ~INF*~SEF*~MAT (Lagos, Manila, Johannesburg, Bogota, Delhi, Mumbai, Cairo, or Buenos Aires). It can, therefore, be concluded that the proposed model, when it is applied to megacities is effective in explaining the transition towards sustainable urban mobility in the case of megacities that do not have a low GDP. Conversely, it is also able to identify the causes that prevent the presence of a high level of readiness for sustainable urban mobility in the case of megacities with a low GDP. Indeed, disparities in the implementation of transit-oriented development between megacities have already been documented [45].

Therefore, we can accept Propositions 2a and 2b. This is why there are differences in the combinations of conditions that explain the level of preparedness of megacities for the implementation of mobility solutions, or their negation.

The failure of megacities with low GDP to achieve a high level of SUM (~SUM) can be explained by ~SEF*(~PUB + ~INF*~MAT). This is because these megacities lack coordination of the mobility network by the municipal government, and they do not value public transport highly. Furthermore, they do not have outstanding infrastructure, and the private sector is not involved to a great extent in the development of a modern mobility regime. In these cities, it can be observed that shared mobility can sometimes be driven by economic rather than sustainability objectives. This results in an increase in the number of vehicles on the road, a pattern that is especially prevalent in the context of developing megacities [68].

For instance, Sao Paulo, a megacity with a high GDP, is explained by ~SEF*~PUB, a city in which approximately 75% of the low-income population uses underdeveloped public transport systems that are inadequate for the size of the city and the transport demand it faces (which can be reflected in ~PUB). In comparison to New York's extensive underground system which spans 373 km, or Beijing's with 690 km (megacities similar in size and GPD), Sao Paulo´s underground system is relatively limited, with only 101 km of track [43]. Furthermore, urban mobility actions in Sao Paulo have been insufficient to bring about real change in the severe segregation and inequality patterns observed in the city [43]. A comparative analysis between three megacities that do not have low GDP (Bangkok, Seoul and Tokyo) revealed a positive correlation between GDP and engagement with cycling or walking and with the use of public transport. Consequently, citizens in Bangkok have a lower level of engagement with cycling/walking than those in Seoul and Tokyo, perhaps due to the limited network of public facilities and services (with an under-provision of bicycle lanes and parking). Seoul has consistently expanded its mobility system with the objective of reducing traffic congestion [44]. Additionally, Bangkok exhibits a comparatively lower level of reliance on public transportation compared to Tokyo and Seoul. Despite the availability of diverse modes of public transportation, including buses, electric trains, and boats, the quantity and quality of these options are limited [69].

These terms reflect some characteristic features of developing megacities, including weak institutional structures and ambivalent transport policies [7,21,22,38,43]. Furthermore, it can be demonstrated that the urban mobility regime in developing cities reflects a set of rules, regulatory environment, institutional arrangements and governance practices that differ from those observed in developed cities [21]. Consequently, the successful introduction of sustainable mobility may be hindered by a lack of transition in infrastructure, technologies, policies or regulations [22].

## 7. Conclusions

This work was developed with the aim of identifying the conditions that determine whether cities are ready to implement sustainable mobility solutions.

As mentioned above, the existence of conditions necessary for SUM, but not for ~SUM, was identified. Thus, if a city wants to achieve SUM, it must have SEF, MAT and PUB. It was also found that these conditions not only enable their existence but also allow the explanatory mechanism of SUM to be present. Likewise, the different transition pathways that explain SUM and ~SUM were identified, thus responding to the research gap identified in the literature. The application of SMMR has allowed us to further identify the conditions that determine the direction of the transition pathways toward sustainable mobility. Furthermore, it has also enabled us to identify the existence of a causal mechanism in the explanation of ~SUM. Finally, it has confirmed the particular reality of developing megacities, reflected in the combination of conditions that explain why they are not highly prepared for the implementation of sustainable urban mobility solutions.

### *7.1. Contributions*

The present work makes several methodological contributions. Firstly, it confirms the suitability of applying QCA, which recognises equifinality, joint causation, asymmetry and differentiation between necessary and sufficient conditions. Secondly, it analyses the existence of causal mechanisms in both types of conditions. Thirdly, it allows for the systematic identification of cases in which to develop within-case analysis by process tracing. Moreover, the application of different methods has made it possible to identify the complementarities between them. Thus, the necessary conditions identified by QCA and NCA are very similar, differing only in PUB. The application of process tracing makes it possible to detect that the necessary conditions for SUM allow the presence of a causal mechanism. A causal mechanism is also identified in the sufficient conditions of ~SUM.

Among the theoretical contributions is the identification of the different pathways that are occurring in cities in their achievement of sustainable urban mobility. Firstly, in the case of those cities that are explained in the SUM solutions, we find pathways of re-alignment and transformation. The re-alignment corresponds to INF*SEF*PUB and INF*MAT*PUB. In these cases, the focus is on infrastructure, as well as public investment through PUB. In this manner, innovations associated with novel modes of mobility can result in the realignment of a novel regime. With regard to the term SEF*MAT*PUB, landscape developments linked to coordination by local administrations (SEF) are coupled with the development of public transport (PUB) and MAT, whereby actors gradually adjust to landscape pressures.

In cases where ~SUM is explained, two of the terms indicate a commitment to infrastructure (INF*~PUB, INF*~SEF*MAT). However, the lack of robust public transport or lack of coordination leads to competing options and a lack of alignment, which in turn affects the viability of the project. In the remaining two terms, namely (~SEF*~PUB, ~INF*~SEF*MAT), it is assumed that in the absence of landscape pressure, the regime remains stable, leading to a reproduction pathway.

In any case, in line with recent approaches, we consider the main theoretical contribution to confirm the suitability of using configurational studies and process tracing to analyse the existence of causal relationships.

Furthermore, it was confirmed that megacities that do not have a high GDP can be explained by transition processes towards not achieving a high level of readiness for sustainable urban mobility. As might be expected, not having a high GDP may determine that these cities are not moving towards sustainable mobility, as their focus may be on achieving greater economic development. This situation may be particularly serious due to the concentration of population in these cities, which has severe negative impacts on sustainability.

Within the contributions of public managers, we examine the various combinations of conditions that can lead to SUM. Firstly, while infrastructures play an important role in the development of a transition towards sustainable mobility, there are cases where this is achieved through good mobility management, unity of strong public transport and the intervention of other mobility options. Secondly, two of the terms that explain ~SUM are based on a situation where the city is endowed with infrastructure. The role of public transport is more evident, as it is present in all three terms that explain SUM, and not obtaining high performance in public transport in two of the four terms that explain ~SUM. However, while the role of public transport is easy to interpret, the role of infrastructure is not. Thus, PUB is a necessary condition for SUM, appears in the terms that explain SUM, and is negated in the two terms that appear in the explanation of ~SUM. Conversely, INF appears in two of the terms that explain ~SUM. In other words, there are cases where a commitment to INF can lead to a high degree of unreadiness for sustainable mobility if it interacts with the negation of public transport or the negation of the efficiency of the system. Furthermore, this paper demonstrates to urban administrators the extensive range of pathways that explain the attainment, or lack thereof, of a high level of readiness for the implementation of sustainable mobility.

### *7.2. Limitations and Future Research*

As a limitation of the study, it should be noted that the data used were sourced from a single source. Had data from multiple sources been triangulated, the conclusions reached may have been more robust. Consequently, future research should consider utilising data from a range of sources, provided that the sample size remains consistent. It would also be interesting to include a larger number of megacities in different geographical areas to confirm the generalisability of the results. Finally, the inclusion of additional analytical techniques would enrich the discussion of the results.

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