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The Identification of Causal Mechanisms in Sustainable Urban Transitions. A Systematic Approach to Case Selection

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Abstract: Cities around the world are betting on sustainable transitions as a formula to respond to some of the challenges they face. Within transitions, the acceleration phase has been little studied, perhaps because it relies on the mechanisms linked to the causes that lead to the desired effects. In the study of sustainable transitions, Qualitative Comparative Analysis is used to identify the causal conditions that generate the outcomes. Identifying causal mechanisms requires complementing this analysis with process tracing, the Set Theoretic Multi-Method Research (SMMR). Although previous work has complemented QCA analysis with process tracing, it did not apply a systematic approach to case selection. So, the research question addressed is: can we systematically select cases to apply process tracing in the explanation of sustainable urban transitions? The present work, by applying a systematic approach in the selection of the cases to which to apply process tracing, verifies the existence of a causal mechanism among the causal conditions that explains the denial of cities' readiness to implement mobility innovations that can be extrapolated. No such mechanism exists for the analysis of readiness. Thus, the fundamental role played by lock-in mechanisms in the maintenance of the existing regimes in sustainable transitions is confirmed.

Keywords: SMMR; causal mechanism; process tracing; QCA; within-case

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1. Introduction

Cities around the world are implementing strategies to meet the Sustainable Development Goals (SDGs). The actions articulated through sustainable transitions involving radical structural transformations result from interrelated social dynamics at different scales [1,2]. The emergence of new urban mobility solutions opens the door to transition processes. Transitions, used to explain innovative processes, involve cross-scale and cross-sectoral dynamics [3,4]. A transition is defined as a social process of non-linear change in cultural, structural, and social practices specific to the contexts in which they occur across different socio-technical systems [5]. Transitions towards sustainable urban mobility keep in mind that any future urban mobility solution should contribute to more sustainable, quieter, and less polluted cities [6]. Therefore, sustainable transitions present the city as a socio-technical system that needs to be reconfigured in line with the SDGs, especially SDG11, linked to inclusive, safe, resilient, and sustainable cities [5,7].

Beyond designing projects to activate sustainable initiatives, it is necessary to specify which of them presents the seeds of radical change and to identify the mechanisms that could stimulate their acceleration [1]. This is because it is necessary to accelerate transitions to disseminate sustainable technologies [4]. However, acceleration—dependent on mechanisms—has been the least attended phase of the transitions [1,2]. It is necessary to study the trajectories of transitions that, after an initial diffusion, stagnate and relapse in terms of the intended change [8]; in other words, to evaluate how to accelerate transitions towards more sustainable production and consumption systems [9]. In its application to sustainable transitions, the focus is on those lock-in causal mechanisms that connect causes with outcomes under certain contextual conditions, favoring incremental over radical innovations and path-dependence [10–13]. The study of sustainable transitions would benefit from attending to the intervening mechanisms to a greater extent [14].

In the study of sustainable transitions, the multilevel perspective (MLP) using Qualitative Comparative Analysis (QCA) is commonly used [4,15], although it is criticized for how it explains causality [16]. Therefore, it is suggested to deepen the understanding of the mechanisms that characterize sustainable transitions by complementing the findings of QCA with process tracing [10,17]. Thus, Set Theoretic Multi-Method Research (SMMR) is consolidated, whereby the analysis of a truth table, with QCA at a cross-case level, is combined with process tracing at a within-case level. Both techniques—QCA and process tracing—are rooted in fuzzy-set theory [18–22].

QCA is sometimes applied to explain “how” and “why” a phenomenon works. While the two questions may seem similar, QCA only answers the second question—the “why?”. Answering both of the questions requires identifying those situations in which the presence or absence of a condition makes a difference for the presence or absence of the effect [23]. Therefore, QCA analysis increases its relevance if, after establishing the causal effect at the cross-case level, the causal mechanisms are identified by applying process tracing [24–26]. The objective of QCA analysis when combined with process tracing is to identify the conditions that are potentially causally relevant and lead to the occurrence of a phenomena. Although different works have applied process tracing after QCA [25,27], they did not employ a systematic approach to case selection. Therefore, the research question addressed by this paper is: can we systematically select cases to apply process tracing in the explanation of sustainable urban transitions?

The application of the R SetMethods package via SMMR makes it possible to systematically select those cases to which process tracing can be applied [19]. Therefore, the aim of this paper is to analyze the existence of the causal mechanisms that prove the existence of causality in the relationship between the level of a city’s readiness to implement mobility innovations and its antecedents. In this way, it responds to the call for multi-method investigations based on QCA [28] and deepens the understanding of the existing mechanisms in the transitions [10,17], this being the gap addressed by the present work. This is because the mechanisms linked to sustainable transitions, and the causal processes linked to them, have been neglected in previous studies [29–32]. In addition, the statistical analyses present limitations in establishing causalities in the study of sustainable transitions, unable to reveal the comprehensive impact of the different combinations of factors [29].

The results obtained allow us to identify the existence of a causal mechanism in the relationship between the denial of readiness to implement mobility innovations and its antecedents. This mechanism can be extrapolated to all of the typical cases. In the case of readiness, no mechanism is identified. Thus, the role of lock-in mechanisms that reinforce the preeminence of established regimes is highlighted, explaining why cities are not prepared for the implementation of mobility innovations.

2. Materials and Methods

QCA unites quantitative and qualitative approaches to establish combinations of the causal conditions that lead to an outcome [24,33,34]. It is a method oriented to the study of cases, in which the knowledge of the cases comes into play during all of the phases that make up their development. Prior to the analysis, knowledge of the cases is accumulated in the delimitation of the universe and its calibration; during the analytical process, the cases should not disappear after the Boolean expressions and fitting parameters; after the analysis, it is important to return to the cases for further study [19,20]. In fact, the idea of going back to the cases is not a peculiarity of QCA, but is its essence [35]. In Boolean solutions, QCA describes the relationship between the sufficient conditions and the outcome in terms of Set Theory [23]. The sufficiency statement in QCA implies cross-case regularity; it identifies the conditions that allow the agents to act in ways that achieve their outcomes [35]. However, QCA does not provide a causal explanation of what processes and mechanisms underlie the effect and link the cause to the outcome. This is because such cross-case regularities are not causal mechanisms per se, but empirical manifestations of the underlying causal mechanisms [18,22,24,35]. The cross-case regularities identified from the truth table in the QCA should be interpreted and verbalized into causal mechanisms [35,36]. Therefore, after applying the QCA, the analysis of the cases is deepened in an attempt to unveil the causal mechanisms between the conditions and the outcome, and to make causal inferences about the way in which the mechanism operates [19,37]. The description and analysis of the mechanisms is crucial to explain causation [11,32]. The causal mechanism is defined as a system in which the activities of the actors transfer causal forces from the causes to the outcomes [11,24,26,36,37]. The mechanistic perspective of causation seeks to uncover the causal process [18], to explain how and through what kind of process an outcome is brought about or produced [38]. The causal mechanism is not an intervening variable, but a theoretical statement or conceptual construct on how a set of variables, or the processes linked to such variables, cause the empirical outcome [39]. This fact endows them with a high level of abstraction, which is criticized [18,35]. The analysis of causal mechanisms via process tracing is one of the most fruitful methods for establishing causal statements in individual cases [18].

Process tracing is a within-case method that uncovers the causal mechanisms through a systematic study of the process that links a cause, or a conjunction of causes, with an outcome [24,39–41]; the mechanisms that enable the outcome to actually unfold [23,25,36,38,42]. As we have commented above, the causes identified at the cross-case level make the outcomes possible; if the agents finally achieve the outcome, that is explained by a within-case analysis via process tracing [35]. Thus, it is argued that process tracing helps to open the black box of causation and explain its results [18,43]; making it possible to identify, track, and trace the causal processes at play and infer the presence of causality [40,43].

The potential of a multi-method design is that it combines the strengths and compensates for the limitations of the different methods applied [18]; thus, it is increasingly popular to combine QCA with process tracing via SMMR [18,19,21,23,26]. Employing configurational and mechanistic approaches together provides an accurate picture of the investigated reality, allowing the identification of potential causes and selecting cases for further within-case analysis [23,36]. QCA distinguishes between the causal conditions that can produce something and the contextual conditions under which the mechanisms act as the causal pathways between causes and effects [11,31,37]. In SMMR, the causal mechanisms are expected to be present in certain cases when the conditions that trigger them are present [24,37]. SMMR involves an in-depth analysis of the specific causal mechanisms that allows examination of the "why"—of combinations of conditions, via QCA, and the "how"—of the causal mechanism, via process tracing of a causal relationship [37]. SMMR is based on the fact that QCA-based inference becomes stronger "if" and "when" within-case evidence is added via process tracing, with the study of selected cases to establish the existence of causal relationships [19,21,36]. After applying QCA, process tracing is conducted on specific cases to: (a) provide evidence of a causal relationship between a combination of conditions and the outcome; and (b) understand how the combination of conditions produces the outcome by tracing the causal mechanism under certain contextual conditions [38,44].

3. Results

In the present work, we opted for that SMMR modality in which first the cross-case analysis is performed with QCA, and then the within-case analysis is performed with process tracing [20,36,38], considered a powerful research strategy [18,44]. Based on the QCA result, the R SetMethods smmr command is "identifies the best available cases for within-case analysis" [19] (p. 181) thus, identifying the best available case or the best matching pair of cases, depending on the analysis to be performed [19].

The application of process tracing, as mentioned above, is based on the solutions identified in QCA. In our case, we start from the results presented in an article that studies the combinations of conditions that explain the readiness of a city to implement mobility innovations through the application of QCA [5]. Starting from the Multi-Level Perspective, the article proposes a model in which the result is "Readiness" (OVE, Readiness as an indication of its future mobility capacity), explained by a condition at the landscape level, "Innovation" (INN, How well does the city leverage local talent and resources to drive technological advances?) and four conditions at regime level: "Infrastructure" (INF, Has the city developed robust infrastructure and expanded connectivity to support future mobility?); "Market Attractiveness" (MAT, How well does the city engage the private sector and secure diverse investments to build out mobility?); "System Efficiency" (SEF, How well does the municipal government coordinate and enhance the city's mobility network through things like traffic management systems?); and "Social Impact" (SIM, Does the city maximize societal benefits like mobility-related employment or airport arrivals while minimizing harmful qualities like poor air quality?). In the article (for further explanation of the analysis model see [5]), the authors start from the Urban Mobility Readiness Index 2021 [45]. To deepen the analysis, we will present the results for one term of the solution, for OVE—the level of readiness of the city to implement mobility innovations—and the other for ~OVE—the denial of the city's readiness to implement mobility innovations. In the case of OVE, the second term was chosen because it is the only one composed of different conjuncts. In the case of ~OVE, the choice of the second term is justified both by the parameters it presents (0.496 unique coverage) and by allowing the application of process tracing In the case of OVE, the remaining solution does not allow SMMR to be performed by having a single conjunct. In the case of ~OVE, the remaining four conjunctions were analyzed without it being possible to identify the existence of any mechanism in any of them.

The table above (Table 1) shows the terms, together with their parameters and the cities explained by each solution.

In addition, since they are applicable to process tracing, the truth tables for OVE (Table 2) and ~OVE (Table 3) are presented.

Table 1. Selected terms for each solution.

Outcome	Term	inclS	PRI	covS	covU	Cities
OVE	INF*MAT*SEF	0.997	0.995	0.819	0.041	Warsaw, Beijing, Shanghai; Berlin, Atlanta, Dallas, Houston, San Francisco, Chicago, New York, Los Angeles, Boston, Sydney, Helsinki, Dublin, Toronto, Vancouver, Madrid, Montreal, Munich, Oslo, Amsterdam, Seoul, Stockholm, Washington D.C., Paris, Barcelona, London, Singapore, Tokyo, Hong Kong
~OVE	~INN*~INF*~SEF	0.976	0.964	0.873	0.496	Johannesburg, Jakarta, Bangkok, Quito, Jeddah, Riyadh, Buenos Aires, Cape Town, Nairobi, Rio de Janeiro, Sao Paulo, Lagos, Manila, Casablanca, Santiago, Mexico City, Cairo, Lima, Delhi, Bogota, Mumbai; Doha, Abu Dhabi; Dubai

Table 2. Truth Table OVE results.

	INF	SIM	MAT	SEF	OUT	n	incl	PRI	Cities
1	0	0	0	0	0	21	0.318	0.004	Johannesburg, Jakarta, Bangkok, Quito, Jeddah, Riyadh, Buenos Aires, Cape Town, Nairobi, Rio de Janeiro, Sao Paulo, Lagos, Manila, Casablanca, Santiago, Mexico City, Cairo, Lima, Delhi, Bogota, Mumbai
3	0	0	1	0	0	1	0.744	0.133	Kuala Lumpur
5	0	1	0	0	1	2	0.852	0.159	Doha, Abu Dhabi
7	0	1	1	0	1	1	0.944	0.679	Dubai
8	0	1	1	1	1	2	0.983	0.918	Milan, Moscow
12	1	0	1	1	1	3	0.998	0.991	Warsaw, Beijing, Shanghai
14	1	1	0	1	1	1	0.990	0.960	Zurich
15	1	1	1	0	1	1	0.991	0.962	Istanbul
16	1	1	1	1	1	28	1.000	1.000	Berlin, Atlanta, Dallas, Houston, San Francisco, Chicago, New York, Los Angeles, Boston, Sydney, Helsinki, Dublin, Toronto, Vancouver, Madrid, Montreal, Munich, Oslo, Amsterdam, Seoul, Stockholm, Washington D.C., Paris, Barcelona, London, Singapore, Tokyo, Hong Kong

OUT: output value; *n*: number of cases in configuration; incl: sufficiency inclusion score; PRI: proportional reduction in inconsistency.

Table 3. Truth Table ~OVE results.

	INN	INF	SIM	MAT	SEF	OUT	n	incl	PRI	Cities
1	0	0	0	0	0	1	21	0.999	0.999	Johannesburg, Jakarta, Bangkok, Quito, Jeddah, Riyadh, Buenos Aires, Cape Town, Nairobi, Rio de Janeiro, Sao Paulo, Lagos, Manila, Casablanca, Santiago, Mexico City, Cairo, Lima, Delhi, Bogota, Mumbai
5	0	0	1	0	0	1	2	0.986	0.916	Doha, Abu Dhabi
7	0	0	1	1	0	1	1	0.935	0.486	Dubai
8	0	0	1	1	1	1	2	0.905	0.135	Milan, Moscow
12	0	1	0	1	1	1	1	0.918	0.035	Warsaw
15	0	1	1	1	0	1	1	0.912	0.110	Istanbul
16	0	1	1	1	1	0	2	0.740	0.000	Madrid, Barcelona
19	1	0	0	1	0	1	1	0.945	0.548	Kuala Lumpur
28	1	1	0	1	1	0	2	0.739	0.000	Beijing, Shanghai
30	1	1	1	0	1	0	1	0.741	0.005	Zurich
32	1	1	1	1	1	0	26	0.298	0.000	Berlin, Atlanta, Dallas, Houston, San Francisco, Chicago, New York, Los Angeles, Boston, Sydney, Helsinki, Dublin, Toronto, Vancouver, Montreal, Munich, Oslo, Amsterdam, Seoul, Stockholm, Washington D.C., Paris, London, Singapore, Tokyo, Hong Kong

Five types of identifiable cases are used in the process tracing in QCA. Typical cases (1) and deviant cases consistency—in degree (2) and in kind (3)—are defined on the basis of their membership in the sufficient term. The deviant cases coverage (4) and the individually irrelevant cases (IIR) (5) are defined based on their membership in the solution formula [20,46].

Once the different types of cases have been identified through fsQCA, the question is which of them should be chosen to deepen the results through process tracing. The answer is firstly through a single within-case analysis (see Section 3.1), followed secondly by a comparative within-case analysis (see Section 3.2). In the single within-case analysis, the uniquely covered type, the deviant consistency in kind, and the deviant coverage are studied. In the comparative within-case analysis, different pairs of cases are compared: typical-IIR; typical-typical; typical-deviant consistency; and IIR-deviant coverage.

3.1. Single Within-Case Analysis

Process tracing applied to typical cases aims to identify the causal mechanism that links the sufficient term to the outcome [19,20]. A term will be causal if each of its conjuncts produces a difference in the mechanism [21]. To test this approach, we analyzed whether leaving out any of the conjuncts makes the mechanism disappear, through as many within-case analyses of typical cases as conjuncts exist in the conjunction. In each of these analyses, one is the focal conjunct (FC), in which it is intended to identify whether a difference for the mechanism is produced; while the complementary conjunct (CC) represents the other conjuncts of the sufficient term [19,20].

In the analysis of the typical cases, the severity principle is applied, whereby the membership in the mechanism can only vary in the corridor established by the membership in the FC—the lowest value that the mechanism can take—and in the solution—the highest value that the mechanism can take. The smaller the corridor, the smaller the range of membership values that the mechanism can take, and the more severe the test will be [20]. Likewise, the typical case should be a pathway case, which is uniquely covered by one of the solution paths—typical only for one of the sufficient terms [18,19]. Thus, the best available typical case should meet the following criteria: the FC defines the membership of the typical case in the term (FC ≤ CC)—attribution principle; the corridor for the mechanism is a small test corridor; the membership in the sufficient term is high; the case is uniquely covered by the sufficient term [20,21].

However, it is pointed out that sometimes fsQCA imposes more restrictive criteria than those of process tracing to identify the mechanisms [36]. Thus, one could relax the requirements [46], such as the need to select only the cases whose fuzzy score for the membership in the conjunction is less than the membership in the result and to select only cases that are members of a single conjunction [40].

The analysis of typical cases for OVE is presented below (Table 4).

Table 4. Analysis of typical cases for OVE.

	FocalConj	Outcome	CompConj	Term	UniqCov	Best	MostTypFC	Rank	ConsFC	MostTypTerm
Typical Cases—Focal Conjunct INF										
Beijing	0.67	0.77	0.82	0.67	TRUE	0.53	FALSE	1	TRUE	FALSE
Shanghai	0.59	0.71	0.86	0.59	TRUE	0.65	FALSE	1	TRUE	FALSE
New York	0.89	0.93	0.91	0.89	FALSE	0.19	FALSE	1	TRUE	FALSE
Washington, D.C.	0.85	0.90	0.88	0.85	FALSE	0.25	FALSE	1	TRUE	FALSE
Oslo	0.82	0.87	0.84	0.82	FALSE	0.28	FALSE	1	TRUE	FALSE
Toronto	0.79	0.85	0.83	0.79	FALSE	0.33	FALSE	1	TRUE	FALSE
Dallas	0.57	0.69	0.64	0.57	FALSE	0.67	FALSE	1	TRUE	FALSE
Typical Cases—Focal Conjunct MAT										

Madrid	0.82	0.82	0.84	0.82	FALSE	0.18	FALSE	1	TRUE	FALSE
London	0.88	0.94	0.89	0.88	FALSE	0.24	FALSE	1	TRUE	FALSE
Singapore	0.84	0.96	0.95	0.84	FALSE	0.40	FALSE	1	TRUE	FALSE
Vancouver	0.71	0.83	0.75	0.71	FALSE	0.53	FALSE	1	TRUE	FALSE
Tokyo	0.74	0.88	0.76	0.74	FALSE	0.54	FALSE	1	TRUE	FALSE
Houston	0.66	0.77	0.67	0.66	FALSE	0.56	FALSE	1	TRUE	FALSE
Munich	0.74	0.94	0.89	0.74	FALSE	0.66	FALSE	1	TRUE	FALSE
Typical Cases—Focal Conjunct SEF										
Helsinki	0.91	0.95	0.93	0.91	FALSE	0.17	FALSE	1	TRUE	FALSE
Berlin	0.90	0.94	0.94	0.90	FALSE	0.18	FALSE	1	TRUE	FALSE
Chicago	0.84	0.91	0.86	0.84	FALSE	0.30	FALSE	1	TRUE	FALSE
Boston	0.80	0.92	0.85	0.80	FALSE	0.44	FALSE	1	TRUE	FALSE
Dublin	0.63	0.69	0.66	0.63	FALSE	0.49	FALSE	1	TRUE	FALSE
SanFrancisco	0.78	0.96	0.88	0.78	FALSE	0.58	FALSE	1	TRUE	FALSE
Sydney	0.63	0.84	0.70	0.63	FALSE	0.79	FALSE	1	TRUE	FALSE

The best available case is always presented first [19]. Thus, for the different focal conjuncts, the best typical cases are as follows: FC INF Beijing; FC MAT Madrid; and FC SEF Helsinki. As can be seen, the typical cases comply with the attribution principle and the corridor test. The UnqCov column indicates whether the case is typical only for the analyzed sufficient term [19]. Only in the case of the FC INF are there typical cases with unique coverage—Beijing and Shanghai—the pathway cases. Although they present lower values than the stable criteria [19], they appear in the first positions as typical cases because they are uniquely covered cases. The Best column indicates whether the case is the best typical case available, while the MostTypFC states whether it has the lowest value in the Best column. No case has the lowest value in the column (Table 4). The Rank column shows the ranking to which it belongs. All of the cases have a Rank 1, the best possible. The ConsFC column indicates whether the membership of the case in the FC is lower than its membership in the result—an element previously analyzed; that is, if it is consistent with sufficiency. This parameter is TRUE for all of the cases. The last column shows whether a case is the most typical case if we look at the full sufficient term instead of the particular conjuncts [19]. It is FALSE for all of the cases. Next, the typical cases were analyzed for ~OVE (Table 5).

Table 5. Analysis of typical cases for ~OVE.

	FocalConj	**Outcome**	**CompConj**	**Term**	**UniqCov**	**Best**	**MostTypFC**	**Rank**	**ConsFC**	**MostTypTerm**
Typical Cases—Focal Conjunct ~INN										
Cairo	0.92	0.92	0.95	0.92	TRUE	0.08	FALSE	1	TRUE	FALSE
Lagos	0.96	0.99	0.99	0.96	TRUE	0.10	FALSE	1	TRUE	FALSE
Riyadh	0.81	0.93	0.90	0.81	TRUE	0.43	FALSE	1	TRUE	FALSE
Jeddah	0.77	0.96	0.94	0.77	TRUE	0.61	FALSE	1	TRUE	FALSE
Doha	0.52	0.75	0.81	0.52	TRUE	0.94	FALSE	1	TRUE	FALSE
Nairobi	0.97	0.98	0.97	0.97	TRUE	0.05	TRUE	2	TRUE	TRUE
Manila	0.92	0.95	0.91	0.91	TRUE	0.15	FALSE	2	TRUE	FALSE
Typical Cases—Focal Conjunct ~INF										
Quito	0.95	0.95	0.96	0.95	TRUE	0.05	FALSE	1	TRUE	TRUE
Bogota	0.91	0.91	0.94	0.91	TRUE	0.09	FALSE	1	TRUE	FALSE
Bangkok	0.78	0.88	0.89	0.78	TRUE	0.42	FALSE	1	TRUE	FALSE
CapeTown	0.75	0.84	0.81	0.75	TRUE	0.43	FALSE	1	TRUE	FALSE
Casablanca	0.80	0.92	0.87	0.80	TRUE	0.44	FALSE	1	TRUE	FALSE
Johannesburg	0.74	0.90	0.81	0.74	TRUE	0.58	FALSE	1	TRUE	FALSE

Santiago	0.56	0.76	0.72	0.56	TRUE	0.84	FALSE	1	TRUE	FALSE
Typical Cases—Focal Conjunct ~SEF										
Jakarta	0.88	0.88	0.90	0.88	TRUE	0.12	FALSE	1	TRUE	FALSE
Lima	0.91	0.93	0.95	0.91	TRUE	0.13	FALSE	1	TRUE	FALSE
Manila	0.91	0.95	0.92	0.91	TRUE	0.17	FALSE	1	TRUE	FALSE
MexicoCity	0.85	0.86	0.86	0.85	TRUE	0.17	FALSE	1	TRUE	FALSE
Mumbai	0.84	0.92	0.91	0.84	TRUE	0.32	FALSE	1	TRUE	FALSE
Delhi	0.81	0.89	0.86	0.81	TRUE	0.35	FALSE	1	TRUE	FALSE
RiodeJaneiro	0.70	0.87	0.92	0.70	TRUE	0.64	FALSE	1	TRUE	FALSE

In the case of ~OVE the best possible case for each FC is: FC ~INN Cairo; FC ~INF Quito; and FC ~INF Jakarta. In this case, all of the typical cases are uniquely covered. It is noteworthy that, in the case of ~INN, the case indicated as MostTypFC is Nairobi, although it has Rank 2. In all of the focal conjuncts, there are typical Rank 1 cases (Table 5). The ConsFC column is TRUE for all of the cases. Finally, the last column—MosTypTerm—is FALSE for all of the cases.

The analysis of the deviant consistency cases allows for the identification of the INUS conditions that should be part of a sufficient term [19]. For this purpose, we started with the analysis of the deviant consistency cases for the OVE outcome, the results of which are shown in Table 6.

Table 6. Deviant Consistency Cases OVE.

	Cases	Term	TermMembership	Outcome	Best	MostDevCons
11	Warsaw	INF*MAT*SEF	0.55	0.49	1.39	TRUE

The deviant consistency cases are presented from the best to worst; in the case of OVE, only Warsaw appears for the sufficient term INF*MAT*SEF. The membership of each case is observed in the term of interest and in the result. The Best column calculates how close it is to the ideal deviant consistency case. The MostDevCons column reports whether the case in question has the lowest value in Best and is the most deviant consistency case in the data, being true for the Warsaw case.

The deviant consistency cases for ~OVE were then identified (Table 7).

Table 7. Deviant Consistency Cases ~OVE.

Cases	Term	TermMembership	Outcome	Best	MostDevCons
11 Dubai	~INN*~INF*~SEF	0.60	0.35	1.15	TRUE

For the sufficient term ~INN*~INF*~SEF it appears as the deviant consistency case Dubai, which happens to be the most deviant consistency case.

Finally, an attempt was made to identify the deviant coverage cases, but they were not identified for either OVE or ~OVE. This analysis would have identified the missing conjunctions, and entire omitted sufficient terms [19].

3.2. Comparative Within-Case Analysis

Comparing a typical case with an IIR allows for the testing of the causal properties linking a specific sufficient term and the outcome. The aim is to identify whether the sufficient condition not only causes the outcome but triggers the mechanism leading to that outcome [19]; whether it creates a causal difference for the outcome both at a cross-case level and for the mechanism at a within-case level [20]. To affirm the existence of a causal inference, each focal conjunct must make a difference to the mechanism [19].

To identify the mechanism, each pair of typical cases and IIR is ranked from 1 to 8 [20] (p. 517). Cases with a lower ranking are more suitable for within-case comparative analysis. Additionally, the typical case should be uniquely covered by the sufficient term under investigation, while the IIR case should be globally uncovered [20].

First, the analysis of typical cases was performed with the IIRs for OVE (Table 8).

Table 8. IIR typical case Analysis for OVE.

	Typical	IIR	UniqCov	GlobUncov	Best	PairRank	ConsFC_Typ	MostTypTerm	MostTypFC	ConsFC_IIR
Focal Conjunct INF										
366	Oslo	RiodeJaneiro	TRUE	TRUE	1.21	3	TRUE	FALSE	FALSE	TRUE
395	Oslo	SaoPaulo	TRUE	TRUE	1.25	3	TRUE	FALSE	FALSE	TRUE
714	Oslo	Mumbai	TRUE	TRUE	1.25	3	TRUE	FALSE	FALSE	TRUE
453	Oslo	Manila	TRUE	TRUE	1.26	3	TRUE	FALSE	FALSE	TRUE
656	Oslo	Delhi	TRUE	TRUE	1.28	3	TRUE	FALSE	FALSE	TRUE
Focal Conjunct MAT										
57	Tokyo	Johannesburg	TRUE	TRUE	1.43	3	TRUE	FALSE	FALSE	TRUE
202	Tokyo	Jeddah	TRUE	TRUE	1.45	3	TRUE	FALSE	FALSE	TRUE
492	Tokyo	Casablanca	TRUE	TRUE	1.45	3	TRUE	FALSE	FALSE	TRUE
33	Houston	Johannesburg	TRUE	TRUE	1.47	3	TRUE	FALSE	FALSE	TRUE
178	Houston	Jeddah	TRUE	TRUE	1.49	3	TRUE	FALSE	FALSE	TRUE
Focal Conjunct SEF										
586	Chicago	Istanbul	TRUE	FALSE	1.61	1	TRUE	FALSE	FALSE	TRUE
592	Dublin	Istanbul	TRUE	FALSE	1.82	1	TRUE	FALSE	FALSE	TRUE
590	Sydney	Istanbul	TRUE	FALSE	2.01	1	TRUE	FALSE	FALSE	TRUE
582	Atlanta	Istanbul	TRUE	FALSE	2.07	1	TRUE	FALSE	FALSE	TRUE
591	Helsinki	Istanbul	FALSE	FALSE	1.51	1	TRUE	FALSE	FALSE	TRUE

As we observe in Table 8, the IIR cases do not meet the condition of being globally uncovered for the FC SEF.

Next, the analysis of the typical cases was performed with the IIRs for the ~OVE case (Table 9).

Table 9. IIR typical case Analysis for ~OVE.

	Typical	IIR	UniqCov	GlobUncov	Best	PairRank	ConsFC_Typ	MostTypTerm	MostTypFC	ConsFC_IIR
Focal Conjunct ~INN										
101	Lagos	SanFrancisco	TRUE	TRUE	1.06	3	TRUE	FALSE	FALSE	TRUE
106	Cairo	SanFrancisco	TRUE	TRUE	1.07	3	TRUE	FALSE	FALSE	TRUE
35	Lagos	Atlanta	TRUE	TRUE	1.09	3	TRUE	FALSE	FALSE	TRUE
40	Cairo	Atlanta	TRUE	TRUE	1.10	3	TRUE	FALSE	FALSE	TRUE
211	Lagos	Boston	TRUE	TRUE	1.11	3	TRUE	FALSE	FALSE	TRUE
Focal Conjunct ~INF										
621	Quito	Zurich	TRUE	TRUE	0.95	3	TRUE	TRUE	FALSE	TRUE
637	Bogota	Zurich	TRUE	TRUE	1.01	3	TRUE	FALSE	FALSE	TRUE
379	Quito	Munich	TRUE	TRUE	1.07	3	TRUE	TRUE	FALSE	TRUE
5	Quito	Berlin	TRUE	TRUE	1.08	3	TRUE	TRUE	FALSE	TRUE
395	Bogota	Munich	TRUE	TRUE	1.13	3	TRUE	FALSE	FALSE	TRUE
Focal Conjunct ~SEF										
531	Jakarta	Moscow	TRUE	FALSE	1.36	1	TRUE	FALSE	FALSE	TRUE
542	Manila	Moscow	TRUE	FALSE	1.36	1	TRUE	FALSE	FALSE	TRUE
547	Lima	Moscow	TRUE	FALSE	1.37	1	TRUE	FALSE	FALSE	TRUE
545	MexicoCity	Moscow	TRUE	FALSE	1.39	1	TRUE	FALSE	FALSE	TRUE
550	Mumbai	Moscow	TRUE	FALSE	1.53	1	TRUE	FALSE	FALSE	TRUE

For the case of ~OVE, in two of the focal conjuncts the criteria are met that each typical case is uniquely covered by the sufficient term under investigation and that the IIR case is globally uncovered. Although Moscow does not meet the criterion that the IIR is globally uncovered, it has a Rank 1. Therefore, it can be accepted for ~OVE that the causal condition identified above triggers the mechanism that leads to the result

The within-case comparative analysis of two typical cases helps to establish whether the identified causal mechanism can be generalized to all of the cases that are typical for the sufficient term under investigation [19].

Pairs of cases are presented from best to worst based on the Best value; whether the typical cases are uniquely covered; whether they belong to Rank 1 or lower; whether the membership of each case in the focal conjunct is consistent; and whether they are more typical for the term and for the focal conjunct [19,20].

In the case of OVE, the results are shown in Table 10.

Table 10. Comparative analysis of two typical cases for OVE.

	Typical1	Typical2	UniqCov1	UniqCov2	Best	PairRank	ConsFC1	ConsFC2	MostTypT1	MostTypT2	MostTypFC1	MostTypFC2
Focal Conjunct INF												
743	Oslo	Shanghai	TRUE	TRUE	0.97	1	TRUE	TRUE	FALSE	FALSE	FALSE	FALSE
685	Oslo	Beijing	TRUE	TRUE	1.07	1	TRUE	TRUE	FALSE	FALSE	FALSE	FALSE
76	Oslo	Dallas	TRUE	TRUE	1.11	1	TRUE	TRUE	FALSE	FALSE	FALSE	FALSE
Focal Conjunct MAT												
115	Tokyo	Houston	TRUE	TRUE	1.40	1	TRUE	TRUE	FALSE	FALSE	FALSE	FALSE
492	Tokyo	Munich	TRUE	TRUE	1.87	1	TRUE	TRUE	FALSE	FALSE	FALSE	FALSE
829	Munich	HongKong	TRUE	TRUE	1.98	1	TRUE	TRUE	FALSE	FALSE	FALSE	FALSE
Focal Conjunct SEF												
325	Chicago	Dublin	TRUE	TRUE	1.03	1	TRUE	TRUE	FALSE	FALSE	FALSE	FALSE
267	Chicago	Sydney	TRUE	TRUE	1.44	1	TRUE	TRUE	FALSE	FALSE	FALSE	FALSE
35	Chicago	Atlanta	TRUE	TRUE	1.50	1	TRUE	TRUE	FALSE	FALSE	FALSE	FALSE

Table 11 presents the results for ~OVE.

Table 11. Comparative analysis of two typical cases for ~OVE.

	Typical1	Typical2	UniqCov1	UniqCov2	Best	PairRank	ConsFC1	ConsFC2	MostTypT1	MostTypT2	MostTypFC1	MostTypFC2
Focal Conjunct ~INN												
13	Lagos	Doha	TRUE	TRUE	1.02	1	TRUE	TRUE	FALSE	FALSE	FALSE	FALSE
18	Cairo	Doha	TRUE	TRUE	1.03	1	TRUE	TRUE	FALSE	FALSE	FALSE	FALSE
145	Lagos	Riyadh	TRUE	TRUE	1.18	1	TRUE	TRUE	FALSE	FALSE	FALSE	FALSE
Focal Conjunct ~INF												
445	Quito	Bogota	TRUE	TRUE	0.94	1	TRUE	TRUE	TRUE	FALSE	FALSE	FALSE
181	Quito	CapeTown	TRUE	TRUE	1.02	1	TRUE	TRUE	TRUE	FALSE	FALSE	FALSE
71	Quito	Bangkok	TRUE	TRUE	1.03	1	TRUE	TRUE	TRUE	FALSE	FALSE	FALSE
Focal Conjunct ~SEF												
355	Jakarta	MexicoCity	TRUE	TRUE	1.01	1	TRUE	TRUE	FALSE	FALSE	FALSE	FALSE
366	Manila	MexicoCity	TRUE	TRUE	1.01	1	TRUE	TRUE	FALSE	FALSE	FALSE	FALSE
371	Lima	MexicoCity	TRUE	TRUE	1.02	1	TRUE	TRUE	FALSE	FALSE	FALSE	FALSE

Thus, we can establish the best match on a pair of two typical cases for FC to analyze the generalizability of the identified mechanism. For OVE: FC INF Oslo-Shanghai; FC MAT Tokyo-Houston; FC SEF Chicago-Dublin. For ~OVE: FC ~INN Lagos-Doha; FC ~INF Quito-Bogota; FC ~SEF Jakarta-MexicoCity. The values obtained in the case of ~OVE FCs allow us to generalize the identified mechanism.

The comparison of a typical case with a deviant case consistency allows for the identification of an INUS condition omitted from a sufficient term that is part of the QCA solution [19,20]. The comparison of a typical case with a deviant case consistency for OVE was performed, the results of which are shown in the table below (Table 12).

Table 12. Comparison of a typical case with a deviant case consistency (OVE).

Term INF*MAT*SEF					
1	Stockholm	Warsaw	1.42	TRUE	TRUE
2	SanFrancisco	Warsaw	1.43	FALSE	TRUE
3	Singapore	Warsaw	1.43	FALSE	TRUE
4	Helsinki	Warsaw	1.44	FALSE	TRUE
5	Amsterdam	Warsaw	1.44	FALSE	TRUE

Table 13 shows the results of the comparison of a typical case with a deviant case consistency for ~OVE.

Table 13. Comparison of a typical case with a deviant case consistency (~OVE).

Term ~INN*~INF*~SEF					
	Typical	**DevCons**	**Best**	**MostTypTerm**	**MostDevCons**
1	Lagos	Dubai	1.16	FALSE	TRUE
2	Nairobi	Dubai	1.17	TRUE	TRUE
3	Jeddah	Dubai	1.19	FALSE	TRUE
4	Quito	Dubai	1.20	TRUE	TRUE
5	Manila	Dubai	1.20	FALSE	TRUE

4. Discussion

Process tracing has started with a single within-case analysis by analyzing typical cases to identify the existence of causal mechanisms. In the OVE analysis, all of the cases pass the attribution principle, the severity test, and present a Rank 1. However, for the FC MAT and FC SEF there are no cases uniquely covered. Therefore, although the possibility of lowering the standards used in fsQCA in the development of process tracing has been raised [40], we cannot empirically prove the existence of a causal mechanism in the case of the INF*MAT*SEF term for OVE. In the analysis of ~OVE all of the criteria are met, so we identify Cairo –FC ~INN-, Quito –FC ~INF-, and Jakarta –FC ~SEF- as the typical cases. Thus, we can confirm the existence of a mechanism for the term ~INN*~INF*~SEF in the explanation of ~OVE. In the three typical cases identified, we find cities with results below the mean of the indicators, and with a decreasing trend in the cases with available information [45]. They also share a common pattern: they obtain their best score in SIM and the worst score in INN.

First, it should be recalled that ~INN was necessary for ~OVE [5]. This condition can be linked to the existing doubts in these cities regarding the change towards a smart city—linked to ~SEF—raising the need to incorporate the human factor into this transition [47]. Likewise, both Jakarta and Cairo are large cities where urban and suburban areas converge [47–49]. Deficiencies in the infrastructure linked to ~INF can result from the pressure of a growing population, which also causes problems of mobility and unhealthiness and makes it necessary to carry out urban transformations to solve them—as in Jakarta and Cairo [47,49,50]. Cairo has experienced a change from being on a pedestrian scale and in harmony with the physical environment to a fragmentation dominated by vehicles and technology [50]. A similar situation is present in Jakarta, a city endowed with a high car fleet that generates significant negative externalities [47]. In Cairo, there are informal districts, lacking a specific center for the necessary facilities that are located in different locations [51].

Next, the deviant consistency cases were analyzed in order to identify missing conjuncts; the INUS conditions that could be included in the sufficient condition. In the choice of deviant consistency cases for OVE, Warsaw is pointed out as belonging to the INF*MAT*SEF*~SIM conjunction (incl. = 0.998; PRI = 0.991). Thus, the possibility of keeping in mind the role played by ~SIM is pointed out. For ~OVE appears the case of

Dubai, belonging to ~INN*~INF*~SEF*SIM*MAT (incl. = 0.935; PRI = 0.485), where the presence of certain conditions can lead to the negation of the result. Thus, the relevance of joint causation is shown where the focus is on the interaction of the conditions in the generation of the outcome. In the case of ~OVE, we recall that the typical cases obtain their best assessment in SIM. Nevertheless, it is suggested that the level of SIM and MAT that they possess explains the denial of readiness to implement mobility innovations.

Finally, no deviant coverage cases have been identified. Thus, two main results can be extracted from the single within-case analysis. The first is the existence of a causal mechanism in the case of the ~INN*~INF*~SEF conjunction in the explanation of ~OVE. This is coupled with the second main result, that is, the possibility of incorporating SIM*MAT in this conjunction.

The comparative within-case analysis was then carried out through a comparative analysis between a typical case and an IIR. For OVE, it can be observed in the truth table that the three best typical cases identified belong to the INF*SIM*MAT*SEF conjunction, while the IIR for the first two focal conjuncts belong to the ~INF*~SIM*~MAT*~SEF conjunction—Rio de Janeiro and Johannesburg—while the one corresponding to the third focal conjunct–Istanbul—belongs to the INF*SIM*MAT*~SEF conjunction. Istanbul is an IIR for the FC SE. However, in the case of OVE, the IIRs do not meet the condition of being globally uncovered. This situation is not surprising, since no typical cases had been identified for the different CFs. Thus, the existence of a mechanism with causal properties cannot be established. Therefore, we will not go further into the analysis of the identified city pairs.

For ~OVE, on the other hand, we can accept the existence of a mechanism in the sufficient condition that not only causes the result, but also triggers the mechanism that leads to the result. The three typical cases belong to the conjunction ~INN*~INF*~SIM*~MAT*~SEF. In this case, the CF IIRs belong to three different conjunctions. The first two are conjunctions that do not explain the output: INN*INF*SIM*MAT*SEF—San Francisco, and INN*INF*SIM*~MAT*SEF—Zurich. Moscow corresponds to the conjunction ~INN*~INF*SIM*MAT*SEF that does explain the output under study.

The following is an analysis of the pairs of cases whose differences may help to explain the reasons for triggering the mechanism leading to the outcome.

If we focus on the FC ~INN we are dealing with Lagos and San Francisco, two very different cities since, while San Francisco is the best in INN, Lagos ranks 59th. This is a difference that can be linked, for example, to the existence of universities or research laboratories, as well as in the coverage of the electricity grid [45]. For ~INF, it is Quito and Zurich. Zurich is a city focused on increasing its competitiveness through the creative industries, because of its ability to attract talent and economic growth [52]. It is also the highest rated city in INF, while Quito is the 54th. This is a difference that may be caused by the quality of the roads, where Zurich obtains the best rating. In the case of ~SEF, it is Jakarta and Moscow, with smaller differences based on the use of public transport [45]. Moscow, ranked among the cities offering the highest quality of life, is moving up the smart city rankings, aspiring to be the smartest city to live in [53]. That is, the difference in INN, INF, and SEF triggers the mechanism that causes cities to result in ~OVE.

The results obtained in the comparison between the two typical cases allow us to accept the possibility of generalizing the mechanism among all of the typical cases. However, since this mechanism is only present in the case of ~OVE, we focus the analysis on the pairs of cities identified for it.

For ~INN the cases identified are Lagos and Doha, two cities with a low INN rating linked to low grid coverage [45]. In addition, Lagos has a high rate of population growth, causing huge physical changes and infrastructure development resulting in a rapid depletion of the stock of green spaces, habitats, and a loss of diversity [54]. In the case of ~INF, the cities are Quito and Bogota, cities with the worst rating in INF, related to the valuation of the connection to an international airport and the quality of roads [45]. The absence of connectivity services in Bogotá is linked to the lack of a framework for metropolitan development. In fact, there are doubts as to the appropriateness and sustainability of the investments in transport infrastructures, such as the Bus Rapid Transit [55]. For ~SEF, Jakarta and Mexico City are very similar cities in the SEF rating, 49th and 47th, linked in both cases to traffic fluidity [45]. Transportation planning in Mexico City has focused on increasing economic resources to provide more road infrastructure, which has led to an increase in the number of cars on the streets [56]. Jakarta is one of the most challenging cities when it comes to drawing a dividing line between formal and informal cities [48]. Jakarta is committed to Transit-Oriented Development, which leads its citizens to opt for homes located in certain planned areas. However, the administration's commitment to increase facilities and green open spaces has been made without the support of the private sector [57]. This lack of support from the private sector is reflected in the MAT, a condition whose incorporation had been suggested in previous analyses.

Thus, we see how the mechanisms exist not to cause cities to be ready to implement mobility innovations, but to cause cities not to be ready. Thus, we find within sustainable transitions a preeminence of lock-in mechanisms that favor certain consolidated regimes over the emergence of new niches [12]. Once again, it can be seen that the regime is linked to a mechanism of selection and retention in the face of innovations [58]. This situation may be reflected in path dependence, the mechanism that keeps socio-technical systems on their current development trajectories. This is due to the existing interactions between different mechanisms that are self-reinforcing and weaken those mechanisms that could contribute to the destabilization of the dominant regime [59].

5. Conclusions

Sustainable urban transitions are key to meeting environmental challenges. For this reason, it is necessary to recognize those initiatives that provide the seeds for real change. To this end, it is useful to identify the mechanisms linking causes and effects [1,10]. Such identification of the mechanisms involves complementing the QCA cross-case analysis with a process-tracing within-case analysis, called SMMR. Several works have applied SMMR to sustainable transitions, although the present work responds to the possibility of applying a systematic approach to case selection by applying process tracing.

The aim of this paper was to analyze the existence of causal mechanisms in the relationship between the level of preparedness of cities to implement mobility innovations and the conditions that explain them. The application of the SetMethod package of R allows us to identify the existence of a mechanism that triggers the relationship between the denial of a city's readiness to implement mobility innovations—the result—and the conditions that explain it—the causes. This mechanism can be extrapolated to all typical cases of the solution.

The fact that there are mechanisms for the denial of readiness but not for readiness brings us in line with other studies, that gave special relevance to the lock-in mechanisms that reinforce the role of dominant regimes and hinder the implementation of radical innovations.

The present work responds to the need to carry out multi-method works based on QCA [28], especially after having seen the limitations of statistical analysis to establish causality in sustainable transitions. It also allows for the deepening of the study of the existing mechanisms in the transitions [10,17]. However, the main limitation of the work is that the application of process tracing should take into account the temporality in the appearance of the causes and the effect [22].

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