

Institutional Improvement and Smart Community Development: A Chain Mediation Analysis in a Third-Tier Chinese City

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Abstract

Purpose: This study examines whether institutional improvement translates into smart community development in a third-tier Chinese city, and whether technological innovation and resident participation transmit that influence individually and in sequence.

Design/methodology/approach: Questionnaire data were collected from 299 residents of Zhanjiang, Guangdong, through combined face-to-face and online administration. Exploratory factor analysis was conducted in SPSS. Confirmatory factor analysis and a chain mediation model were estimated in Mplus using maximum likelihood with 1,000 bias-corrected bootstrap replications. Pairwise contrasts were used to compare the magnitude of the three indirect paths against one another.

Findings: Institutional improvement was positively associated with smart community development (total effect 0.230). Both mediators carried significant indirect effects: 0.066 through technological innovation and 0.045 through resident participation. The sequential path from institutions through technology to participation was significant but small (0.012). Together the indirect paths accounted for 53.5 per cent of the total effect. Contrast tests showed that the two single-mediator paths did not differ from one another, while each exceeded the sequential path, indicating that institutions operate mainly through two broadly parallel channels rather than a single cascade.

Research limitations/implications: The cross-sectional, single-city, self-report design limits causal and external inference. Community size and residents' education level were recorded but conditional effects were not modelled; boundary conditions await larger samples.

Practical implications: Because the two channels carry statistically indistinguishable effects, administrators in resource-constrained cities can prioritise whichever is locally cheaper to strengthen. The weakness of the sequential path suggests that participation should not be expected to follow from technology deployment.

Originality/value: The study provides a fully decomposed mediation estimate for a third- to fourth-tier Chinese city, a setting under-represented in the smart city literature, and moves beyond establishing that mediation exists to identifying which channel carries more of the effect.

Key Word: Smart community, Institutional improvement, Resident participation, Technological innovation, Chain mediation, Third-tier cities, China, Urban governance

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I. INTRODUCTION

Communities are the basic units through which urban governance models are renewed and optimised [1]. The development of smart communities has consequently attracted broad attention, and its progress depends not only on the deployment of technology but also on the quality of governance mechanisms and the level of resident involvement [2]. Yet theoretical work has grown considerably faster than empirical work that combines prediction with practice [3], and the challenges facing community governance are rarely confined to a single dimension. Studies of grid-based governance have identified problems ranging from incomplete transformation of government functions to lagging information systems [4], which argues for examining technology, management and people together rather than separately.

Two gaps motivate this study. First, most quantitative work on smart communities analyses single factors or single dimensions, leaving the pathways connecting institutions, technology and residents under-specified. Where mediation is examined at all, it is typically established rather than compared: analyses report that an indirect

effect exists without assessing how much of the total effect it carries relative to competing channels. Second, the literature is dominated by first- and second-tier cities, while third- and fourth-tier cities — which face tighter fiscal constraints, slower policy diffusion and persistent outflows of skilled personnel — remain under-studied, even though they house the majority of China's urban population.

This paper addresses both gaps by treating institutional improvement as the independent variable and technological innovation and resident participation as sequential mediators of smart community development. It contributes in three ways: it specifies and tests a chain mediation model rather than a single-factor model; it decomposes the total effect into its direct and three indirect components and tests those components against one another, so that the relative weight of each channel can be established rather than assumed; and it reports evidence from a third- to fourth-tier city, extending the empirical base of the field.

II. LITERATURE REVIEW AND HYPOTHESES

Institutional improvement and smart community development

Smart community development is driven by policy, technology and residents acting together [5, 6]. Institutional arrangements supply the framework within which resources are allocated and measures are implemented in an orderly way; policy support and management standardisation are treated as indispensable foundations of smart community development [7]. Comparative work likewise identifies governance mechanisms as an under-theorised dimension of smart city transitions [8] and points to governance quality, power dynamics and user capacity as important conditions of smart city outcomes [9].

H1. The level of institutional improvement is positively associated with the level of smart community development.

Technological innovation as a mediator

Technological infrastructure and institutional capacity building have been found to jointly condition the effective implementation of electronic governance in smart cities [10]. Institutional design shapes what technologies are procured and how transparently they are applied; conversely, opaque technological application and poorly coordinated deployment have been identified as obstacles to smart governance capacity [11]. Assessments of smart cities emphasise human welfare and balanced sustainability rather than technology counts alone [12], and open government data has been shown to act as a catalyst for smart city development [13]. On this reading, institutions do not raise development outcomes by direct provision alone; they also determine what technological capability a community acquires.

H2. Technological innovation mediates the relationship between institutional improvement and smart community development.

Resident participation as a mediator

Residents are not only recipients of smart community services but also participants in governance [14]. Active involvement improves service quality and efficiency while strengthening cohesion and belonging [15], and the internal logic of public participation in smart community governance has been elaborated in institutional terms [16]. Evidence in the public administration literature supports treating participation as an institutionally conditioned outcome: smart urban governance is a dynamic process shaped by governance modes, technologies and government–citizen interaction [17]; digital transparency raises participation in online crowdsourcing [18]; smart city initiatives can generate active and passive citizen discontent where rules, information and empowerment are inadequate [19]; and digital participatory tools facilitate information flows but may still deliver insufficient accountability feedback [20].

Work in the urban studies literature points in the same direction. Residents' preferences frequently diverge from municipal investment priorities [21], which has prompted calls for a societal conception of the smart city incorporating social rights and democratic values [22]. Community initiatives can strengthen individual and collective efficacy [23]; online platforms, open data and direct interaction support participation [24]; citizens cluster into distinct preference groups for smart services [25]; democratic stakeholder participation remains weak in emerging-economy smart cities [26]; participation is context-specific and data-enabled [27]; the timeliness and quality of government responses affect satisfaction in China [28]; and citizen relationship management systems shape participation in local governance [29]. Taken together, these findings suggest that institutional arrangements shape whether residents engage, and that engagement shapes in turn what a community achieves.

H3. Resident participation mediates the relationship between institutional improvement and smart community development.

The sequential path from technology to participation

The two mediators are unlikely to be independent. Institutional rules plausibly enable technology, and technology in turn creates the platforms — service applications, consultation portals, open data interfaces — through which residents can engage. A chain running from institutions through technology to participation is therefore theoretically available alongside the two simple paths. Stakeholder inclusion has been shown to depend on trust formation, shared language and role transformation [30], and clear roles and common purpose matter in urban innovation ecosystems [31]. Related evidence links smart device use to community trust and participation [32], while value orientation and compliance costs shape participation in data governance [33]. User-centred open data portals [34], procedural justice and inclusive governance [35], and data governance arrangements [36] all condition whether technology translates into engagement, and investment in participation and placemaking has been found to support community formation [37].

Whether this sequential route carries substantial weight relative to the two simple routes is an empirical question that the existing literature leaves open, since studies rarely compare indirect paths against one another. This study tests the chain and then contrasts it with the simple paths.

H4. Technological innovation and resident participation sequentially mediate the relationship between institutional improvement and smart community development.

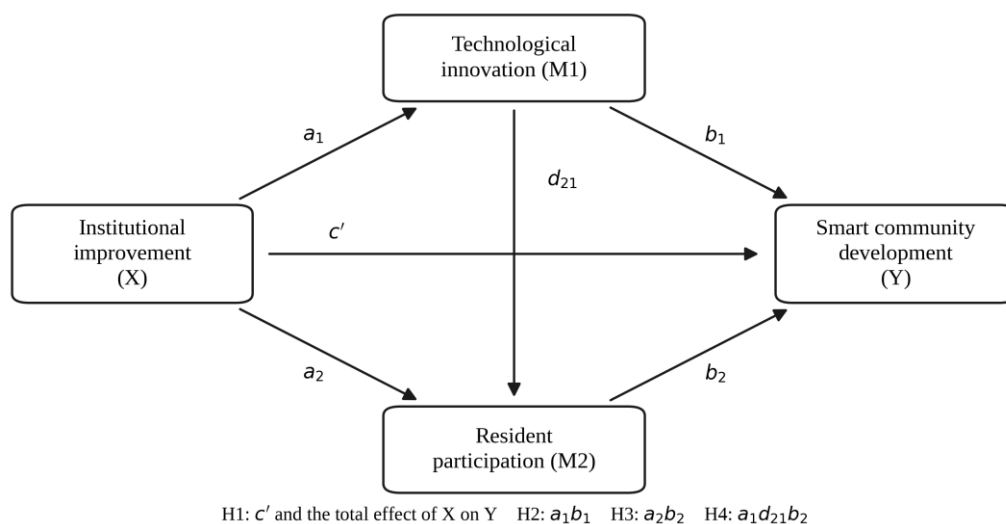


Figure 1: Hypothesised chain mediation model. X = institutional improvement; M1 = technological innovation; M2 = resident participation; Y = smart community development. c' denotes the direct effect of X on Y controlling for both mediators.

III. METHODS

Research setting

Zhanjiang, Guangdong, has long been classified between third- and fourth-tier status in China's urban hierarchy. It is a suitable setting for two reasons. It faces the constraints typical of its tier — limited fiscal capacity, delayed policy diffusion and loss of specialist talent — yet it has issued dedicated policy instruments, including the 2022 work guidelines for digital government reform and the implementation plan for new smart city construction (2021–2025), and has implemented projects such as the 5G smart community at the Jinyuyaxuan residential area. Its experience is therefore informative for comparable cities.

Sample and procedure

Data were collected between July and August 2024 using a combined strategy. Field visits were made to selected residential communities, where questionnaires were administered face-to-face; in parallel, online questionnaires were distributed through existing community communication platforms to widen coverage. All respondents were aged 18 or over and participated voluntarily. A total of 299 valid responses were obtained, more than ten times the number of scale items. Respondent characteristics (gender, age band, educational attainment and community size) are available from the corresponding author on request.

Measures

The instrument comprised four demographic items and 23 substantive items scored on seven-point scales, and the full questionnaire is available from the corresponding author on request. Constructs were operationalised for the Zhanjiang setting as follows. Institutional improvement (five items) refers to the presence of government policy instruments within the community and the service standards and property management regulations developed under external property management. Technological innovation (five items) refers to the presence of intelligent public management facilities, including security, parking and community interaction platforms. Resident participation (eight items) refers to willingness to participate, participation behaviour, governance cognition and behavioural attitudes, reflected in the frequency and diversity of residents' involvement. Smart community development (five items) refers to residents' assessment of intelligent facility coverage, service quality and satisfaction. Community size and residents' education level were each recorded as a single demographic item and are used here to describe the sample.

Analytical strategy

Exploratory factor analysis was performed in SPSS using principal component extraction with varimax rotation. Confirmatory factor analysis and the structural model were estimated in Mplus. Model fit was assessed using χ^2/df , RMSEA, CFI, TLI and SRMR. Composite reliability and average variance extracted were evaluated against thresholds of 0.60 and 0.50 respectively, following Fornell and Larcker [38].

A single structural model was specified, comprising three equations: institutional improvement predicting technological innovation; institutional improvement and technological innovation predicting resident participation; and institutional improvement together with both mediators predicting smart community development. All parameters were estimated by maximum likelihood, and the total effect, the direct effect and the three indirect effects — through technological innovation, through resident participation, and through both in sequence — were obtained with 1,000 bias-corrected bootstrap replications. The same procedure was used to test three pairwise contrasts between the indirect effects, following the approach to comparing indirect effects in multiple mediator models set out by Preacher and Hayes [39]. An indirect effect was treated as supported when its 95 per cent bootstrap confidence interval excluded zero; this is the decisive criterion throughout, and conventional p-values are reported alongside it for reference.

The model is deliberately parsimonious. With 299 cases and four latent constructs, adding interaction terms would have required a substantially larger parameter set to be estimated on a sample with limited power to detect conditional effects, and would have introduced the collinearity that product terms typically generate. Community size and education level are therefore reported descriptively, and the question of boundary conditions is left to future work with samples designed for it.

Ethics

The study was approved by the Ethics Committee of Lingnan Normal University, Zhanjiang, Guangdong, China (approval number LNU-2026-S0703; approval date 6 July 2026). Ethical review was obtained retrospectively for the purpose of academic publication. Written informed consent was obtained from all participants before administration, participation was voluntary, no personally identifying information was collected, and respondents were informed that data would be used for academic research and publication.

IV. RESULTS

Exploratory factor analysis

With 299 cases and 23 items, the Kaiser–Meyer–Olkin measure was 0.917 and Bartlett's test of sphericity was significant ($\chi^2 = 5,887.061$, $df = 253$, $p < 0.001$), confirming suitability for factor analysis. Four components were extracted, jointly explaining 75.64 per cent of total variance. All items loaded above 0.70 on their intended component and none cross-loaded above 0.40: items C1–C8 on resident participation, B1–B5 on technological innovation, D1–D5 on institutional improvement and A1–A5 on smart community development (see Table 1 and Table 2).

Table 1: Exploratory Factor Analysis: Sampling Adequacy and Variance Explained
Panel A. KMO and Bartlett's test

Measure	Value
Kaiser–Meyer–Olkin measure of sampling adequacy	0.917
Bartlett's test of sphericity: approximate χ^2	5,887.061
Degrees of freedom	253
Significance	< 0.001

Panel B. Total Variance Explained (four extracted components)

Component	Initial eigenvalue	Variance %	Cumulative %	Rotated SS Loadings	Variance %	Cumulative %
1	10.078	43.819	43.819	5.801	25.222	25.222
2	2.850	12.391	56.209	3.919	17.041	42.263
3	2.264	9.843	66.052	3.850	16.740	59.004
4	2.204	9.582	75.635	3.825	16.631	75.635

Notes: N = 299; 23 items. Extraction method: principal component analysis. Components 5–23 had eigenvalues below 1.00 and are not reported. Full eigenvalue table available on request.

Table 2: Rotated Component Matrix

Item	Component 1	Component 2	Component 3	Component 4
C1	0.945			
C5	0.814			
C6	0.789			
C4	0.789			
C8	0.787			
C7	0.784			
C3	0.774			
C2	0.757			
B1		0.924		
B3		0.819		
B5		0.815		
B4		0.802		
B2		0.788		
D2			0.935	
D4			0.829	
D5			0.810	
D1			0.778	
D3			0.768	
A1				0.916
A2				0.840
A5				0.779
A4				0.770
A3				0.752

Notes: N = 299. Extraction method: principal component analysis. Rotation method: varimax with Kaiser normalisation. Loadings below 0.40 suppressed. Component 1 = resident participation; Component 2 = technological innovation; Component 3 = institutional improvement; Component 4 = smart community development.

Measurement model and common method variance

The four-factor confirmatory model fitted the data well ($\chi^2/df = 2.608$; RMSEA = 0.073; CFI = 0.938; TLI = 0.930; SRMR = 0.066). Three constrained alternatives were estimated for comparison. Fit deteriorated sharply as factors were merged. The single-factor model, in which all 23 items load on a single latent variable, fitted very poorly ($\chi^2 = 3,137.927$, $df = 230$, $\chi^2/df = 13.643$; RMSEA = 0.206; CFI = 0.501; TLI = 0.451; SRMR = 0.152). This provides the standard single-factor evidence on common method variance: because one latent factor cannot reproduce the observed covariance structure, method variance is not a plausible account of the associations reported below.

Average variance extracted was 0.703 for institutional improvement, 0.720 for technological innovation, 0.689 for resident participation and 0.702 for smart community development; corresponding composite reliabilities were 0.922, 0.928, 0.947 and 0.921. All values exceeded the recommended thresholds, supporting convergent validity and internal consistency.

Table 3: Confirmatory Factor Analysis: Competing Measurement Models and Construct Validity
Panel A. Competing Measurement Models

Model	χ^2	df	χ^2/df	RMSEA	CFI	TLI	SRMR
Four-factor (f1, f2, f3, f4)	584.270	224	2.608***	0.073	0.938	0.930	0.066
Three-factor (f1+f2, f3, f4)	1,526.617	227	6.725***	0.138	0.777	0.751	0.112
Two-factor (f1+f2+f3, f4)	2,316.889	229	10.117***	0.175	0.642	0.604	0.138
One-factor (f1+f2+f3+f4)	3,137.927	230	13.643***	0.206	0.501	0.451	0.152

Notes: N = 299. *** $p < 0.001$. f1 = institutional improvement; f2 = technological innovation; f3 = resident participation; f4 = smart community development. The hypothesised four-factor model fits substantially better than all constrained alternatives. The poor fit of the one-factor model provides the single-factor test of common method variance: a single latent factor cannot reproduce the observed covariance structure.

Panel B. Composite Reliability and Convergent Validity

Construct	AVE	CR
Institutional improvement (X)	0.703	0.922
Technological innovation (M1)	0.720	0.928
Resident participation (M2)	0.689	0.947
Smart community development (Y)	0.702	0.921

Notes: Thresholds follow Fornell and Larcker [38]: $AVE \geq 0.50$, $CR \geq 0.60$. Standardised item loadings available on request.

Structural model

All six structural paths were significant and positive. Institutional improvement predicted technological innovation ($b = 0.384$, $SE = 0.075$, $t = 5.138$, $p < 0.001$, 95% CI [0.224, 0.522]) and resident participation ($b = 0.370$, $SE = 0.065$, $t = 5.720$, $p < 0.001$, 95% CI [0.244, 0.500]), and technological innovation in turn predicted resident participation ($b = 0.267$, $SE = 0.061$, $t = 4.419$, $p < 0.001$, 95% CI [0.153, 0.384]), supporting the sequential ordering of the two mediators.

In the final equation, institutional improvement retained a significant direct association with smart community development ($b = 0.108$, $SE = 0.046$, $t = 2.343$, $p = 0.019$, 95% CI [0.020, 0.212]), and both mediators contributed independently: technological innovation ($b = 0.171$, $SE = 0.044$, $t = 3.897$, $p < 0.001$, 95% CI [0.079, 0.253]) and resident participation ($b = 0.121$, $SE = 0.049$, $t = 2.459$, $p = 0.014$, 95% CI [0.027, 0.221]). The three equations explained 15.2, 28.4 and 22.4 per cent of the variance in technological innovation, resident participation and smart community development respectively.

Table 4: Chain Mediation Model: Path Coefficients

Equation	Outcome	Predictor	R ²	b	SE	t	p	95% CI
1	M1	X	0.152	0.384	0.075	5.138	< 0.001	[0.224, 0.522]
2	M2	X	0.284	0.370	0.065	5.720	< 0.001	[0.244, 0.500]
2	M2	M1		0.267	0.061	4.419	< 0.001	[0.153, 0.384]
3	Y	X	0.224	0.108	0.046	2.343	0.019	[0.020, 0.212]
3	Y	M1		0.171	0.044	3.897	< 0.001	[0.079, 0.253]
3	Y	M2		0.121	0.049	2.459	0.014	[0.027, 0.221]

Notes: N = 299. X = institutional improvement; M1 = technological innovation; M2 = resident participation; Y = smart community development. Maximum likelihood estimation; 95 per cent bias-corrected bootstrap confidence intervals, 1,000 replications. R² is reported once per equation.

Decomposition of effects and contrasts between indirect paths

The total effect of institutional improvement on smart community development was 0.230 (Boot SE = 0.060, 95% CI [0.104, 0.347]), supporting H1. Decomposing this effect, the direct component was 0.108 (95% CI [0.020, 0.212]) and the total indirect component was 0.123 (95% CI [0.054, 0.217]), so that 53.5 per cent of the influence of institutional improvement reached development outcomes through the two mediators rather than directly.

All three indirect paths were supported. The path through technological innovation was 0.066 (95% CI [0.026, 0.119]), accounting for 28.7 per cent of the total effect, which supports H2. The path through resident participation was 0.045 (95% CI [0.010, 0.093]), accounting for 19.6 per cent, which supports H3. The sequential

path through technological innovation and then resident participation was 0.012 (95% CI [0.002, 0.032]), accounting for 5.2 per cent, which supports H4.

The contrasts sharpen this picture. The difference between the two single-mediator paths was not significant (contrast = 0.021, 95% CI [-0.032, 0.074]), so the technological and participatory channels cannot be distinguished in magnitude on these data. By contrast, the sequential path was significantly smaller than the path through technological innovation alone (contrast = 0.053, 95% CI [0.018, 0.104]) and than the path through resident participation alone (contrast = 0.032, 95% CI [0.008, 0.072]). Institutional improvement therefore reached development outcomes chiefly through two channels of comparable strength operating largely in parallel, while the cascade from technology into participation made a real but minor additional contribution.

Table 5: Decomposition of Effects and Contrasts between Indirect Paths
Panel A. Direct, Indirect and Total Effects

Effect	Estimate	Boot SE	Boot 95% CI	Total effect %
Total effect	0.230	0.060	[0.104, 0.347]	100.0
Direct effect	0.108	0.046	[0.020, 0.212]	46.5
Total indirect effect	0.123	0.041	[0.054, 0.217]	53.5
X → M1 → Y	0.066	0.023	[0.026, 0.119]	28.7
X → M2 → Y	0.045	0.021	[0.010, 0.093]	19.6
X → M1 → M2 → Y	0.012	0.007	[0.002, 0.032]	5.2

Panel B. Pairwise Contrasts between Indirect Effects

Contrast	Estimate	Boot SE	Boot 95% CI
C1: (X→M1→Y) – (X→M2→Y)	0.021	0.027	[-0.032, 0.074]
C2: (X→M1→Y) – (X→M1→M2→Y)	0.053	0.022	[0.018, 0.104]
C3: (X→M2→Y) – (X→M1→M2→Y)	0.032	0.017	[0.008, 0.072]

Notes: N = 299. Bias-corrected bootstrap intervals, 1,000 replications; an effect or contrast is supported when its interval excludes zero. All three indirect paths are supported, and the indirect component accounts for 53.5 per cent of the total effect. C1 is not significant, indicating that the two single-mediator paths are indistinguishable in magnitude; C2 and C3 are significant, indicating that each single-mediator path exceeds the sequential path. Contrasts follow Preacher and Hayes [39].

V. DISCUSSION

Three findings merit discussion.

First, institutional improvement was positively associated with smart community development, and the association remained significant once both mediators were entered. This is consistent with the argument that optimising the institutional environment advances community intelligence [40] and that policy support and management standardisation are foundational [7]. The decomposition adds a sense of proportion: slightly more than half of the total effect travelled through the mediators, so an account of institutional influence that stops at the direct effect captures less than half of what institutions do. Clear operating rules and transparent channels plausibly build residents' confidence in government, echoing arguments that verifiable, credible data underpins trust in smart cities [41] and that institutional transparency is central to that trust [4]. The result is consistent with a reading of institutions as enabling technological empowerment rather than merely authorising technology deployment [42].

Second, and more informatively, the two mediating channels were statistically indistinguishable in size. The technological channel carried 28.7 per cent of the total effect and the participatory channel 19.6 per cent, but the contrast between them was not significant. This is consequential for a literature that has tended to treat smart community development as a technology narrative in which residents appear late, as users. On these data, institutional rules that raise participation deliver returns comparable to institutional rules that raise technological capability. The finding supports arguments that participation directly raises the efficiency of smart community construction [43] and strengthens cohesion and vitality [44], and it aligns with evidence that residents' preferences diverge from municipal priorities [21] and that inadequate empowerment generates discontent [19]. It also indicates that weak institutional support constrains community intelligence along more than one route [45].

Third, the sequential chain was supported but was significantly weaker than either simple path, carrying only 5.2 per cent of the total effect. The mechanism by which technology creates platforms that then draw residents in is therefore real but modest, which qualifies evidence linking smart device use to trust and then to participation [32]. The practical reading is that participation cannot be expected to arrive as a by-product of technological

investment. Since the greater part of the institutional effect on resident participation did not run through technological innovation, engagement mechanisms such as consultation rules, feedback obligations and accessible channels are doing work that hardware does not do for them. This is consistent with calls to centre humanistic values and supporting rules rather than relying on a single technology [46], and with findings that procedural justice and inclusive governance condition whether technology translates into engagement [35].

VI. CONCLUSION

This study modelled smart community development in a third- to fourth-tier Chinese city as a chain mediation process. Institutional improvement raised development outcomes both directly and through two mediators; the technological and participatory channels carried comparable weight; the sequential path from technology into participation was significant but small; and the indirect component as a whole accounted for slightly more than half of the total effect.

Three practical implications follow. Institutional design should be assessed by what it enables as well as by what it delivers directly, since roughly half of its influence reached outcomes by way of technology and residents rather than through direct provision. Because the two channels are statistically indistinguishable, administrators facing budget constraints have genuine discretion: strengthening whichever channel is locally cheaper to improve should yield comparable returns, and there is no evidence here that technological investment must come first. And because the cascade from technology into participation is weak, engagement mechanisms warrant their own budget line rather than being treated as a downstream benefit of platform deployment.

Several limitations qualify these conclusions. The cross-sectional design cannot capture the lagged effects of institutional change, which require time to be implemented and to generate feedback. The sample is drawn from a single city and is modest in size, limiting external validity; replication across regions and community types is needed. Measures rely on residents' subjective assessments collected by a single method at a single point in time; although the single-factor test argues against common method variance as an explanation, objective indicators of facility coverage and service performance should be incorporated in future work. The model estimates average effects and does not test boundary conditions: community size and residents' education level were recorded and are plausible moderators of both channels, but establishing conditional effects reliably would require a larger sample and a specification designed for that purpose, which we recommend as the next step. Finally, mediation was tested on cross-sectional data, which establishes consistency with the hypothesised ordering but not causal precedence; longitudinal or experimental designs would be required to settle the sequence.

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