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Geographic equity in community rehabilitation service capacity in Shanghai, China: a five-year entropy-weighted TOPSIS study

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Abstract

Background: Community rehabilitation is central to continuity of care, yet average citywide provision may conceal substantial local inequalities. Shanghai has expanded demonstration community rehabilitation centres since 2021. We assessed changes associated with this programme and examined variation between urban and suburban areas and across six administrative districts.

Methods: We conducted a longitudinal observational study of 48 community rehabilitation centres in Fengxian, Jiading, Jing'an, Minhang, Putuo and Xuhui districts from 2020 to 2024, comprising 240 centre-year observations. Service capacity was evaluated with an 85-indicator structure-process-outcome framework. Indicator weights were derived objectively by the entropy method, and a technique for order preference by similarity to ideal solution (TOPSIS) closeness coefficient was calculated for each centre-year. Paired t tests, independent-samples t tests and one-way analysis of variance with least significant difference post-hoc comparisons were used for subgroup analyses.

Results: Among 32 demonstration centres, the mean closeness coefficient increased from 0.27 (SD 0.07) before construction to 0.30 (SD 0.05) afterwards ($P < 0.001$; Cohen's $d = 1.21$). The change among 16 non-demonstration centres was smaller and did not reach statistical significance (0.20 [SD 0.06] to 0.22 [SD 0.06]; $P = 0.051$). There was no statistically significant urban–suburban difference in any study year (all $P > 0.05$). District-level differences were present throughout 2020-2024 (all $P < 0.05$). Jing'an had the highest mean coefficient in 2024 (0.34 [SD 0.07]), whereas Fengxian remained lowest (0.22 [SD 0.06]). Putuo performed strongly in 2020-2021 but its advantage weakened after 2022, alongside marked volatility in equipment investment, outpatient activity, home-based rehabilitation and research output.

Conclusions: Improvements in service capacity were associated with participation in Shanghai's demonstration-centre programme. The absence of an overall urban-suburban difference did not imply geographic equity: persistent differences between districts remained. Municipal monitoring should therefore combine citywide standards with district-specific support, stable investment and stronger referral and workforce arrangements.

Background

Rehabilitation is an essential health service rather than an optional stage of care. In 2019, an estimated 2.41 billion people worldwide had conditions that could benefit from rehabilitation [1]. Access remains uneven, particularly for people with disabilities and in low- and middle-income settings [2, 3]. When rehabilitation is available close to where people live, it can support recovery after acute illness, help people manage long-term disability and reduce avoidable use of hospital services. The World Health Assembly has called for rehabilitation to be integrated across health systems, and equitable access is increasingly recognised as part of progress towards universal health coverage [4, 5]. Community-based services are particularly important in large cities, where population ageing, chronic disease and disability create sustained demand but specialist resources remain concentrated in major hospitals [6].

China has sought to strengthen rehabilitation within its tiered delivery system, including through national guidance issued in 2021 [7]. These efforts sit within a broader reform agenda that has expanded primary care infrastructure and coverage, while persistent weaknesses in workforce capability, continuity, incentives and coordination between primary institutions and hospitals remain [8–10]. In Shanghai, demonstration community rehabilitation centres have been developed as a municipal public-service programme since 2021. The programme combines standards for premises and equipment with staff training, technical support from higher-level hospitals and routine quality oversight. By the end of 2023, 91 demonstration centres had been completed [11]. The policy question is no longer only whether more centres have been built, but whether service capacity has improved and whether improvement has been geographically even.

Most Chinese studies of health-service equalisation compare provinces or broad urban-rural groups [12–14]. Work using spatial accessibility and resource-density measures has also shown that apparently adequate averages can coexist with substantial geographic inequality [15, 16]. Such comparisons are useful, but they can overlook marked differences between districts within the same metropolitan health system. Existing work on Shanghai has largely described construction progress, service content or the experience of individual districts [11, 17–19]. A 2024 cross-sectional survey, for example, described 119 demonstration centres but did not follow the same institutions over time [11]. Longitudinal evidence is needed to distinguish citywide convergence from the persistence of local gaps.

We therefore examined a fixed panel of community rehabilitation centres over five years. The analysis used an 85-indicator evaluation system developed from the Donabedian structure-process-outcome framework and an entropy-weighted TOPSIS model to summarise multidimensional service capacity. The study had three aims: to compare performance before and after demonstration-centre construction; to assess differences between urban and suburban institutions; and to describe trajectories across Fengxian, Jiading, Jing'an, Minhang, Putuo and Xuhui districts. This multi-level view was intended to provide evidence for allocating rehabilitation resources within a megacity rather than treating Shanghai as a single homogeneous unit. It is also consistent with recommendations that inequality monitoring define the geographic dimension explicitly and disaggregate results before interpreting aggregate measures [20].

Methods

Study design and setting

This was a longitudinal observational study of community rehabilitation centres in Shanghai from 2020 to 2024. The unit of analysis was the centre-year. Forty-eight centres contributed complete observations for all five years, yielding 240 centre-year records.

A stratified random sampling approach was used. Shanghai's 16 administrative districts were first grouped into urban and suburban strata according to the municipal territorial classification. Three

districts were randomly selected within each stratum, after which community rehabilitation centres were sampled within the selected districts. The initial sample comprised 66 centres. Eighteen were excluded because they had extensive missing data across consecutive years, had ceased operation or had changed function during follow-up. The final panel included 12 centres in Fengxian, nine in Jiading, six in Jing'an, eight in Minhang, four in Putuo and nine in Xuhui. Because Putuo contributed only four centres, its trajectory was interpreted cautiously.

Data sources and study groups

Data were drawn from three sources: the Shanghai Health Statistics Yearbook and annual centre operating ledgers; the municipal annual survey database for rehabilitation services; and internal financial and service records held by the sampled centres. These sources provided information on equipment, staffing, service activity, home-based rehabilitation, remuneration, maintenance and other operational indicators. Demonstration status was taken from the municipal rehabilitation survey database.

Centres were classified in three ways. First, 32 centres that entered the municipal demonstration programme and received the associated financial and technical support formed the demonstration group; the remaining 16 formed the non-demonstration comparison group. Second, 21 centres were classified as urban and 27 as suburban. Third, centres were grouped by their six administrative districts. Centres were eligible if they participated in the municipal community rehabilitation quality-control system and reported the required operational indicators for five consecutive years. Centres operating for less than one year, those that closed or changed function, and those with more than 30% of core indicators missing in a year were excluded. Isolated missing values were replaced with the corresponding district-year mean.

Evaluation framework

The primary outcome was the TOPSIS relative closeness coefficient, a composite measure of operational service capacity ranging from 0 to 1. Higher values indicate that a centre is closer to the best observed combination of performance across the included indicators.

The evaluation framework had been developed previously through two rounds of Delphi consultation [21]. It followed Donabedian's structure-process-outcome model and contained three first-level domains, 15 second-level domains and 85 third-level indicators. The indicators covered policy and organisational support, resource allocation, rehabilitation activity, operating efficiency, and patient and staff experience. Details of indicator development and validity assessment have been reported elsewhere [21]; the data domains and sources used in the present analysis are summarised in Additional file 1: Table S1.

Entropy-weighted TOPSIS analysis

The entropy method was used to derive data-driven weights, reducing dependence on subjective scoring [22-25]. TOPSIS then ranked each centre-year according to its distance from the best and worst observed performance profiles. The 85 indicators were first oriented so that higher standardised values always represented better performance. For a positive indicator:

$y_{ij} = [x_{ij} - \min(x_j)] / [\max(x_j) - \min(x_j)]$

For a negative indicator:

$y_{ij} = [\max(x_j) - x_{ij}] / [\max(x_j) - \min(x_j)]$

Here, x_{ij} is the observed value for centre-year i on indicator j, and y_{ij} is its standardised value. The proportion, entropy and divergence for each indicator were calculated as follows:

$p_{ij} = y_{ij} / \Sigma_i y_{ij}$

$e_j = -k \Sigma_i [p_{ij} \ln(p_{ij})], \quad \text{where } k = 1 / \ln(n)$

$g_j = 1 - e_j, \quad \text{and} \quad w_j = g_j / \Sigma_j g_j$

Terms with $p_{ij} = 0$ were treated as zero. The weighted standardised matrix was then obtained:

$z_{ij} = w_j y_{ij}$

The positive ideal solution z_j+ comprised the maximum weighted value for each indicator, and the negative ideal solution z_j- comprised the minimum. Euclidean distances from the two solutions were calculated as:

$d_i^+ = \sqrt{[\Sigma_j (z_{ij} - z_j^+)^2]}$

$d_i^- = \sqrt{[\Sigma_j (z_{ij} - z_j^-)^2]}$

The relative closeness coefficient for centre-year i was:

$C_i = d_i^- / (d_i^+ + d_i^-)$

A larger C_i indicates a performance profile closer to the positive ideal solution.

Statistical analysis

Data preparation was performed in Microsoft Excel and statistical analyses in IBM SPSS Statistics, version 30. Continuous results are reported as means and standard deviations (SDs), with a two-sided alpha level of 0.05. Paired t tests compared pre- and post-construction closeness coefficients within the demonstration group and the corresponding two-period values within the non-demonstration group; Cohen's d quantified the magnitude of within-group change. Independent-samples t tests compared

urban and suburban centres in each year, with Cohen's d quantifying the magnitude of between-group differences. One-way analysis of variance followed by least significant difference post-hoc comparisons was used to assess differences between the six districts, with eta-squared (η^2) describing effect size.

Results

Overall trends in service capacity

Across the 48 centres, the mean TOPSIS closeness coefficient rose modestly between 2020 and 2024, but the distribution remained uneven. Centres in Fengxian were concentrated towards the lower end of the ranking, while several centres in Jing'an remained near the top. Putuo began the observation period with comparatively strong performance, but its district mean ceased to improve after 2022.

Changes by demonstration status

The 32 demonstration centres improved from a mean closeness coefficient of 0.27 (SD 0.07) before construction to 0.30 (SD 0.05) afterwards. The paired difference was statistically significant (t = -3.26, P < 0.001), with a large effect size (Cohen's d = 1.21). Non-demonstration centres increased from 0.20 (SD 0.06) to 0.22 (SD 0.06), but this difference narrowly missed the conventional threshold for statistical significance (t = -2.02, P = 0.051; Cohen's d = 0.49) (Table 1).

Table 1
Changes in TOPSIS closeness by demonstration status

Group	Period	n	Mean	SD	t	P value	Cohen's d
Demonstration	Before	32	0.27	0.07	-3.26	< 0.001	1.21
	After	32	0.30	0.05			
Non-demonstration	Before	16	0.20	0.06	-2.02	0.051	0.49
	After	16	0.22	0.06			

Note: Values are based on paired comparisons within each group. TOPSIS, technique for order preference by similarity to ideal solution; SD, standard deviation.

District-level differences

Performance differed across the six districts in every year (all P < 0.05), with eta-squared values ranging from 0.28 to 0.41. Post-hoc comparisons placed Fengxian significantly below Jing'an, Minhang, Putuo and Xuhui. Jing'an increased steadily from 0.28 (SD 0.07) in 2020 to 0.34 (SD 0.07) in 2024 and occupied the leading position by the end of follow-up. Fengxian improved from 0.17 (SD 0.06) to 0.22 (SD 0.06) but remained the lowest-performing district. Jiading, Minhang and Xuhui occupied an intermediate range and changed more gradually. Putuo rose from 0.31 (SD 0.08) in 2020 to 0.33 (SD 0.10) in 2021–2022, then declined slightly to 0.32 in 2023 and 2024 (Table 2; Fig. 1). The LSD post-hoc contrasts involving Fengxian are summarised in Additional file 1: Table S2.

Table 2
District-level TOPSIS closeness, 2020–2024

Year	District	n	Mean (SD)	F	P value
2020	Fengxian	12	0.17 (0.06)	4.68	< 0.05
	Jiading	9	0.22 (0.04)		
	Jing'an	6	0.28 (0.07)		
	Minhang	8	0.23 (0.06)		
	Putuo	4	0.31 (0.08)		
	Xuhui	9	0.26 (0.07)		
2021	Fengxian	12	0.18 (0.06)	4.19	< 0.05
	Jiading	9	0.24 (0.06)		
	Jing'an	6	0.29 (0.09)		
	Minhang	8	0.27 (0.06)		
	Putuo	4	0.33 (0.10)		
	Xuhui	9	0.26 (0.06)		
2022	Fengxian	12	0.18 (0.07)	6.56	< 0.05
	Jiading	9	0.24 (0.04)		
	Jing'an	6	0.32 (0.08)		
	Minhang	8	0.28 (0.05)		
	Putuo	4	0.33 (0.10)		
	Xuhui	9	0.26 (0.05)		
2023	Fengxian	12	0.19 (0.06)	6.53	< 0.05
	Jiading	9	0.25 (0.04)		
	Jing'an	6	0.33 (0.07)		
	Minhang	8	0.29 (0.03)		
	Putuo	4	0.32 (0.08)		
	Xuhui	9	0.28 (0.05)		
2024	Fengxian	12	0.22 (0.06)	5.95	< 0.05

Note: F and P values are from one-way analysis of variance for the six districts within each year. SD, standard deviation; TOPSIS, technique for order preference by similarity to ideal solution.

Year	District	n	Mean (SD)	F	P value
	Jiading	9	0.25 (0.04)		
	Jing'an	6	0.34 (0.07)		
	Minhang	8	0.29 (0.04)		
	Putuo	4	0.32 (0.07)		
	Xuhui	9	0.28 (0.05)		

Note: F and P values are from one-way analysis of variance for the six districts within each year. SD, standard deviation; TOPSIS, technique for order preference by similarity to ideal solution.

(A) Locations of the six sampled districts and numbers of included community rehabilitation centres; unsampled districts are shown in grey. (B) Mean district-level TOPSIS relative closeness coefficients from 2020 to 2024. Exact means and standard deviations are reported in Table 2. Administrative boundaries were derived from DataV GeoAtlas [26]. TOPSIS, technique for order preference by similarity to ideal solution.

Operational changes in Putuo District

Examination of the 85 component indicators suggested that Putuo's loss of relative advantage was concentrated in several operational domains. Equipment investment rose sharply in 2021 and then fell by 54.4% in 2022. Numbers of intelligent rehabilitation devices and both Western-medicine and traditional Chinese medicine outpatient rehabilitation visits also fell substantially between 2021 and 2022. Home-based Western-medicine rehabilitation activity was highly volatile, peaking in 2022 before dropping markedly. Research applications remained sparse, and average therapist income declined modestly in 2024. Equipment availability nevertheless remained high throughout (Table 3). These patterns identify where instability occurred; they do not by themselves establish whether the underlying cause was budgeting, management, changing demand or data-recording practice.

Table 3
Operational indicators in Putuo District, 2020–2024

Indicator	2020	2021	2022	2023	2024	Largest decline	Magnitude
Rehabilitation equipment investment (10,000 RMB)	45.75	140.81	64.15	56.00	71.93	2021–2022	54.4%
Intelligent rehabilitation devices (n)	1.50	4.25	2.00	2.00	2.75	2021–2022	52.9%
Western-medicine outpatient rehabilitation visits	16,038	17,510	11,524	15,854	19,507	2021–2022	34.2%
TCM outpatient rehabilitation visits	90,207	100,190	64,308	95,086	107,080	2021–2022	35.8%
Home-based Western-medicine rehabilitation visits	131	6,535	34,225	1,293.5	617.7	2023–2024	52.2%
Mean annual therapist income (10,000 RMB)	17.18	18.83	20.21	21.48	20.70	2023–2024	3.6%
Annual rehabilitation research applications (n)	0.75	0.25	0.50	0.25	0.50	2020–2021	66.7%
Equipment availability (%)	99.5	100.0	99.5	98.75	98.75	2021–2023	1.25 pp

Note: The largest decline is the consecutive-year interval with the greatest reduction. Magnitude is the percentage reduction, except for equipment availability, which is expressed in percentage points (pp). RMB, Chinese yuan; TCM, traditional Chinese medicine.

Urban–suburban differences

Independent-samples t tests showed no statistically significant difference between urban and suburban centres in any year (all $P > 0.05$). Cohen's d values ranged from 0.08 to 0.35 (Table 4). Suburban means were numerically higher throughout the observation period. The citywide urban–suburban grouping therefore produced a different picture from the district analysis: broad-area averages appeared similar in these tests, while district-level performance remained heterogeneous.

Table 4
Urban-suburban differences in TOPSIS closeness

Year	Area	n	Mean (SD)	t	P value	Cohen's d
2020	Urban	21	0.19 (0.06)	1.61	0.21	0.35
	Suburban	27	0.26 (0.07)			
2021	Urban	21	0.21 (0.06)	0.31	0.58	0.09
	Suburban	27	0.28 (0.07)			
2022	Urban	21	0.20 (0.07)	0.01	0.93	0.08
	Suburban	27	0.29 (0.07)			
2023	Urban	21	0.22 (0.06)	0.15	0.70	0.10
	Suburban	27	0.30 (0.06)			
2024	Urban	21	0.23 (0.05)	0.85	0.36	0.18
	Suburban	27	0.30 (0.06)			

Note: Values are from independent-samples comparisons conducted for each year. SD, standard deviation; TOPSIS, technique for order preference by similarity to ideal solution.

Discussion

This five-year study points to two different forms of change in Shanghai's community rehabilitation system. First, centres participating in the demonstration programme improved more clearly than non-demonstration centres. Second, a broad urban-suburban comparison suggested convergence, but this citywide pattern coexisted with persistent district-level differences. Jing'an maintained high performance, Fengxian improved slowly from a low baseline, and Putuo's early advantage weakened after 2022. Geographic equity therefore depended on the scale at which it was examined.

The demonstration finding is consistent with the design of the programme. Participating centres received a package of support rather than a single isolated input: equipment standards, earmarked resources, training, links with higher-level hospitals and ongoing quality review [7, 11, 18]. A multidimensional intervention of this kind should affect structure and process before changes become visible in service outcomes. The large within-group effect size suggests that the composite measure captured a meaningful shift. The study was observational, however, and the comparison group was not assigned randomly. The result should be interpreted as an association with demonstration-centre construction, not as proof that the programme alone caused the improvement.

Urban–suburban convergence and district-level disparities

Shanghai's municipal governance arrangements offer a plausible explanation for the absence of an overall urban–suburban gap. Citywide procurement and quality standards, staff rotation and technical support from secondary and tertiary hospitals can reduce disadvantages associated with distance from the urban core [17, 18, 27]. National and local efforts to strengthen primary care have also made equipment and service specifications less dependent on whether a centre is located in an urban or suburban area [8–10, 27]. In this respect, the findings differ from studies that describe larger regional disparities in primary healthcare resources across China [12–16].

Yet the six-district analysis shows why the conclusion should not be simplified to “equity achieved”. Municipal policies set a common floor, but district governments retain important responsibilities for recurrent funding, staffing, implementation of medical consortia and local performance management. These arrangements can differ even within the same urban or suburban category. Equity-focused implementation frameworks similarly caution that universal reforms require explicit attention to local context, implementation capacity and distributional effects [28, 29]. Jing'an's sustained position and Fengxian's slower improvement are consistent with unequal local capacity to renew equipment, recruit staff and integrate rehabilitation into referral networks. The present dataset did not include district fiscal expenditure, workforce turnover or referral completion, so these mechanisms remain plausible explanations rather than directly tested mediators.

Putuo illustrates the value of looking below a single composite score. Its coefficient remained comparatively high, but the component data showed unstable investment and sharp changes in several service volumes. The fall in home-based rehabilitation after a pronounced peak deserves particular attention because such services are important for people with mobility restrictions. The small Putuo sample and the unusual magnitude of year-to-year change mean that changes in reporting practice or programme definitions should be ruled out before attributing the pattern to service contraction.

Policy implications

Three policy implications follow from the results. First, the demonstration model should be converted from a time-limited construction project into a more durable operating arrangement. Capital investment is useful, but equipment maintenance, staff development, information systems and supervision require predictable recurrent funding. A centre that meets a construction standard once may not retain the same capacity several years later.

Second, equalisation policy should be tailored to district trajectories. Fengxian would benefit from targeted municipal support for workforce development, equipment renewal and links with high-performing centres. Jing'an can serve as a learning site, but transferring its practices will require attention to local staffing and fiscal conditions rather than copying a checklist. Putuo needs a focused review of equipment planning, home-based service organisation and data continuity. Jiading, Minhang and Xuhui may gain more from identifying service gaps and strengthening coordination between centres than from another general expansion target.

Third, monitoring should connect institutional capacity with patient pathways. A municipal dashboard could track equipment functionality, therapist staffing, waiting time, referral completion, home-based service use and selected functional outcomes. Results should be stratified by district, age, disability and socioeconomic need where data permit. Such an approach would move performance assessment beyond the number of centres built and make it easier to identify a district whose average score is stable while a key service is deteriorating.

The medical-consortium pathway also warrants stronger operational rules. Shared referral criteria, interoperable records and feedback from community centres to hospital teams are necessary if rehabilitation is to be continuous. Periodic staff rotation can provide short-term expertise, but stable local teams require clearer career progression, continuing education and remuneration that reflects the complexity of community and home-based rehabilitation [17, 18, 30].

Strengths and limitations

The study followed the same centres for five years and assessed service capacity with a broad structure-process-outcome framework rather than a single resource indicator. It also compared two spatial scales, revealing differences that would have been missed by an urban-suburban analysis alone.

Several limitations should be considered. The study was confined to Shanghai, and its findings may not transfer to smaller cities or rural counties. The composite measure was derived mainly from institutional operational records; it did not directly measure unmet rehabilitation need, travel time, affordability, patient-reported access, satisfaction or functional recovery. District expenditure, population ageing, insurance payment and local rehabilitation need were not modelled, limiting explanation of the observed geographic differences. Putuo contributed only four centres. Mean imputation for isolated missing values may have reduced variability. The five-year period was too short to establish the durability of programme effects, and the non-randomised design does not support causal attribution. Finally, entropy weights depend on variation in the study sample; rankings may change if other centres, years or indicators are included. External validation and sensitivity analyses using alternative weighting schemes would strengthen future work.

Future research should test the framework in cities at different levels of economic development and follow centres for longer periods. Linking operational records to district expenditure, population need, insurance payment and patient-reported outcomes would allow a fuller assessment of equity. Comparative case studies and staff interviews could clarify why similar municipal standards are implemented differently across districts. With a larger sample, panel-data models or carefully validated machine-learning approaches could also be used to identify which factors most consistently predict improvement.

Conclusions

Community rehabilitation service capacity in Shanghai improved between 2020 and 2024, and the improvement was more evident among centres included in the municipal demonstration programme. Urban–suburban comparisons showed no statistically significant difference, but district trajectories remained unequal. Jing'an sustained high performance, Fengxian continued to lag despite improvement, and Putuo showed signs of operational instability after an early advantage. Citywide standards should therefore be retained, but they need to be paired with district-specific support, stable recurrent investment, stronger workforce and referral arrangements, and monitoring that reflects both institutional capacity and residents' access to rehabilitation.

Abbreviations

ANOVA
analysis of variance
LSD
least significant difference
SD
standard deviation
SPO
structure-process-outcome
TCM
traditional Chinese medicine
TOPSIS
technique for order preference by similarity to ideal solution.

Declarations

Declarations

Ethics approval and consent to participate

Not applicable. This study analysed aggregate institution-level operational data and did not involve human participants, identifiable personal data, human tissue or animals.

Consent for publication

Not applicable.

Supplementary information

Additional file 1 (.docx). Supplementary Tables S1 and S2. Table S1 summarises the SPO evaluation domains, representative measures and study data sources. Table S2 summarises the Fengxian district

contrasts identified in the LSD post-hoc analysis.

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Author Contribution

Lingling Li and Yuhang Liu contributed equally to this work. Lingling Li conceptualized the study, developed the methodology, performed the formal analysis, prepared the tables and figure, and drafted the manuscript. Weigang Wang and Zhenqing Tang contributed to data acquisition, data curation, validation, and interpretation of the findings. Chunlin Jin and Wei Lu contributed to study conceptualization, methodological guidance, supervision, project administration, and critical revision of the manuscript. All authors read and approved the final manuscript.

Data Availability

The datasets used and/or analysed during the current study are not publicly available because they contain non-public institutional operational data, but are available from the corresponding author on reasonable request and subject to approval by the relevant data custodians.

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Figures

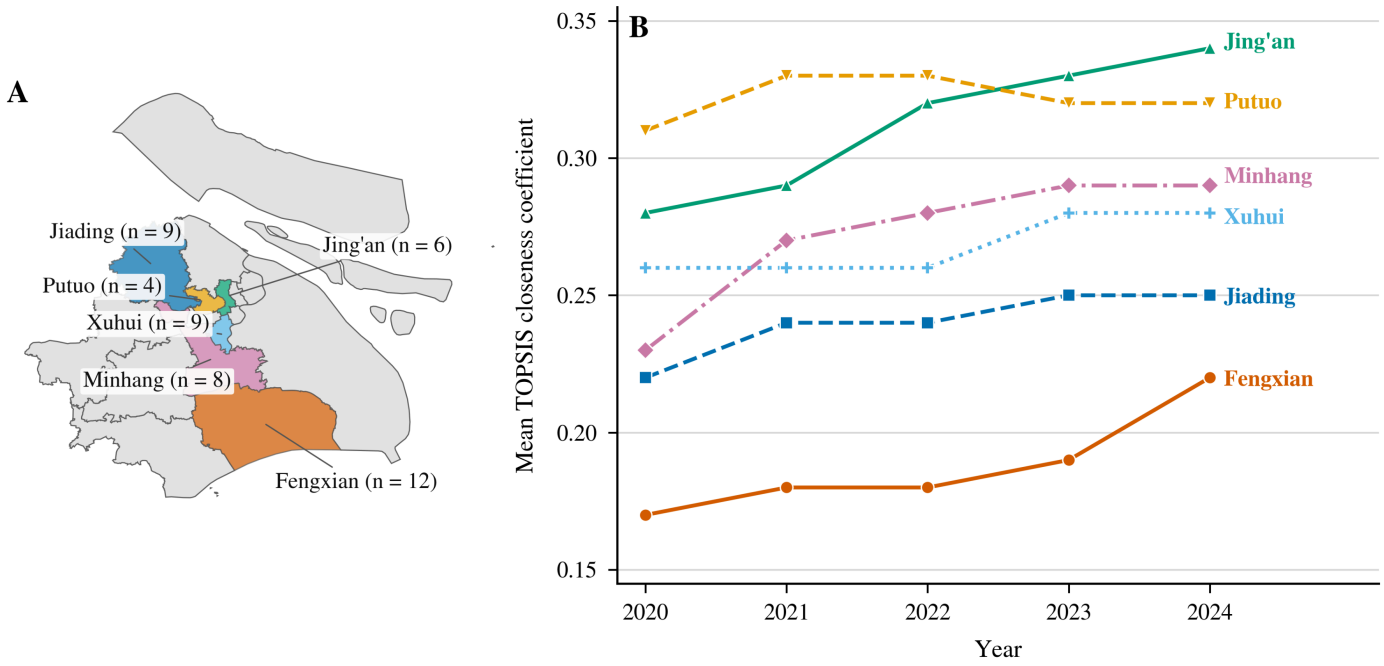


Figure 1

Study districts and five-year TOPSIS trajectories in Shanghai

(A) Locations of the six sampled districts and numbers of included community rehabilitation centres; unsampled districts are shown in grey. (B) Mean district-level TOPSIS relative closeness coefficients from 2020 to 2024. Exact means and standard deviations are reported in Table 2. Administrative boundaries were derived from DataV GeoAtlas [26]. TOPSIS, technique for order preference by similarity to ideal solution.

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