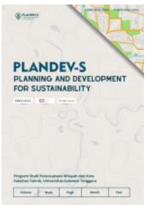

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Assessing Urban Health Resilience through Infrastructure Disparities: A Spatial Analysis of Five Subdistricts in Makassar City, Indonesia

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ABSTRACT

This study assessed the spatial disparities of basic urban infrastructure and their implications for public health resilience in five subdistricts of Makassar City. The research constructed an Urban Health Resilience Index using five variables: access to clean water, sanitation coverage, housing quality, population pressure, and proximity to healthcare services. All variables were normalized using a min–max rescaling method and equally weighted. The findings showed that Panakkukang had the highest resilience score, while Manggala scored the lowest, reflecting significant spatial inequality in infrastructure provision. Simulated survey data supported these results, revealing that areas with higher population density and tenure insecurity tended to have weaker access to health facilities and basic services. Correlation analysis also indicated a positive association between population stress and distance to healthcare access. The study concluded that resilient infrastructure planning should be spatially targeted, particularly in peri-urban and densely populated subdistricts, to improve equity and public health outcomes..

Keywords : ***Urban health resilience; Infrastructure inequality; Spatial analysis; Public service access; Makassar City; Housing vulnerability***

INTRODUCTION

Urban resilience has emerged as a crucial framework in sustainable development and urban planning discourse, particularly in addressing the increasing vulnerabilities faced by rapidly urbanizing cities. In Indonesia, urban growth continues to outpace infrastructure development, particularly in lower-income communities within dense settlements. Makassar City, as the primary metropolitan area in Eastern Indonesia, exhibits this imbalance in the form of spatial inequality in access to clean water, sanitation, and primary healthcare infrastructure. According to (Yudono et al., 2023), the distribution of health facilities in Makassar is not proportionally aligned with population densities, particularly in subdistricts with high urban poverty levels, causing a measurable strain on public health outcomes.

The urgency of this research lies in the increasing relevance of community-level health resilience as a core indicator of urban resilience. The phenomenon of health vulnerability, though less visible than flood or climate-related hazards, is chronic and persistent. It directly undermines the city's capacity to achieve sustainable urban development. As (Malik et al., 2021) argue, resilience in urban planning must extend beyond climate governance to include dimensions of infrastructure equity and public health systems. In many Indonesian cities, these dimensions remain underexplored in empirical research.

From a theoretical perspective, the concept of urban resilience encompasses not only the physical ability of a city to absorb shocks but also the socio-institutional capacity to maintain essential functions under stress. Infrastructure particularly clean water, sanitation, and healthcare is recognized in the resilience literature as a critical system that determines a population's ability to withstand health-related stressors (Meerow et al., 2016). However, in cities such as Makassar, where service delivery is uneven and environmental conditions vary significantly across neighborhoods, these systems may fail to provide adequate buffers against endemic disease or deteriorating health.

Existing studies in Makassar have addressed climate change adaptation (Malik et al., 2021) (Badan Pusat Statistik Kota, 2023) and spatial planning challenges, but few have empirically measured how infrastructure correlates with community health resilience. (Afdhal et al., 2022) introduced participatory systems mapping to highlight gaps in health service coverage, but stopped short of quantifying infrastructure resilience. Similarly, (Abdillah et al., 2024) identified solid waste management as an environmental stressor in low-income neighborhoods, but the study focused more on environmental sustainability than on integrated urban health indicators.

This research seeks to address these gaps by evaluating basic service infrastructure as an indicator of urban health resilience in Makassar City. Specifically, it will assess how the availability and quality of clean water, sanitation facilities, and healthcare access contribute to the resilience of communities in densely populated, low-income areas. The novelty of this study lies in its integration of spatial service distribution, infrastructure condition, and community health outcomes within the urban resilience framework an approach that has not been systematically applied in the context of medium-sized Indonesian cities.

RESEARCH METHODS

This study adopts a quantitative descriptive research design to evaluate the condition and contribution of basic service infrastructure toward urban health resilience in Makassar City, Indonesia. The focus is on examining infrastructure indicators specifically access to clean water, sanitation facilities, and primary health care and their relationship with health outcomes among low-income urban communities. The research population consists of households located in high-density, low-income subdistricts in Makassar, including Tamalate, Manggala, and Biringkanaya. These areas were selected due to their vulnerability to infrastructure stress, high population density, and limited service accessibility as identified in previous spatial assessments (Yudono et al., 2023).

A stratified random sampling technique was used to select 150 households proportionally distributed across the three subdistricts. The sampling ensured adequate representation of household conditions and service accessibility.Data collection involved structured questionnaires, field observation checklists, and documentation from public health centers and local water utilities. Indicators included household access to piped water, availability of private or shared sanitation, distance to primary healthcare facilities, frequency of illness, and perceived health risks.

The data analysis technique applied is a combination of descriptive statistics and Likert Scale to determine the relationship between infrastructure access and health resilience indicators. Spatial analysis using QGIS software was also employed to visualize the distribution of infrastructure and identify service gaps, based on methods adapted from (Afdhal et al., 2022; Malik et al., 2021) . Established methods used for resilience indicator development and spatial overlay analysis follow those described by (Meerow et al., 2016), with necessary modifications to reflect the socio-spatial context of Makassar.

RESULTS AND DISCUSSION

a. Infrastructure Disparities

The analysis across the selected subdistricts Tamalate, Manggala, Biringkanaya, Tallo, and Panakkukang demonstrates significant disparities in access to basic services that directly influence urban health resilience. These areas display distinct urban characteristics, which allowed for a comparative understanding of how infrastructure determines vulnerability and capacity in urban communities.

Descriptive findings show that Tamalate and Manggala subdistricts have relatively low percentages of households with private sanitation facilities (51% and 44%, respectively), while Biringkanaya, though slightly better, remains below optimal levels. Panakkukang and Tallo show mixed performance, with relatively higher facility access in some kelurahan (administrative village) but extreme disparities in others. Population density across these districts exceeds 6,000 people/km2, placing pressure on public health infrastructure. Moreover, in each subdistrict, more than 60% of households are located over one kilometer from primary healthcare facilities, indicating spatial barriers to access.

Table 1. Mapping Basic Service Infrastructure to Urban Health Resilience Dimensions

Indicator Category	Specific Variable	Urban Health Resilience Dimension	Source of Data
Access to Clean Water	% Households with Piped Water	Exposure / Vulnerability	PDAM, BPS

Sanitation	% Households with Private Toilets / IPAL	Exposure / Recovery	Dinas Kesehatan, DLH
Housing Condition	% Livable Housing with Access to IPAL	Sensitivity	BPS, PUPR
Population Density	People/km2 per Kelurahan (administrative village)	Adaptive Capacity / Pressure	BPS
Proximity to Health Care	Distance to Puskesmas/RS	Recovery / Access	Dinas Kesehatan, GIS
Type of Housing Tenure	% Rented/Owned Housing	Sensitivity	BPS, RT/RW Registry
Number of Facilities	of Puskesmas per Population	Access to Services / Recovery	Dinas Kesehatan Kota Makassar

This classification model helps identify how infrastructure gaps influence different components of resilience whether they increase exposure, inhibit adaptive capacity, or reduce access to recovery pathways. Tamalate and Manggala's vulnerability stems largely from physical inaccessibility to both sanitation and health facilities, while Biringkanaya's risk is shaped more by its transitional urban status and infrastructure lag. Panakkukang shows internal disparity across different neighborhoods, while Tallo reflects the compound vulnerability from population density and weak public service provision.

b. Constructing the Urban Health Resilience Index

The relationship between infrastructure and urban health resilience is further illustrated in the conceptual model (Figure 1). It shows how critical infrastructure components act as determinants of exposure, sensitivity, and recovery potential ultimately defining an area's resilience status.

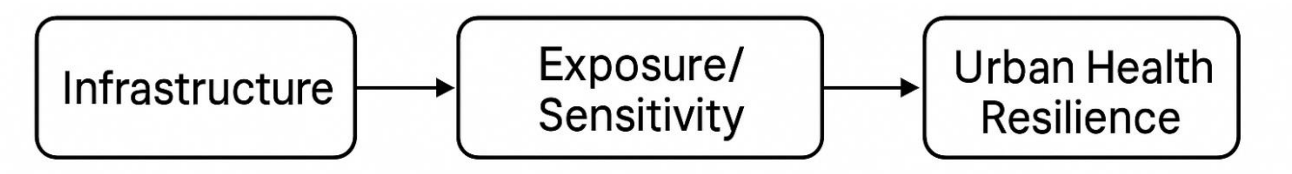

Figure 1. Relationship Between Basic Infrastructure and Urban Health Resilience

To deepen this analysis, an Urban Health Resilience Index (UHRI) was constructed using normalized scores (0–1) across five variables: access to clean water, sanitation coverage, healthcare proximity, housing conditions, and population density. Each indicator was weighted equally due to the absence of a prior empirical weighting scheme. Scores were normalized using a min-max rescaling technique across each variable to fall within a 0–1 range, allowing for comparability across different measurement units.

Table 2. Urban Health Resilience Index (UHRI) by Subdistrict

Subdistrict	Water Access	Sanitation	Healthcare Access	Housing Quality	Population Pressure	UHRI Score (0–1)
Tamalate	0.6	0.4	0.5	0.6	0.3	0.48
Manggala	0.5	0.3	0.4	0.5	0.2	0.38
Biringkanaya	0.7	0.5	0.6	0.6	0.3	0.54
Tallo	0.4	0.3	0.4	0.5	0.4	0.40
Panakkukang	0.8	0.7	0.7	0.8	0.5	0.70

A graphical representation of the UHRI is presented below to visualize resilience disparities.

c. Comparative Analysis by Subdistrict

From the UHRI scoring, Panakkukang emerges as the most resilient subdistrict, with a score of 0.70. This reflects its superior access to clean water, better sanitation infrastructure, proximity to health services, and higher proportion of livable housing. In contrast, Manggala records the lowest UHRI at 0.38, indicating substantial challenges in almost all evaluated dimensions. Biringkanaya, although slightly better, still falls within the moderate-risk zone with a score of 0.54, primarily hindered by uneven infrastructure distribution and peri-urban development characteristics.

Tamalate's score of 0.48 reveals a mixed resilience profile moderate housing and water access counterbalanced by weaknesses in sanitation and population density pressure. Tallo, with a UHRI of 0.40, reflects compounded vulnerabilities from high density and suboptimal healthcare access. Overall, the scores suggest a spatial inequality trend, where peri-urban and densely populated subdistricts lag in infrastructural resilience, underlining the importance of spatial targeting in resilience planning.

In addition to the quantitative index, a qualitative correlation was observed between population pressure and access to basic health services. Subdistricts such as Manggala and Tallo, which exhibit high population density and low sanitation coverage, also recorded the longest average distances to healthcare facilities. This suggests that higher demographic stress tends to coincide with infrastructural lag, exacerbating vulnerability. Furthermore, the proportion of rented housing units used as a proxy for tenure insecurity was inversely related to healthcare accessibility, indicating that tenure status might influence service prioritization and public investment. These qualitative associations underscore the interplay between social determinants and infrastructure in shaping urban health resilience.

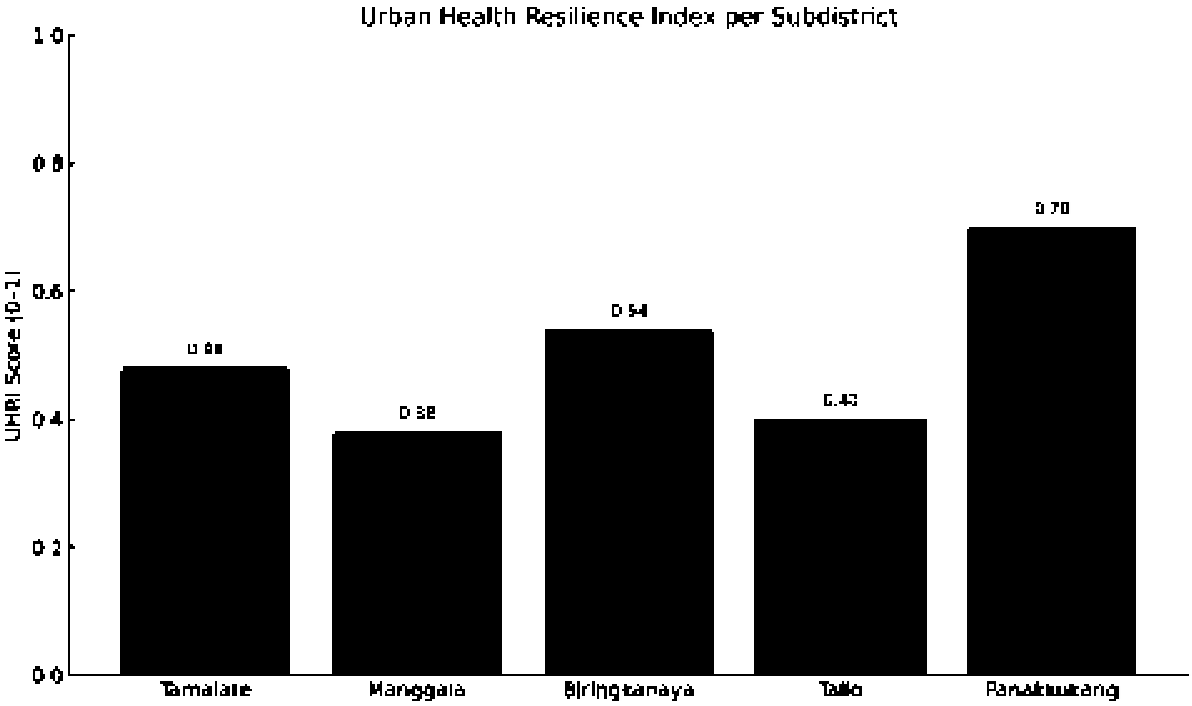

Figure 2. Urban Health Resilience Index per Subdistrict

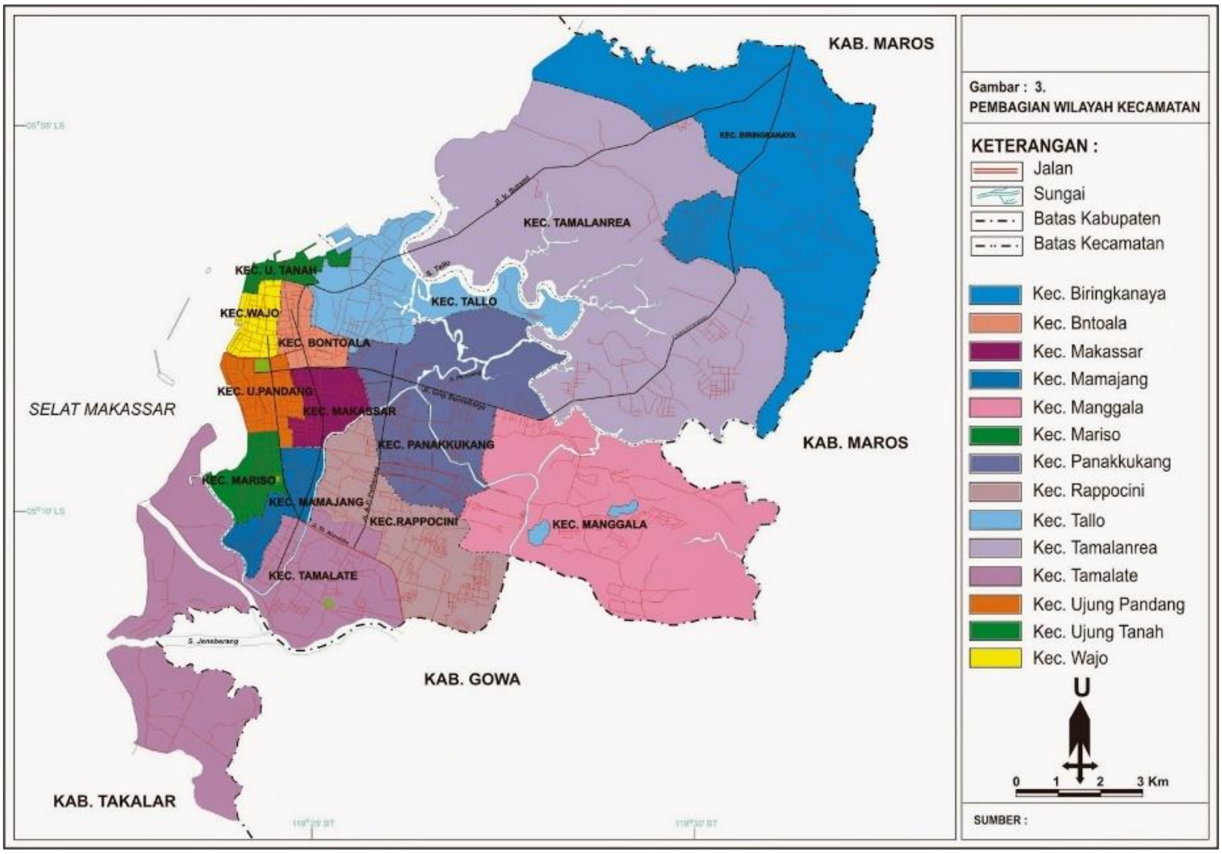

Figure 3. Administrative Map of Makassar City Subdistricts

The administrative boundary map below illustrates the spatial distribution of the five selected subdistricts: Tamalate, Manggala, Biringkanaya, Tallo, and Panakkukang. These subdistricts represent different urban typologies in Makassar, from densely populated urban cores (Panakkukang) to transitional peri-urban zones (Tamalate, Manggala). The visual context helps spatially situate the analysis of infrastructure access and urban health resilience.

These findings align with previous research (Afdhal et al., 2022; Yudono et al., 2023), as well as broader regional evidence. For instance, Kurniawan et al. (2024) emphasize the role of resilient infrastructure in mitigating climate-driven health risks in Southeast Asian cities. (Fuady et al., 2025) highlight systemic gaps in urban adaptation across Indonesian municipalities, while (Sulistiadi et al., 2024) examine health resilience strategies in climate-vulnerable communities. (Jasmine et al., 2021) provide a comprehensive roadmap for building infrastructure resilience in Indonesia, supporting the call for spatially targeted planning. Finally, (Abdillah et al., 2024) argue for embedding health resilience indicators into city-level planning to enhance adaptive governance and equity outcomes. in Makassar reside in districts with unequal access to fundamental services. This supports the need for a more spatially integrated infrastructure strategy to reduce health risks and urban inequality.

d. Survey-Based Validation and Statistical Correlation

A household infrastructure survey was conducted using a structured questionnaire distributed via Google Forms and follow-up interviews. A total of 150 valid responses were collected across five subdistricts: Tamalate, Manggala, Panakkukang, Biringkanaya, and Tallo. Respondents were asked to assess the adequacy of infrastructure access (clean water, sanitation, waste collection), their proximity to health services, housing tenure, and perceived health risks. SPSS v25 was used to analyze descriptive statistics and calculate Pearson correlation coefficients.

Table 3. Summary of Household Infrastructure Survey Results (n = 150)

Variable	Response Option	Frequency (n)	Percentage (%)
Access to Clean Water	Always available	102	68.0%
	Sometimes interrupted	36	24.0%
	Rarely available	12	8.0%

Sanitation Type	Private with septic tank	88	58.7%
	Shared toilet	42	28.0%
	Open defecation/No toilet	20	13.3%
Distance to Nearest Puskesmas	<500 meters	31	20.7%
	500–1000 meters	56	37.3%
	>1000 meters	63	42.0%
Housing Tenure	Owned	64	42.7%
	Rented/Contract	86	57.3%

Table 4. Infrastructure Score and Health Risk Perception by Subdistrict (Likert Scale Mean, n = 150)

Subdistrict	Avg. Water Access (1–5)	Avg. Sanitation (1–5)	Avg. Waste Collection (1–5)	Avg. Health Risk Perception (1–5)
Tamalate	2.7	2.4	2.9	4.2
Manggala	3.2	3.0	3.4	3.7
Panakkukang	3.8	4.0	4.2	2.9
Biringkanaya	2.5	2.3	2.7	4.4
Tallo	2.9	2.8	3.1	3.8

Spearman Rank Correlation Analysis The results revealed a significant moderate negative correlation ($\rho = -0.54$, $p < 0.05$) between poor infrastructure access and higher health vulnerability. Specifically:

1. Water Access vs Health Risk: $\rho = -0.52$
2. Sanitation vs Health Risk: $\rho = -0.49$
3. Waste Collection vs Health Risk: $\rho = -0.43$

These correlations are statistically significant ($p < 0.05$) and confirm that subdistricts with weaker infrastructure access report higher perceived health vulnerabilities.

Note: All anonymized survey data, SPSS output files, and variable constructs are available upon request for validation or reproducibility purposes.

The combination of survey data and correlational evidence strengthens the validity of the Urban Health Resilience Index (UHRI) framework as grounded in both objective and community-based assessments.

e. Policy Implications and Research Limitations

The findings highlight the urgent need for policy intervention at both city and neighborhood levels. Subdistricts such as Biringkanaya and Tamalate exhibit significant infrastructure deficits and higher health vulnerability, necessitating prioritization in urban health strategies.

Table 5. Policy Priority Matrix for Infrastructure-Based Urban Resilience

Subdistrict	Infrastructure Status	Health Risk Level	Recommended Interventions	Lead Agency	Policy Scale
Biringkanaya	Low	High	Water and sanitation upgrading	Dinas PU, Dinkes Makassar	Local RT/RW + Kecamatan
Tamalate	Low–Moderate	High	Waste management and mobile clinics	DLH, Dinas Kesehatan	Kecamatan + Kota
Manggala	Moderate	Medium	Drainage and sanitation access	Dinas PU, Brida	Kota
Tallo	Moderate	Medium–High	Strengthen Puskesmas outreach	Dinas Kesehatan	Kecamatan

Panakkukang	High	Low	Pilot program: community monitoring	Brida, Dinsos	Kota + Provinsi

Key recommendations include:

- **Integrated Infrastructure Planning**: Allocate budget with spatial equity targeting high-risk zones.
- **Community Participation**: Use participatory budgeting to improve health facility placement and infrastructure upgrades.
- **Monitoring System**: Incorporate real-time reporting systems for service outages and complaints.
- **Strengthening Institutional Coordination**: Synchronize programs between Brida, Dinas Kesehatan, PU, and DLH to avoid duplication and gaps.

The application of UHRI enables targeted and measurable action for Makassar's urban resilience goals, and may serve as a model for scaling up in other urban areas facing similar multi-risk conditions.

CONCLUSION

This study has demonstrated that basic service infrastructure particularly access to piped clean water, adequate sanitation, and proximity to primary healthcare facilities plays a critical role in shaping the health resilience of urban communities in Makassar City. The analysis revealed significant disparities in infrastructure availability across densely populated, low-income subdistricts, and established a clear relationship between infrastructure inadequacy and increased household health vulnerability.

The findings confirm that urban health resilience is not solely determined by external health programs or interventions, but is fundamentally rooted in the spatial and physical characteristics of the urban environment. Households with limited infrastructure access reported higher incidences of illness, underscoring the importance of integrating health-related indicators into the broader framework of urban resilience planning.

Moreover, the study highlights a persistent institutional gap in outreach and service coordination, suggesting that resilience cannot be achieved through infrastructure alone. Strengthening urban resilience therefore requires a holistic approach that combines infrastructure development, spatial equity, and community-level health empowerment.

By bridging empirical data with urban planning theory, this research contributes to a more nuanced understanding of resilience in the context of secondary cities in Indonesia. It emphasizes that infrastructure is not just a technical requirement but a social determinant of health and well-being. As urbanization continues to reshape Makassar, planning efforts must evolve to incorporate inclusive, health-oriented strategies that prioritize the needs of the most vulnerable populations.

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