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Towards a Seamless City Framework: Integrating Sentiment Analysis and Adaptive Indicators in Bandung's Urban Development

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Abstract

Smart city agendas in Indonesia are organized around administrative boundaries rather than functional urban dynamics, producing disconnected and fragmented digital services. This study develops the Seamless City as an analytical lens for urban-service integration and translates it into adaptive indicators for Bandung. The methodology uses lexicon-based sentiment analysis of an archived corpus of 6,795 Twitter/X posts on urban services, mapping the resulting citizen-perception signals against ISO 37120, ISO 37122, ISO 37123, and the Sustainable Development Goals. The results show that public discourse centers on service discontinuity rather than on the absence of technology, with governance sentiment distributed as 58.9% positive, 30.4% negative, and 10.7% neutral, indicating divided rather than uniformly critical opinion. Accordingly, 237 candidate indicators are proposed across four pillars: governance (111), mobility (24), economy (21), and environment (81). Urban-service integration therefore depends on cross-agency coordination rather than platform provision, with Bappeda a plausible convenor.

Keywords: Seamless City; Urban Governance; Sentiment Analysis; ISO Urban Indicators; Sustainable Development Goals.

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1. Introduction

Digital technology has transformed how city governments deliver services and interact with citizens, but the availability of advanced technology does not automatically produce a well-coordinated governance system. For over a decade the Smart City paradigm has shaped urban development policy worldwide with employing ICT and data-driven management to improve urban management practices (Nam & Pardo, 2011; Caragliu, Del Bo, & Nijkamp, 2011; Batty, 2013; Kitchin, 2014), yet substantial investment in technology has not necessarily produced integrated public services or more effective government agencies (Hollands, 2008; Meijer & Bolívar, 2016). Indonesia faces this challenge in a particular form, as much of its territory consists of a mix of villages and cities, and planning is further complicated by *desakota* areas where urban and rural elements merge and planning boundaries blur (McGee, 1991). Addressing this requires stronger institutional coordination and a more integrated approach to spatial planning (Anthopoulos, 2017; Janssen et al., 2015; Pambudi, 2022). Digital transformation in Indonesia has been driven by smart city agendas at national and local levels, spurring innovation in public communication, digital service provision, and data management. The expansion of digital services nevertheless raises a planning question whether platforms that function independently can be harmonised into a unified urban service system that residents can understand and use. A city may possess a wide array of applications without making it easier for citizens to complete tasks spanning multiple agencies, sectors, and locations, just as the availability of data does not guarantee that institutions can share, interpret, and act on it collectively.

The communicative city perspective offers a starting point. Within this framework, information flows, interactions among development stakeholders, and the quality of communication are treated as essential to planning coordination rather than as supplementary to technology. Sutriadi and Wulandari (2014) demonstrate how information and communication technology can support urban planning coordination in the Bandung Metropolitan Area, and further work on communicative-city characteristics in Bandung underscores the role of stakeholder interaction, institutional communication, and knowledge exchange in developing a technopole-oriented urban agenda (Sutriadi et al., 2022). The planning value of digital technology therefore lies not only in its technical capacity but in its ability to facilitate relationships among urban stakeholders. The concept of soft infrastructure extends this argument. Sutriadi (2023) argues that smart and sustainable city development cannot be understood through physical facilities, sensors, networks, or applications alone; it also depends on governance, institutional capacity, human resources, social systems, and citizen participation. A technologically advanced city may still be poorly integrated if agencies operate in silos or if citizens cannot contribute to improving urban services, which makes digital transformation a process of planning and governance rather than branding or isolated technological intervention (Sutriadi et al., 2023). Examining sustainable smart city development through urban innovation performance, Sutriadi, Hadicahyono, and Drestalita (2025) similarly find that innovation is shaped by the interaction of institutional, social, and infrastructural conditions, and this is consistent with calls to move smart-city governance away from technology-centric implementation towards socio-technical and citizen-oriented approaches (Nam & Pardo, 2011; Anthopoulos, 2017; Yigitcanlar et al., 2018). The same logic applies to specific technologies: in disaster and emergency management, spatial tools such as digital twin models yield tangible value only when embedded in official guidelines capable of adapting to diverse community conditions and spatial scales (Prihatmanto et al., 2025).

This study develops the Seamless City as an analytical lens within that tradition rather than as a standalone theory. Seamlessness describes the extent to which urban services are connected across institutional, digital, and spatial boundaries as experienced by the public, where residents access services with minimal friction while all responsibilities and data remain aligned among public agencies. The concept draws on the communicative-city perspective, soft infrastructure, smart-city governance, and the service-integration principles associated with Mobility-as-a-Service (MaaS) and digital public-service delivery (Jittrapirom et al., 2017; Meijer & Bolívar, 2016; Sutriadi, 2023). Bandung is a relevant setting for examining this issue with its established reputation for smart city initiatives in Indonesia and international recognition of its smart governance agenda. Implementation nevertheless remains constrained by cross-sector integration problems spanning governance, mobility, the digital economy, and environmental management, involving both the alignment of institutional roles and the capacity of planning systems to translate public aspirations into actionable priorities. In this context, citizen-generated digital data can complement administrative records and surveys, since planning research has demonstrated the potential of combining large-scale digital traces, public documents, and computational methods to examine public aspirations within urban development discourse (Syabri et al., 2024; Verma, 2022). The empirical material is an archived Twitter/X corpus on urban issues in Bandung, assembled by the first author for an earlier undergraduate study (Aldhiya, 2025) and used here as secondary empirical data. The study does not claim to generate a new citywide measure of public sentiment, nor to re-present the prior study as a new empirical discovery. It interprets citizen-perception signals as contextual input for a proposed architecture of urban-service indicators.

Two gaps follow from this literature. First, seamlessness has been operationalized almost exclusively in mobility research, where Mobility-as-a-Service defines it as the integration of modes, information, booking, payment, and service access to reduce discontinuities for users (Jittrapirom et al., 2017). Second, established urban indicator systems assess sectoral performance domain by domain and therefore do not capture the cross-sector coordination on which service continuity depends. Reviews of urban sustainability metrics report that the field remains fragmented and inconsistent, with indicators typically treated sectorally rather than as an integrated set (Di Liddo et al., 2025). This study addresses both gaps by extending seamlessness beyond the transport sector and by translating citizen-perception signals into an indicator architecture aligned with international standards. The intention is not to assume that all sectors can be merged into a single platform but to examine whether institutional and digital arrangements enable coordinated service delivery where cross-sector interaction is required.

The framework proposed here comprises four interrelated domains: seamless governance, covering the institutional and data arrangements that condition the other three; seamless mobility, covering movement and accessibility across modes and land-use systems; seamless economy, covering inclusive access to digital and urban economic opportunity; and seamless environment, covering the coordination of resources, infrastructure, and ecological management. The four are linked by a single question whether the urban system can coordinate services, information, institutional responsibilities, and feedback across institutional boundaries. Accordingly, this study pursues two objectives: to examine public perceptions of urban services in Bandung using social media data, and to translate these findings into Seamless City indicators that reflect local conditions while remaining aligned with ISO 37120, ISO 37122, ISO 37123, and the SDGs.

2. Methods

2.1. Research Design

This study employs an embedded mixed-methods approach (Creswell & Plano Clark, 2018) in which quantitative sentiment classification derived from an archived Twitter/X corpus is interpreted alongside qualitative thematic material, document review, and indicator mapping. Rather than using social media data to draw broad conclusions about the attitudes of Bandung residents towards urban services, the corpus serves to identify the aspects of urban infrastructure that residents perceive as poorly connected and the urgency of the associated service problems. Social media data were selected because they offer direct insight into residents' experiences and opinions of daily life and capture shifts in perception relatively quickly (Kaplan & Haenlein, 2010; Kitchin, 2014). Compared with conventional sources such as surveys and official government reports, such data provide a more immediate picture of public discourse in a continuously changing urban environment. Sentiment analysis is used to identify public perceptions of and concerns about urban services (Pang & Lee, 2008; Liu, 2012), an application whose growing use in the analysis of government policy has been documented in systematic review (Harwenda et al., 2025). Twitter/X was chosen for its relatively open and accessible data environment and its role as a forum for discussing urban issues and governance, which allows a diversity of perspectives to be observed (Bruns & Burgess, 2012). The qualitative thematic material referenced mentioned before consists of external–internal factor pairs identified for each pillar in the original study (Aldhiya, 2025). External factors were derived from keywords drawn from relevant literature and global reports (including the Digital Economy Report, the World Employment and Social Outlook, and World Economic Forum publications) and traced through Twitter/X via keyword scraping. Each external factor was then paired with a corresponding internal factor representing a plausible city-level policy response. The resulting factor pairs were scored on a star-rating scale by the first author and subsequently validated by the thesis supervisor as a form of expert judgement to strengthen the justification for the ranking and reduce subjectivity in factor selection.

2.2. Data Provenance

The archived dataset contains 6,795 Twitter/X posts retrieved between 26 May 2020 and 27 May 2025. It was assembled for an earlier undergraduate study through eight keyword-based searches associated with four domains: governance, mobility, economy, and environment. Each search had a retrieval limit of 1,000 posts. Four searches used a geographic filter through the near:Bandung criterion. The distribution of posts is presented in Table 1.

Table 1: Keyword Frequencies Across Seamless City Pillars

Keyword	Pillars	N
political inertia	Governance	56
policy	Governance	1004
urbanization	Mobility	1016
transportation and infrastructure	Mobility	1005
digital divide	Economy	1011
digital	Economy	1001
climate change	Environment	1010
energy	Environment	692

Source: Aldhiya, 2025.

Prior to sentiment classification, preprocessing involved removing user mentions, non-alphabetic characters, and punctuation; normalising text to lowercase; and removing a custom stopword list comprising common Indonesian words and platform-specific noise terms. The original study cleaned the Indonesian text, translated it into English using Google Translate via the googletrans library, and classified sentiment polarity using TextBlob. Posts with polarity values greater than zero were categorised as positive, those below zero as negative, and those equal to zero as neutral. The present study reuses these archived classification outputs and does not claim to validate or improve their accuracy. The classifications are therefore interpreted cautiously. They indicate discourse patterns within the corpus, not verified public satisfaction or causal explanations of service quality: the procedure was not evaluated against a manually labelled dataset using accuracy, precision, recall, or F1-score, and translation effects, informal language, sarcasm, negation, and local linguistic context may have affected the results.

2.3. Indicator Mapping Procedure

Building upon prior analysis, this study extends the existing Seamless City framework by systematically mapping its four pillars, along with their associated indicators, to the 17 Sustainable Development Goals (SDGs). The four-pillar framework, the thematic factor pairings, and the alignment with ISO 37120, ISO 37122, and ISO 37123 standards were established in the study by Aldhiya (2025). The study's contribution lies in extending the framework through an SDG-oriented mapping process and interpreting the resulting relationships by linking them to the sentiment patterns and thematic analyses derived from previous research. Steps of the procedure are:

1. Identify service-integration issues associated with the four analytical domains from the archived discourse patterns and thematic materials.
2. Review relevant thematic domains and definitions in ISO 37120, ISO 37122, and ISO 37123.
3. Select candidate indicators that can represent both sectoral performance and cross-sector coordination, service continuity, accessibility, data interoperability, or institutional responsiveness.
4. Map each indicator to relevant SDG goals and, where feasible, specific SDG targets.
5. Visualise the resulting indicator–SDG relationships as a Sankey diagram in order to show where linkages concentrate across the four pillars.

Each candidate indicator was assessed against five criteria: (1) its conceptual relevance to the integration of city services; (2) its alignment with one or more domains of ISO 37120, ISO 37122, or ISO 37123; (3) its link to SDG targets; (4) the potential availability of city-level data; and (5) the institutional arrangements required for implementation. The result of this process is a set of proposed indicators for the framework. These do not constitute a validated performance index. The objective is to clarify how signals of citizen perception can serve as a baseline for government data collection, how inter-agency cooperation can support a response, and how regulations might be reviewed to enable more appropriate adjustment. Further validation should involve the relevant Bandung municipal agencies, such as Bappeda, together with service providers, academic experts, and community representatives.

3. Results and Discussion

3.1. Theoretical Adaptation and the Emergence of Seamless City Pillars

Sentiment analysis consistently reveals the same underlying pattern where residents of Bandung perceive urban services as fragmented across the areas of mobility, governance, the economy, and the environment. This is consistent with earlier evaluations of the city's Smart City rollout, which found that platforms continue to operate as silos despite digitalisation without giving an proper integrated experience. The six-dimensional model proposed by Giffinger et al. (2007) served as the initial reference for building the seamless concept In here. In this study the four pillars—governance, mobility, economy, and environment—are treated as an established structure, revisited specifically to examine their relationship with ISO 37120, ISO 37122, ISO 37123, and the SDGs rather than to reformulate them or re-analyse the underlying sentiment data. Each pillar reflects a distinct set of challenges. The four pillars shift the analytical focus away from smart city technology as an end in itself and towards service integration, user experience, and the specific urban pressures facing Bandung.

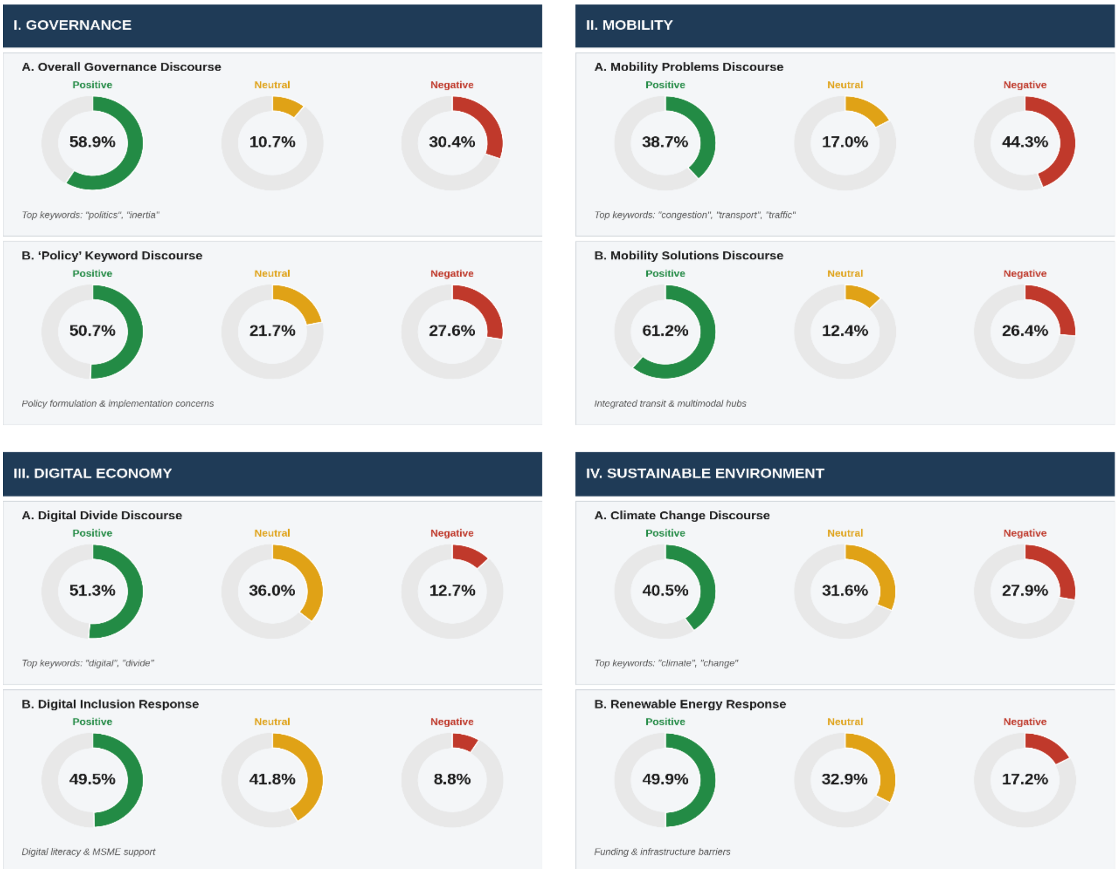

Figure 1. Sentiment Distribution Across the Four Seamless City Pillars (Governance, Mobility, Economy, and Environment) by Problem/Discourse and Policy/Response Dimensions
Source: Aldhiya, 2025.

3.2. Seamless Governance

Governance emerges as the pillar of highest importance, on both the factor assessment and the analysis of the Twitter/X data. This pattern is consistent with comparable Twitter-based analyses of smart city governance in Southeast Asian capitals, which likewise find that citizen sentiment on social media reflects institutional and participatory concerns rather than purely technological ones (Mutiarin & Lawelai, 2023). Among the five external–internal factor pairs evaluated in the governance dimension, the relationship between political inertia and policy adaptability received the highest score, followed by social inequality versus agile governance and opaque bureaucracy versus system transparency. The public therefore places greater emphasis on the institutional adaptability of government than on new technology, which underlines the role of institutional factors in shaping public perception. The two terms appearing most frequently in governance-related posts are "politics" and "inertia". Sentiment is distributed as 58.9%

positive, 30.4% negative, and 10.7% neutral (Figure 1), a spread that indicates genuine variation in how the public views urban governance. Positive sentiment should not be interpreted as a sign of satisfaction. A more plausible reading is that it reflects public expectation of an appropriate government response rather than confirmation that such a response has been delivered. The distinction is clearer for the keyword “policy”, with a split of 50.7% positive, 27.6% negative, and 21.7% neutral, a more balanced distribution than that for governance as a whole. Public concern therefore attaches not merely to the presence or absence of digital systems in governance but to how the underlying policies are formulated and implemented. The core of seamless governance is coordination rather than technology alone. This is consistent with the concept of adaptive governance (Folke et al., 2005).

3.3. Seamless Mobility

Mobility shows some contrast in the dataset. Among the five factor pairs tested, traffic congestion versus integrated transit systems recorded the highest score, followed by urban expansion versus transport regulation and, in third place, the dominance of informal transport versus digital monitoring. This is reflected in the vocabulary, in which “congestion”, “transport”, and “traffic” dominate. Posts concerned with problems show a sentiment breakdown of 44.3% negative, 38.7% positive, and 17% neutral (Figure 1 right side), reflecting daily dissatisfaction with a transport system that operates as a set of fragmented modes rather than an integrated network. Posts concerned with solutions show almost the reverse pattern, at 61.2% positive, 26.4% negative, and 12.4% neutral, which suggests that although residents are frustrated with current conditions they remain optimistic about the prospect of change. These spatial and operational gaps echo challenges identified in recent literature on smart mobility across Indonesian urban corridors, where transport planning frequently lacks integration with regional development goals (Almassawa et al., 2025). A shift is required from piecemeal transport implementation towards integrated payment platforms and multimodal transit hubs.

3.4. Seamless Economy

Within the economic pillar, the pair comprising digital exclusion and digital participation recorded the great score among the five factor pairs tested, indicating that public concern in this domain centres on who is able to participate in the digital economy rather than on economic performance in a broader sense. Technological disruption versus the digital economy, and economic instability versus a sustainable economy, follow closely. Read together, the three point to a single conclusion: the economic resilience of Bandung depends on integrating technological change with policies that maintain broad access rather than confining it to a few groups. “Digital” and “divide” are the words appearing most frequently in economy-related posts (Aldhiya, 2025). Sentiment regarding the digital divide was recorded as 51.3% positive, 36% neutral, and 12.7% negative (Figure 3). These results are explicable in terms of the topics the public discusses, such as digital literacy programmes, the expansion of internet access for economic activity, and digitalisation support for MSMEs (Rahayu et al., 2023).

Digital inclusion records the lowest negative sentiment of any topic in the dataset, at 8.8% negative compared with 49.5% positive and 41.8% neutral. Residents generally regard the existing gap as surmountable rather than structural, and their concerns attach more to the consistency with which initiatives are implemented and to the opportunity to evaluate whether those initiatives meet community needs. As in the other pillars, these sentiment patterns reflect public expectations of digital economic inclusion; they cannot serve as direct evidence of programme effectiveness (Verma, 2022).

3.5. Seamless Environment

Climate change and renewable energy emerged as the most frequently mentioned factor pair in environmental pillars followed by energy crisis versus renewable energy and climate change versus nature-based solutions. These relationships suggest a need to develop energy diversification and ecosystem-based approaches simultaneously. Consistent with this, “climate” and “change” are the most frequent words in environment-related posts, with sentiment distributed as 40.5% positive, 31.6% neutral, and 27.9% negative (Figure 4). Positive posts express support for renewable energy initiatives and climate policy, neutral posts largely convey factual information, and negative posts concentrate on extreme weather, environmental degradation, and doubts about the capacity of government to respond effectively. Posts on renewable energy show a distribution close to that for climate change, at 49.9% positive, 32.9% neutral, and 17.2% negative. Public support for sustainability policy depends largely on the perceived feasibility of implementation; the principal obstacles are not a lack of public acceptance but insufficient funding and supporting infrastructure. The environmental discourse in the data reveals a misalignment between the state of local natural resources and existing policy. This corresponds to the 'water paradox' observed in Bandung, where abundant rainfall often fails to deliver water security or flood control because of fragmented spatial planning and weak cross-sectoral management (Sunarwibowo et al., 2025).

3.6. Proposed Seamless City Framework

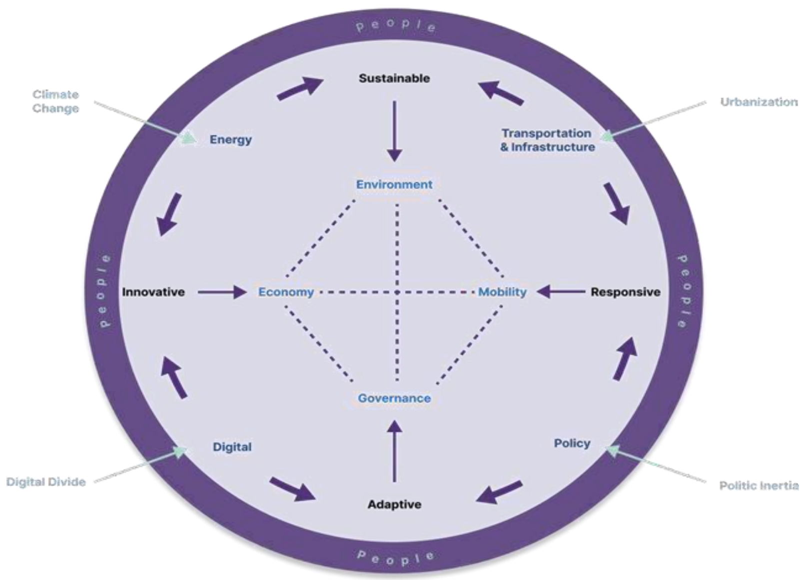

Figure 2. Seamless City Framework
Source: Aldhiya, 2025.

Seamless governance functions as the enabling condition. It concerns institutional coordination, policy adaptability, public participation, data governance, transparency, and continuity of essential services. Seamless mobility concerns the experience of moving across modes, places, and information systems. Seamless economy concerns equitable access to digital and urban economic opportunity. While Seamless environment concerns the integration of resource management, ecological systems, infrastructure, and resilience planning.

The framework is people-centred in the sense that it evaluates technology according to whether it reduces friction in the everyday experience of residents and service users. Technology in here acts as means rather than an endpoint. A digital application that duplicates existing processes, excludes users, or remains disconnected from institutional responsibility does not create seamlessness. The orientation also responds to a longstanding critique that planning agendas built around physical or technological modernisation risk displacing lower-income residents (Watson, 2009).

The framework also differs from a conventional sectoral dashboard. It asks whether a city can coordinate systems where their boundaries overlap. For example, flood resilience requires alignment among spatial planning, drainage, river management, waste collection, emergency communication, road accessibility, health services, and community information. A single-sector indicator may monitor one component, while a seamlessness-oriented approach examines whether relevant agencies possess shared data, agreed responsibilities, response protocols, and mechanisms for incorporating public feedback

3.7. Development and Analysis of Adaptive Indicators for the Seamless Cities Framework

The Seamless City framework requires adaptive indicators that can be applied operationally. Existing indicator systems such as ISO 37120, ISO 37122, and ISO 37123 provide foundations for assessing urban performance by measuring urban services and quality of life, smart city performance, and urban resilience. These standards nevertheless evaluate each domain separately and do not fully capture the cross-sectoral interactions (White, 2021; Patel et al., 2017) that are central to the Seamless City framework. Adaptive indicators were therefore developed by integrating three approaches: (1) combining thematic clusters drawn from the three ISO standards; (2) applying an urban systems perspective based on the relationships among input, process, output, and outcome; and (3) linking the indicators to the four pillars of the framework. This ensures that the indicators assess not only technical performance but also community experience and institutional interoperability.

Example in governance pillar, five thematic areas were identified: education, public finance, institutional governance, safety and emergency response, and urban planning. The indicators emphasise interoperability, inclusiveness, resilience, evidence-based decision making, inter-agency data integration, digital service readiness, fiscal sustainability, and public participation, thereby extending the scope of the three ISO standards while remaining relevant to the local context. This approach to translating city-level indicators into SDG-aligned measures reflects experience with localising global sustainability agendas in urban contexts (Patel et al., 2017). In total, 237 candidate indicators are proposed across the four pillars: 111 for governance, 24 for mobility, 21 for economy, and 81 for environment. Tables 2 to 5 present them pillar by pillar with giving each indicator's thematic domain and its SDG alignment. These are proposals for validation, not a scored performance index.

3.7.1. Seamless Governance Indicators

The indicators below illustrate the interrelationships among institutional processes, public service systems, and regulatory mechanisms within urban governance. Table 2 presents the main governance themes, the indicators representing each theme, and their links to the relevant SDGs.

Table 2: Seamless Governance: Proposed Candidate Indicators and SDG Alignment by Thematic Domain

Seamless Cities Pillars	Theme	Proposed Candidate Indicators	SDG Alignment
Seamless Governance	Education	[1] Percentage of children aged 7–18 registered in formal education using integrated DAPODIK & DUKCAPIL data [2] Availability of a city education dashboard integrating data from public and private schools [3] Number of annual/biannual public forums for education evaluation based on citizen input [4] Existence of a cross-sector platform integrating Education, Social Affairs, and Civil Registry data for educational inclusion tracking [5] Number of local policies explicitly integrating gender & social inclusion in primary and secondary education [6] Existence of local policy mandating cross-agency integrated systems for teacher & school management [7] Education quality disparity index across districts [8]Percentage of schools integrating national/local digital learning platforms [9] Gender parity index for school participation at primary–senior high levels [10] Percentage of female senior high graduates employed, self-employed, or engaged in formal community roles [11] Average student–teacher ratio at primary school level per district [12] Number of schools receiving staffing allocation based on digital mapping of teacher shortages [13] Share of regional basic education budget allocated for teacher training & capacity building [14] Existence of local policy mandating cross-agency integrated systems for teacher & school management [15] Percentage of schools implementing teacher performance evaluation based on competence & community participation [16] Education quality disparity index across districts [17] Ratio of bachelor graduates per 100,000 working-age population [18] Ratio of STEM graduates per 100,000 residents [19] Number of regional/national scholarship recipients in last 5 years & budget trends [20] Percentage of higher-education institutions with LMS, e-learning platforms & adequate bandwidth [21] Percentage of new or revised study programs aligned to local development roadmap [22] Percentage of university graduates tracked (employment status) within 1–2 years after graduation [23] City labour competitiveness index (employability, productivity, local absorption) [24] Existence of collaboration forum: universities – local government – private sector [25] Active digital devices per 1,000 students [26] Percentage of schools integrating national/local digital learning platforms	[1] SDG 4, SDG 16 [2] SDG 4 [3] SDG 4, SDG 16 [4] SDG 4, SDG 16 [5] SDG 4, SDG 16 [6] SDG 4, SDG 9 [7] SDG 4, SDG 16 [8] SDG 4, SDG 5 [9] SDG 4, SDG 5 [10] SDG 5, SDG 8 [11] SDG 4 [12] SDG 4, SDG 16 [13] SDG 4 [14] SDG 16 [15] SDG 4, SDG 16 [16] SDG 4, SDG 10 [17] SDG 4, SDG 8 [18] SDG 4, SDG 9 [19] SDG 4 [20] SDG 4, SDG 9 [21] SDG 4, SDG 11 [22] SDG 4, SDG 8 [23] SDG 8, SDG 9 [24] SDG 9, SDG 17 [25] SDG 4, SDG 9 [26] SDG 4, SDG 9 [27] SDG 4 [28] SDG 4, SDG 16 [29] SDG 16 [30] SDG 4, SDG 8 [31] SDG 4, SDG 16 [32] SDG 4, SDG 16 [33] SDG 4, SDG 16 [34] SDG 4, SDG 16 [35] SDG 4, SDG 11 [36] SDG 11, SDG 13 [37] SDG 11, SDG 16 [38] SDG 11, SDG 13 [39] SDG 11, SDG 13

Seamless Cities Pillars	Theme	Proposed Candidate Indicators	SDG Alignment
		[27] Percentage of teachers trained in educational technology use [28] Existence of system monitoring digital device utilisation in schools (yes/no) [29] Existence of local regulations supporting digital education [30] Percentage of students & university students holding recognized foreign-language certifications [31] Percentage of public servants and public-sector staff trained / certified in foreign languages [32] Number of e-learning language training programs integrated with local government systems [33] Existence of local policy on multilingual education / training [34] Existence of an active citizen language-competency database used by relevant agencies [35] Percentage of formal schools that have integrated disaster-education modules into curriculum/activities [36] Number and percentage of students, teachers, parents attending verified disaster-preparedness training [37] Existence of digital multi-language emergency-publication system [38] Frequency / duration of learning disruptions due to disasters within one academic year [39] Existence of SOP for emergency response based on local risk data at educational units	
	Finance	[1] Annual debt service ratio to total local government revenue (%; DSR <10% considered fiscally sound) [2] Share of locally generated revenue (PAD) in total city revenue (>50% indicates fiscal autonomy) [3] Share of expenditure allocated to social, environmental, and emergency response sectors (% of total budget) [4] Ratio of tax and levy payment transactions conducted via digital channels to total transactions (%) [5] Share of revenue from sharing-economy platforms (ride-hailing, accommodation, logistics, etc.) relative to total local revenue (PAD) [6] Share of annual budget allocated to maintenance of public facilities (roads, water supply, drainage, etc.) [7] Percentage of budget allocated to green–blue infrastructure projects (parks, retention ponds, water corridors) [8] Share of dedicated budget for disaster preparedness, emergency response, and recovery systems [9] Ratio of tax and levy payment transactions conducted via digital channels to total transactions (%) [10] Share of revenue from sharing-economy platforms (ride-hailing, accommodation, logistics, etc.) relative to total local revenue (PAD) [11] Share of annual budget allocated to maintenance of public facilities (roads, water supply, drainage, etc.) [12] Proportion of infrastructure budget allocated to drainage systems, water retention, and stormwater control [13] Ratio of annual budget allocated to rehabilitation of green open spaces, watershed areas, and ecological protection [14] Percentage of budget allocated to green–blue infrastructure projects (parks, retention ponds, water corridors) [15] Share of dedicated budget for disaster preparedness, emergency response, and recovery systems	[1] SDG 16 [2] SDG 9, SDG 11 [3] SDG 16 [4] SDG 1, SDG 11, SDG 13 [5] SDG 16 [6] SDG 16 [7] SDG 9, SDG 11 [8] SDG 1, SDG 11, SDG 13 [9] SDG 9, SDG 16 [10] SDG 8, SDG 9 [11] SDG 11 [12] SDG 11, SDG 13 [13] SDG 11, SDG 15 [14] SDG 11, SDG 13 [15] SDG 11, SDG 13, SDG 16
	Public Administration/ Governance	[1] Proportion of women holding city-level public office positions per electoral period [2] Ratio of voting-age citizens registered in the digital electoral system [3] Proportion of inter-agency memoranda of understanding (MoUs) that include shock-response or service continuity provisions [4] Number of annual unique user accesses to the open data portal containing procurement, budget, and agency performance information [5] Percentage of city public services (licensing, civil registry, complaints, etc.) available and active online via official government platforms [6] Average response time (hours) of the city government to non-emergency public inquiries through digital channels [7] Average downtime duration (hours per month) of public digital services due to server, system, or maintenance disruptions [8] Proportion of essential service sectors (water, electricity, health, transport) with documented service continuity plans during crises [9] Proportion of formal intergovernmental cooperation agreements related to disaster and shock-response coordination [10] Number of annual unique user accesses to the open data portal containing procurement, budget, and agency performance information	[1] SDG 5, SDG 16 [2] SDG 16 [3] SDG 16 [4] SDG 11, SDG 13, SDG 16 [5] SDG 11, SDG 16 [6] SDG 11, SDG 16 [7] SDG 16, SDG 17 [8] SDG 11, SDG 16 [9] SDG 16 [10] SDG 16 [11] SDG 9, SDG 16 [12] SDG 16 [13] SDG 9, SDG 16 [14] SDG 11, SDG 13 [15] SDG 11, SDG 16 [16] SDG 11, SDG 16 [17] SDG 11, SDG 13 [18] SDG 11, SDG 17

Seamless Cities Pillars	Theme	Proposed Candidate Indicators	SDG Alignment
		[11] Percentage of city public services (licensing, civil registry, complaints, etc.) available and active online via official government platforms [12] Average response time (hours) of the city government to non-emergency public inquiries through digital channels [13] Average downtime duration (hours per month) of public digital services due to server, system, or maintenance disruptions [14] Number of annual updates to disaster response and contingency planning documents by the city government [15] Proportion of essential service sectors (water, electricity, health, transport) with documented service continuity plans during crises [16] Percentage of critical public service institutions (including private providers) with documented and tested business continuity plans (BCP) [17] Number of public activities on disaster preparedness (outreach, workshops, simulations) conducted per district [18] Proportion of formal intergovernmental cooperation agreements related to disaster and shock-response coordination	
	Security	[1] Ratio of professional firefighters to total population [2] Ratio of volunteer firefighters to total population [3] Ratio of police officers to total population [4] Average response time (minutes) from incident reporting to arrival of emergency personnel [5] Proportion of emergency response personnel (police, firefighters, volunteers) with certified training [6] Fire-related mortality rate by district (per sub-district) [7] Fatality ratio from natural disasters (floods, landslides, earthquakes) [8] Number of occupational fatalities or industrial accidents in industrial zones [9] Homicide rate by location and time of occurrence [10] Number of reported cases of theft, robbery, and damage to public or private property [11] Number of reported cases of physical violence, sexual violence, and domestic violence against women [12] Percentage of city area covered by digital surveillance cameras, based on public and strategic zoning [13] Proportion of residents registered to and receiving notifications from the early warning system [14] Percentage of hazard alerts received by residents within five minutes of initial detection [15] Number of medical bed facilities rendered unusable after disasters per 100,000 population	[1] SDG 11, SDG 16 [2] SDG 11, SDG 17 [3] SDG 16 [4] SDG 11, SDG 16 [5] SDG 11, SDG 16 [6] SDG 11 [7] SDG 11, SDG 13 [8] SDG 8, SDG 16 [9] SDG 16 [10] SDG 16 [11] SDG 5, SDG 16 [12] SDG 11, SDG 16 [13] SDG 11, SDG 13 [14] SDG 9, SDG 11 [15] SDG 3, SDG 11
	Urban Planning	[1] Total area of public and private green open spaces with ecological functions per 100,000 population [2] Total number of recorded trees (digitally or manually inventoried) that are actively maintained per 100,000 population [3] Percentage of public infrastructure (sidewalks, parks, open spaces) with active infiltration features relative to total urban land area [4] Proportion (%) of informal settlement land per district [5] Annual growth rate of informal settlement areas [6] Number of regularization or relocation areas implemented per year [7] Jobs–Housing Ratio (JHR) by district [8] Average distance from residence to workplace [9] Proportion of zones with mixed-use functions [10] Level of spatial mismatch between residential and employment locations [11] Percentage of population with access to basic services (healthcare, education, clean water) within 500 meters [12] Density of basic service facilities per zone [13] Index of inequality in basic service distribution across districts [14] Level of inter-agency data integration for basic service provision [15] Percentage of built-up area relative to total land area per zone [16] Proportion of population living in zones with density exceeding 8,000 persons/km² [17] Share of high-density zones relative to total city population [18] Number of residents actively participating (online or offline) in urban planning consultations per 100,000 population per year [19] Level of engagement on digital public participation platforms (e.g., applications, forums) [20] Percentage of building permit applications submitted through the official electronic government system [21] Percentage of urban areas covered by publicly accessible disaster risk maps [22] Percentage of high-disaster-risk zones implementing active mitigation measures	[1] SDG 11, SDG 13 [2] SDG 11, SDG 13, SDG 15 [3] SDG 11, SDG 13 [4] SDG 11 [5] SDG 11 [6] SDG 11, SDG 16 [7] SDG 11 [8] SDG 11 [9] SDG 11 [10] SDG 11 [11] SDG 11 [12] SDG 11 [13] SDG 10, SDG 11 [14] SDG 16, SDG 17 [15] SDG 11, SDG 15 [16] SDG 11 [17] SDG 11 [18] SDG 11, SDG 16 [19] SDG 9, SDG 16 [20] SDG 9, SDG 16 [21] SDG 11, SDG 13 [22] SDG 11, SDG 13 [23] SDG 11, SDG 16 [24] SDG 9, SDG 11

Seamless Cities Pillars	Theme	Proposed Candidate Indicators	SDG Alignment
		[23] Percentage of government agencies and utility providers conducting regular risk assessments [24] Percentage of vital infrastructure affected by flooding relative to total critical infrastructure	

Source: Authors' analysis, 2026

This table shows that Seamless Governance has some alignment with relevant SDG like SDG 9 (Industry, Innovation, and Infrastructure), SDG 11 (Sustainable Cities and Communities) and SDG 16 (Peace, Justice, and Strong Institutions). Seamless Governance in here serves as one of the foundation for the other three pillars mentioned.

3.7.2. Seamless Mobility Indicators

The Seamless Mobility pillar comprises indicators that reflect the relationship between transport systems, spatial planning, and public accessibility. These indicators highlight the need for an integrated mobility system that reduces barriers between modes while improving service connectivity in real time. Table 3 presents the mobility themes, their corresponding indicators, and their alignment with the relevant Sustainable Development Goals. Within this pillar, sentiment analysis reveals persistent public dissatisfaction with the lack of coordination among private vehicles, ride-hailing services, and public transport, which have historically operated as fragmented systems. This relates to urban challenge about achieving genuinely integrated multimodal connectivity. One proposed indicator addressing it is the percentage of public transport services using integrated digital payment systems. These initial indicators require further empirical validation.

Table 3: Seamless Mobility: Proposed Candidate Indicators and SDG Alignment

Seamless Cities Pillars	Theme	Proposed Candidate Indicators	SDG Alignment
Seamless Mobility	Transportation	[1Length of public transportation network (km) per 100,000 inhabitants [2] Percentage of population living within 0.5 km of a public transport stop [3] Percentage of transit corridors equipped with real-time tracking systems [4] Percentage of public transport services using integrated digital payment [5] Percentage of transit routes providing public Wi-Fi connectivity [6] Traffic injury and fatality rate per 100,000 population/year [7] Percentage of pedestrian crossings equipped with disability-access systems [8] Percentage of traffic lights operating under smart control systems [9] Number of active disaster-evacuation routes per 100,000 residents [10] Average commute time (minutes) to workplace [11] Percentage of major roads equipped with real-time traffic information [12] Percentage of urban area mapped under real-time digital road infrastructure [13] Private car ownership per capita [14] Number of motorcycles per capita [15] Length of cycling paths (km) per 100,000 population [16] Percentage of registered low-emission vehicles [17] Percentage of legally registered autonomous vehicles in operation [18] Percentage of road infrastructure compatible with autonomous vehicle systems [19] Percentage of bus fleet electrified or using clean energy [20] Number of public bikes (bike-sharing) per 100,000 population [21] Number of active users of sharing-based mobility platforms [22] Percentage of public parking spaces integrated with electronic payment [23] Percentage of public parking equipped with real-time availability information [24] Percentage of buildings integrated with smart mobility systems	[1] SDG 11 [2] SDG 10, SDG 11 [3] SDG 9, SDG 11 [4] SDG 9, SDG 11 [5] SDG 9 [6] SDG 3, SDG 11 [7] SDG 10, SDG 11 [8] SDG 9, SDG 11, SDG 13 [9] SDG 11, SDG 13 [10] SDG 11 [11] SDG 9, SDG 11 [12] SDG 9 [13] SDG 11, SDG 13 [14] SDG 3, SDG 13 [15] SDG 11, SDG 13 [16] SDG 11, SDG 13 [17] SDG 9 [18] SDG 9, SDG 11 [19] SDG 13 [20] SDG 11, SDG 13 [21] SDG 9, SDG 11, SDG 12 [22] SDG 9, SDG 11 [23] SDG 11, SDG 13 [24] SDG 9, SDG 11

Source: Authors' analysis, 2026

The mobility indicator table shows that the main aspects of concern are infrastructure integration, accessibility for the community, and environmental sustainability. This is closely linked with SDG 11 (Sustainable Cities and Communities) and SDG 13 (Climate Action). Integrated and sustainable transport systems improve urban accessibility while supporting lower greenhouse gas emissions and more environmentally sustainable urban development.

3.7.3. Seamless Economy Indicators

The Seamless Economy pillar aims to secure equitable access and participation across society. Adaptive indicators were therefore developed to measure three areas: digital inclusion, economic resilience, and innovation-driven growth. These indicators also show how current digital platforms allow separate economic systems to connect and function as one. Table 4 presents the indicators representing each aspect of the economic pillar and their alignment with the relevant SDGs. Sentiment analysis for this pillar identifies public concern centered on who can participate in the digital economy rather than on the overall economic situation which corresponds to the urban problem of unequal access to the digital economy. The study accordingly proposes the percentage of the workforce in the ICT sector (Table 5) as an initial proxy for participation in the digital economy. As with the mobility indicators, this is a preliminary measure requiring further empirical validation.

Table 4: Seamless Economy: Proposed Candidate Indicators and SDG Alignment by Thematic Domain

Seamless Cities Pillars	Theme	Proposed Candidate Indicators	SDG Alignment
Seamless Economy	Economy	[1] Urban unemployment rate	[1] SDG 8
		[2] Percentage of full-time workers	[2] SDG 8
		[3] Youth unemployment rate (15–24 years old)	[3] SDG 8
		[4] Percentage of workforce in ICT sector	[4] SDG 8, SDG 9
		[5] Percentage of workforce in education & R&D	[5] SDG 4, SDG 9
		[6] Percentage of informal workers	[6] SDG 8
		[7] Job concentration index by district	[7] SDG 8, SDG 11
		[8] Number of registered businesses per 100,000 population	[8] SDG 8
		[9] Number of new patents per 100,000 population per year	[9] SDG 9
		[10] GRDP (PDRB) per capita (USD)	[10] SDG 8
		[11] New business survival rate per 100,000 population	[11] SDG 8, SDG 9
		[12] Average household disposable income	[12] SDG 8, SDG 10
		[13] Commercial & Industrial property value (% of total property value)	[13] SDG 8, SDG 9
		[14] Insured value as percentage of total exposed value	[14] SDG 11, SDG 13
		[15] Percentage of properties covered by high-risk insurance	[15] SDG 11, SDG 13
		[16] Historical disaster losses as percentage of city product	[16] SDG 11, SDG 13
		[17] Average annual disaster loss as % of city product	[17] SDG 11, SDG 13
		[18] Annual overnight visitor rate per 100,000 population	[18] SDG 8
		[19] Average household income (USD)	[19] SDG 8, SDG 10
		[20] Annual inflation rate (5-year average)	[20] SDG 8
		[21] Percentage of city service contracts under open data policy	[21] SDG 9, SDG 16

Source: Authors' analysis, 2026

The mapping above shows that the Seamless Economy pillar is closely linked and aligned with SDG 8 (Decent Work and Economic Growth), SDG 9 (Industry, Innovation, and Infrastructure), and SDG 10 (Reduce Inequalities). A more connected economy removes roadblocks and makes city economies tougher. This resilience is essential to achieve these goals.

3.7.4. Seamless Environment Indicators

The Seamless Environment pillar comprises indicators that measure resource management, energy systems, and ecological sustainability, connecting global environmental pressures to city-level policy action. Table 5 presents the main environmental themes, the indicators representing each theme, and their alignment with the relevant SDGs.

Table 5: Seamless Environment: Proposed Candidate Indicators and SDG Alignment by Thematic Domain

Seamless Cities Pillars	Theme	Proposed Candidate Indicators	SDG Alignment
Seamless Environment	Energy	[1] Percentage of population with official electricity access	[1] SDG 7
		[2] Percentage of electricity from decentralised systems	[2] SDG 7
		[3] Percentage of critical facilities with off-grid supply	[3] SDG 7, SDG 11
		[4] Electricity supply capacity as percentage of peak demand	[4] SDG 7
		[5] Final energy consumption per capita	[5] SDG 7, SDG 12
		[6] Final energy consumption of public buildings (GJ/m²)	[6] SDG 7, SDG 13
		[7] Heating degree days & cooling degree days	[7] SDG 13
		[8] Percentage of public buildings requiring renovation	[8] SDG 9, SDG 11
		[9] Percentage of buildings with smart energy meters	[9] SDG 7, SDG 9
		[10] Percentage of electricity & heat generated from waste	[10] SDG 7, SDG 12
		[11] Percentage of Energy from wastewater and solid/liquid waste per capita	[11] SDG 7, SDG 12, SDG 13
		[12] Percentage Electricity consumption for street lighting	[12] SDG 7, SDG 11
		[13] Average electricity outage hours per household	[13] SDG 7
		[14] Percentage of streetlights under smart management	[14] SDG 7, SDG 11
			[15] SDG 11
			[16] SDG 7, SDG 11, SDG 13

Seamless Cities Pillars	Theme	Proposed Candidate Indicators	SDG Alignment
		[15] Percentage of street lighting that has been retrofitted/newly installed [16] Total of EV charging stations [17] Total Gas distribution service connections per 100,000 population	[17] SDG 7
	Environment & Climate Change	[1] Daily/Monthly PM2.5, PM10, NO_2, SO_2, O_3 levels [2] Percentage of ambient noise pollution [3] Number of real-time air monitoring stations per km^2 [4] Percentage of public buildings with indoor air monitoring [5] GHG emissions per capita [6] Percentage of green buildings (new/retrofit ≤5 yrs) [7] Percentage of urban surface with high-albedo material [8] Urban heat island intensity index [9] Share of land under natural protection [10] Percentage of change in native species population [11] Percentage of ecologically-assessed natural area [12] Ecosystem restoration area as percentage of city [13] Percentage of Urban tree canopy cover [14] Frequency of extreme precipitation/heat/cold/flood events	[1] SDG 3, SDG 11, SDG 13 [2] SDG 3, SDG 11 [3] SDG 9, SDG 11 [4] SDG 3, SDG 11 [5] SDG 13 [6] SDG 9, SDG 11, SDG 13 [7] SDG 11, SDG 13 [8] SDG 11, SDG 13 [9] SDG 11, SDG 15 [10] SDG 15 [11] SDG 15 [12] SDG 13, SDG 15 [13] SDG 11, SDG 15 [14] SDG 11, SDG 13
	Solid Waste	[1] Percentage of population with regular waste collection [2] Percentage of waste disposal distribution (landfill/open/other) [3] Total of Municipal solid waste generation per capita [4] Percentage of hazardous waste recycled per capita [5] Temporary waste management sites per km^2 [6] Percentage of waste containers with telemetering [7] Percentage of public bins using smart-sensor [8] Percentage of population with monitored door-to-door collection [9] Percentage of waste recycled, biologically processed, or used as biogas [10] Percentage of waste used in power plants [11] Percentage of total waste-to-energy [12] Percentage of plastic and e-waste recycled	[1] SDG 3, SDG 11, SDG 12 [2] SDG 11, SDG 12 [3] SDG 11, SDG 12 [4] SDG 12 [5] SDG 11, SDG 12 [6] SDG 9, SDG 11, SDG 12 [7] SDG 9, SDG 11, SDG 12 [8] SDG 11, SDG 12 [9] SDG 12 [10] SDG 7, SDG 12 [11] SDG 7, SDG 12 [12] SDG 12
	Urban Planning	[1] Green open-space area (ha) per 100,000 residents [2] Number of trees per 100,000 residents [3] Percentage of urban land using porous drainage materials [4] Percentage of informal-settlement land [5] Jobs–housing ratio [6] Coverage of basic service facilities [7] Population density (per km^2) [8] Built-environment density [9] Percentage of population living in medium–high density [10] Number of citizens involved in planning per 100,000 people/year 11] Percentage of building permits submitted electronically [12] Percentage of urban area covered by hazard mapping [13] Percentage of high-risk zones with mitigation applied [14] Percentage of agencies/utilities conducting risk assessment [15] Percentage of critical infrastructure exposed to flooding [16] Annual expenditure for water-retention as % of urban prevention budget	[1] SDG 11, SDG 15 [2] SDG 15 [3] SDG 11 [4] SDG 11 [5] SDG 8, SDG 11 [6] SDG 11 [7] SDG 11 [8] SDG 11 [9] SDG 11 [10] SDG 11, SDG 16 [11] SDG 9, SDG 16 [12] SDG 11, SDG 13 [13] SDG 13 [14] SDG 11, SDG 13 [15] SDG 11, SDG 13 [16] SDG 13
	Waste Water	[1] Percentage of urban population with wastewater collection services [2] Percentage of population with improved sanitation access [3] Percentage of wastewater processed centrally [4] Wastewater treatment compliance level [5] Percentage of treated wastewater reused [6] Percentage of biosolids reused (dry-mass basis) [7] Percentage of total wastewater used for energy generation [8] Energy from wastewater as percentage of city energy consumption [9] Percentage of wastewater pipelines monitored via real-time data-tracking	[1] SDG 6 [2] SDG 6 [3] SDG 6 [4] SDG 6 [5] SDG 6, SDG 12 [6] SDG 12 [7] SDG 7, SDG 12 [8] SDG 7 [9] SDG 9, SDG 11
	Clean Water	[1] Percentage of population with drinking-water supply services [2] Percentage of population with sustainable access to improved water sources [3] Number of water sources supplying ≥5% of total capacity [4] Percentage of population maintainable by alternative supply for 72 hours [5] Total water consumption per capita (L/day) [6] Average annual water service interruption time per household (hours/year) [7] Water-loss percentage (Non-Revenue Water) [8] Percentage of urban water-distribution monitored by smart systems [9] Percentage of buildings with smart water meters [10] Drinking-water quality compliance rate	[1] SDG 6 [2] SDG 6 [3] SDG 6, SDG 11 [4] SDG 11, SDG 13 [5] SDG 6 [6] SDG 6 [7] SDG 6 [8] SDG 6, SDG 9 [9] SDG 6, SDG 11 [10] SDG 3, SDG 6 [11] SDG 6 [12] SDG 6, SDG 11 [13] SDG 6

Seamless Cities Pillars	Theme	Proposed Candidate Indicators	SDG Alignment
		[11] Percentage of drinking water monitored by real-time quality stations [12] Number of real-time environmental water-quality monitoring stations per 100,000 population [13] Total domestic water consumption per capita (L/day)	

Source: Authors' analysis, 2026

Table 5 shows close links between the Seamless Environment pillar and several environmental SDGs, particularly SDG 6 (Clean Water and Sanitation), SDG 7 (Affordable and Clean Energy), SDG 13 (Climate Action), and SDG 15 (Life on Land). This range reflects how interconnected urban environmental systems are: each domain affects the others, reinforcing the case for integrated resource management rather than sector-by-sector treatment. On this evidence, environmental integration is not a peripheral concern for sustainable and resilient urban development but a core component of it.

3.7. Relational Mapping of Seamless City Indicators and SDGs Using Sankey Visualization

This SDG-oriented mapping approach is consistent with emerging evidence that smart city strategies act as practical vehicles for localizing the SDGs at the municipal level (Clement et al., 2023). Although the tables above provide detailed information, they present it in a largely linear format and cannot show how indicators grouped within sectoral themes feed into several SDGs simultaneously, or how the four Seamless City pillars interact across sectors. Because the Seamless City framework is designed to operate across interconnected socio-technical systems, a relational rather than tabular representation captures that design more accurately. Figure 6 presents a Sankey diagram of the relationships among the four pillars, the twelve sectoral development themes, and the SDGs within a single visualization, showing how the indicators interconnect and how each contributes to the Sustainable Development Goals.

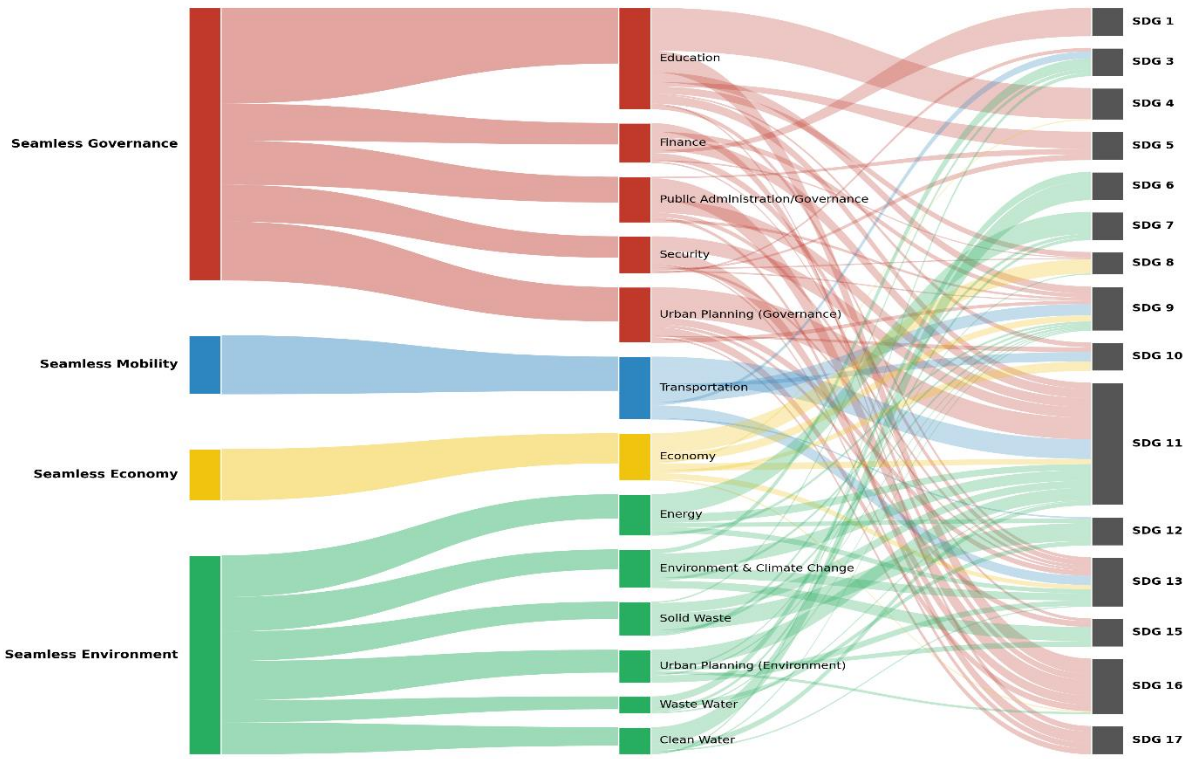

Figure 6. Sankey Visualisation of Seamless City–SDG Interlinkages
Source: Author's Analysis, 2026

Figure 6 places the four Seamless City pillars — governance, environment, mobility, and economy — on the left, each in a distinct colour. None connects directly to an SDG on the right; twelve sectoral themes mediate between them: education, urban planning, transportation, economy, public administration and governance, energy, finance, environment and climate change, security, solid waste, clean water, and wastewater. These twelve themes are the level at which the framework becomes operationally actionable for a planning agency.

Each pillar encompasses several themes. Governance relates to education, urban planning, and government regulation and administration, indicating that integrated policy simultaneously affects land use, public services, and workforce development. The environmental pillar relates to weather, energy, clean water, wastewater management, and waste disposal, none of which operates in isolation. The scope of mobility is narrowe with combining transportation and urban planning since the mobility system of a city is shaped by its physical layout. The economic pillar supports an inclusive and resilient urban economy by extending economic opportunity across social groups and strengthening financial systems against urban shocks.

No theme in the diagram is associated with only one SDG; each contributes to several. Education, for example, is closely linked to SDG 4 while also contributing to SDG 8 and SDG 10. Urban planning and mobility support SDG 11, SDG 9, and SDG 13. The environmental cluster — energy, clean water, waste management, and climate change — is linked to SDGs 6, 7, 12, 13, and 15. Governance and security relate closely to SDG 16 and SDG 17, which underlines the importance of strong institutional and inter-institutional cooperation.

Conclusion

This study develops the Seamless City as an analytical lens for examining urban-service integration in Bandung. The lens is situated within scholarship on the communicative city, soft infrastructure, smart-city governance, and citizen-oriented service delivery. It shifts attention away from the quantity of digital applications and toward a more fundamental planning question: whether urban institutions can coordinate data, responsibilities, services, and feedback across sectoral boundaries in ways residents experience as continuous and accessible.

Using an archived Twitter/X corpus of 6,795 posts as secondary empirical material, the study identifies governance, mobility, economy, and environment as domains in which public discourse indicates recurring concerns about service discontinuity. Governance is the most prominent of these, with discourse distributed as 58.9% positive, 30.4% negative, and 10.7% neutral, reflecting divided rather than uniformly critical opinion. These discourse patterns should not be interpreted as representative measures of citywide satisfaction. Their value lies in providing contextual signals that can inform the formulation of planning questions and candidate indicators. Measured against the two objectives set out at the outset, the study establishes where public perception of urban services concentrates and translates those signals into 237 candidate indicators across the four pillars: 111 for governance, 24 for mobility, 21 for economy, and 81 for environment, each mapped to ISO 37120, ISO 37122, or ISO 37123 and to the relevant SDG targets.

The proposed architecture highlights the importance of institutional coordination as a cross-cutting condition of urban-service integration. In Bandung, Bappeda may serve as a plausible convenor for an integrated planning and monitoring agenda because of its cross-sector planning role. However, this proposition requires further assessment through formal review of institutional mandates, data-governance arrangements, resource capacity, and coordination practices among municipal agencies. Diskominfo remains important as a technical and digital-governance actor, but cannot alone resolve organizational fragmentation across the city administration.

Recommendations

Developing an integrated city through the Seamless City framework requires a shift of focus away from the proliferation of digital platforms towards institutional consolidation and the strengthening of core public services. Following from the convening role discussed above, the practical task at municipal level is to harmonize the planning cycles and data holdings of the Transport Agency, the Environment Agency, and the Investment and One-Stop Integrated Service Agency (DPMPTSP) around a shared set of service-continuity measures, so that cross-sectoral coordination is not left to a single technical agency. Institutional strengthening of this kind (SDGs 16 and 17) is the precondition for the sectoral measures to which the indicator set points: more unified fare systems and traffic management to address transport fragmentation (SDGs 9, 11, and 13), and expanded capacity-building and market access for micro, small, and medium enterprises to narrow socio-economic gaps (SDGs 8 and 10). Should the framework be extended beyond a single municipality, alignment of data standards and evaluation protocols with national agencies such as Bappenas and Komdigi would become a prerequisite. That extension lies outside the scope of the present evidence.

The long-term environmental carrying capacity of the city depends on integrated, evidence-based resource management, from air quality monitoring and responsive waste management to the expansion of blue-green infrastructure (SDGs 6, 7, 12, and 15) where such measures require energy-transition financing, coordination with the relevant national ministries would be necessary. This regulatory and operational framework will succeed only if it places citizens at the center of the planning process. Assessment of public service performance can no longer rely solely on document-based administrative metrics. It must capture the everyday experience of residents adaptively.

Limitations

This article has several limitations. The social-media corpus was collected through predefined keywords and involved no post hoc bot detection, duplicate removal, language filtering, manual relevance screening, or representative sampling procedure. The inherited lexicon-based sentiment classifications were not independently validated against manually coded data. The indicators proposed here have not been tested against official municipal data, stakeholder validation, or field observation, and should therefore be understood as candidate indicators rather than as a complete measurement system. The framework does not address all dimensions of sustainable development: SDG 2 (Zero Hunger) and SDG 14 (Life Below Water) are not represented in the current indicator set. Finally, because the framework was developed using social media data from Bandung, the extent to which it transfers to other urban contexts remains uncertain.

Future research should validate the indicator architecture through expert review and field testing, compare it with official data held by the city government, and co-design it with municipal agencies and community stakeholders. Each proposed indicator needs to be assessed for data availability and for the institutional mandate required to collect it. The social media data should be updated and re-analyzed using Indonesian-language models, along with manually labeled validation samples, to make the empirical component more credible. Comparative application in other Indonesian cities would clarify which dimensions of seamlessness are city-specific and which are generalizable and also which can support implementation of the Seamless City framework at a larger scale.

Declaration of Generative AI

During the initial drafting and revision phases of this study, the author used ChatGPT (OpenAI) and Google Translate to draft and translate the English text covering the study and the preliminary findings of the independent research conducted. All text drafted with the assistance of AI has been carefully reviewed and rewritten by the author. The author takes full responsibility for the integrity and originality of the publication's content. The dataset, the sentiment analysis method employed, and the research results presented are derived from the author's previous research (Aldhiya, 2025).

Author Contributions

The first author was responsible for conceptualization, methodology, data curation, formal analysis, and investigation, and prepared the original draft. The second author provided supervision and validation and contributed to conceptualization. Both authors contributed to the review and editing of the manuscript, and both have read and approved the final version.

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Conflict of Interest

The authors declare no competing financial interests or personal relationships that could have appeared to influence the work reported in this article. The archived Twitter/X corpus used as secondary empirical material was compiled by the first author for an earlier undergraduate study, and this prior authorship is disclosed in Section 2.2. Neither author holds any affiliation with, or received any consideration from, the municipal agencies discussed in the analysis.

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