

ESG evaluation in Chinese cities: system development and empirical evidence from the Four Municipalities

Tongxin Li^{1, CDFM}, Hao Yuan^{2, CM}, Jue Dai^{3, CR}, Xing Li^{4, C}, Le Liu^{5, R}, Shenzu Shi^{6, R}

^{1,2,3,4,5,6}Shanghai Polytechnic University, School of Resources and Environmental Engineering, Shanghai, China;

²e-mail: yuanhao@sspu.edu.cn (corresponding author); ²<https://orcid.org/0009-0003-8569-2981>

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Abstract. Driven by global sustainability imperatives, urban ESG (Environmental–Social–Governance) evaluation has gained theoretical and practical urgency. This study introduces an “n+1” framework tailored to Chinese municipalities, integrating international standards and local context through 21 indicators across environmental, social and governance dimensions. Applying the Analytic Hierarchy Process–Entropy Weight Method to data from Beijing, Tianjin, Shanghai and Chongqing, we find Shanghai leads in overall ESG performance, followed by Beijing, Chongqing and Tianjin. Among the indicators, the Government Online Transparency Index stands out as a key driver within the governance pillar, highlighting the importance of transparency-oriented digital governance in advancing urban sustainability within the four municipalities. Regional ESG profiles diverge markedly, reflecting uneven development and uneven capacities for governance. We propose policy recommendations to strengthen ESG governance and inter-city coordination. These insights advance both the theory and practice of urban sustainability governance across the evaluated municipalities.

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1. Introduction

The global sustainability agenda has continued to advance steadily. As hubs of human activity, cities are increasingly recognized as critical arenas for addressing worldwide challenges such as climate change and regional inequality through the coordinated development of environmental, social and governance dimensions (Michalina et al., 2021). Cities function as complex systems defined by dynamic interactions among population, economy and resources. Their long-term prosperity and resilience rely not solely on economic growth, but equally on ecological sustainability, social equity and inclusiveness, and effective governance frameworks (Cohen, 2017). In this context, the establishment of an urban Environmental–Social–Governance (ESG) evaluation system carries important theoretical and practical implications. Such a system is essential for driving urban development models from extensive expansion toward quality-oriented intensive development (Hiremath et al., 2013). From the perspective of policy requirements, China's national strategies provide strong endogenous impetus and clear guidance for urban ESG research (Zhou, 2022). These strategies include “Ecological Civilization (a development concept emphasizing harmonious human–nature coexistence)”, “Dual Carbon Goals (carbon peak and carbon neutrality goals)”, and “Digital China (a strategy advancing smart urban governance)”, as well as complementary initiatives such as “Rural Vitalization (covering industrial, talent, cultural, ecological and organizational revitalization)” and “Common Prosperity (a development goal of promoting social equity and shared prosperity for all)”. Together, they define a paradigm of New-Type Urbanization – one characterized by environmental sustainability, social inclusiveness and governance effectiveness. These strategies are not isolated from one another but form an interconnected organic whole, demanding a comprehensive assessment tool that integrates environmental, social and governance dimensions to quantify their synergistic progress. Developing an urban ESG evaluation system aligned with these strategic synergies has become an urgent policy imperative (Zheng, 2016).

Applying corporate ESG frameworks directly to urban assessments is inadequate because urban systems are far more complex than corporate entities (Yang, 2002). Corporate ESG is typically built around a board-driven governance structure with clear organizational boundaries. For example, corporate carbon emissions only cover production processes, and employee benefits are limited to internal staff. In contrast, a city functions as a complex macro-system composed of multiple stakeholders, including governments, enterprises, residents and social organizations

(Lowe et al., 2024). It must balance diverse objectives spanning economic growth, public welfare, ecological conservation and regional collaboration (Yang et al., 2023). A comparative analysis across ESG dimensions reveals fundamental disparities. In the environmental domain, cities hold responsibilities that extend beyond regulating industrial emissions, which parallels corporate duties. Urban management also includes assessing the spatial equity of green space distribution and coordinating cross-regional pollution control, as demonstrated by the joint haze-prevention mechanism in the Beijing–Tianjin–Hebei region (Li & Li, 2017). Urban social governance must go beyond aggregate metrics to address challenges like public service accessibility and equitable resource allocation in aging communities (Hu et al., 2025). Urban governance further requires the integration of digital platforms to enhance operational responsiveness and public participation – demands that exceed the conventional scope of corporate internal management systems (Du & Tian, 2016). Moreover, urban development exhibits strong path dependence, illustrated by Tianjin's industrial legacy and Chongqing's urban–rural dichotomy. Such context-specific trajectories necessitate that urban ESG evaluations incorporate historical pathways, further complicating system design.

Grounded in integrated theoretical discourse and policy evolution, this study conducts an empirical analysis focusing on China's four municipalities directly under the central government: Beijing, Tianjin, Shanghai and Chongqing (collectively referred to simply as “the four municipalities”). These cities are selected not for economic scale alone, but for their representativeness. They serve as pivotal testbeds for national strategies, with their ESG performance offering insights into sustainable development pathways nationwide (Shang et al., 2009). They embody differentiated national strategic priorities across regions and development models, and their ESG outcomes provide a concentrated manifestation of how macro level policies are implemented in China's most resource intensive urban contexts (Jing & Wang, 2020). Methodologically, we employ the Analytic Hierarchy Process–Entropy Weight Method (AHP–EWM) to quantitatively assess ESG development levels across the four municipalities, identify core drivers and unpack regional disparities.

The remainder of the paper is structured as follows: Section 2 reviews the evolution of urban ESG concepts, examines existing research on indicator systems and evaluation methodologies, and identifies critical knowledge gaps. Section 3 elaborates the design logic of the urban ESG evaluation system, including indicator selection criteria, sample rationale and data processing procedures. Section 4 details the

AHP-EWM and reports the empirical results of the comprehensive ESG evaluation. Section 5 explores the root causes of ESG performance variations among the four municipalities and analyzes how digital governance mechanisms influence urban development outcomes. Section 6 concludes by summarizing the findings, proposing policy recommendations, and acknowledging the study's limitations.

2. Theoretical background

The conceptual origins of ESG can be traced to the emergence of corporate social responsibility and ethical investment in the late 20th century (Huang, 2021). However, ESG did not crystallize as a systematic investment framework until the early 21st century, largely propelled by international institutions such as the United Nations. In 2004, the UN Global Compact released its report *Who Cares Wins*, which formally introduced the term “ESG” and advocated integrating environmental, social and governance factors into asset valuation and investment decisions (Zheng & Wang, 2024). This milestone marked ESG's transition from an ethical consideration to a mainstream element of financial and corporate practice (Xiao, 2024). While urban ESG assessment is a relatively new field, its theoretical underpinnings are deeply rooted in decades of urban scholarship. Sustainability theory forms the normative foundation (Liu & Cao, 2024), emphasizing the fulfillment of contemporary needs without compromising the well-being of future generations. It requires the coordinated advancement of the three pillars: environmental, economic and social. Urban ESG operationalizes this ideal by balancing economic growth, social equity and ecological integrity, aligning closely with the Sustainable Development Goals – particularly Goal 11, “Sustainable Cities and Communities” (Xu et al., 2019). Building upon this foundation, urban resilience theory further expands the scope of ESG (Elmqvist et al., 2019). The theory expands ESG's scope by exploring how cities, through robust governance and adaptive social services, can absorb, recover from and adapt to external shocks while preserving core functions (Ribeiro & Pena Jardim Gonçalves, 2019). In operational terms, collaborative governance theory underscores the necessity of multi-stakeholder involvement in urban ESG. Unlike corporate ESG's board-centric model, urban ESG demands multi-stakeholder coordination. For example, enhancing air quality requires government regulation, corporate emission management and public supervision; equitable healthcare provision relies on aligning public planning with market mechanisms

(Li & Yi, 2020). This theory underscores the need for urban ESG indicators to reflect interdependencies between governments, enterprises and civil society. More recently, digital governance theory has emerged as a pivotal enabler of urban ESG. Driven by national initiatives such as “Digital China” development, digital tools including open government data and online service platforms are emerging as core hubs. These tools link environmental monitoring, social services and governance effectiveness (Wu & Ma, 2023), making Digital Governance Capacity a critical dimension of modern urban ESG. Together, these theories shape the urban ESG evaluation system: a practical tool that translates abstract concepts into measurable, comparable governance metrics (Beck, 2022).

Against this backdrop, a growing number of global initiatives have sought to apply ESG principles to urban assessment. Internationally, frameworks like the Global Reporting Initiative standards and Sustainable Development Goals offer comprehensive metrics for urban sustainability reporting, enabling global benchmarking (Sharifi et al., 2024). Complementary tools like the Green City Index and the Global City Competitiveness Index also offer valuable references from ecological and economic perspectives, respectively (Sgambati & Gargiulo, 2022). Nevertheless, these Western-developed systems often struggle to adapt to Chinese cities, as they are rooted in distinct political systems, market environments and sociocultural contexts (Ameen & Mourshed, 2019). International indicators prioritize global issues like climate change mitigation, while Chinese cities face overlapping tasks that require more granular, context-specific metrics (Dong et al., 2024). Directly applying international indicator systems may misinterpret or underestimate Chinese cities' ESG performance. In China, urban ESG research has grown rapidly. Pioneering domestic studies, such as the “Research on the ESG Rating System of Local Governments in China”, reveal substantial regional disparities and identify green transition and digital governance capacity as key drivers of ESG performance in eastern coastal cities (Tsinghua University, 2023). Similarly, Zhang et al. (2023) further developed a five-dimensional framework (urban governance, economic development, ecology, livelihoods, culture), laying a theoretical groundwork for subsequent studies. While these advances provide a strong foundation, there remains an opportunity to further align evaluation frameworks with overarching national strategies. Although national guidelines outline clear ESG priorities, the integration of these strategic goals into objective, actionable core indicators can be further deepened to enhance the direct policy relevance of evaluation outcomes for local governments (Halla et al., 2022). Furthermore,

empirical coverage remains geographically limited. Most studies focus on developed eastern cities, like those in the Yangtze and Pearl River Deltas, with little attention to northern industrial bases like Tianjin or south-western ecological centers such as Chongqing. This narrow scope fails to capture China's "uneven regional development" context and cannot support cross-regional collaborative governance (Yin et al., 2023). To address these gaps, this study develops a context-sensitive urban ESG evaluation system – one that integrates international norms with Chinese policy priorities. This work establishes both a theoretical basis for indicator design and empirical evidence for policy-making.

3. Urban ESG evaluation system

3.1. Indicator design

This study develops an urban ESG evaluation framework that achieves robust integration of international standards and Chinese contextual priorities, addressing the limitations of conventional systems by proposing an innovative "n+1" structure (Table 1). The "n" dimension comprises baseline metrics aligned with global norms, ensuring international comparability and cross-border knowledge exchange. Rather than referring to specific additional indicators, the "+1" dimension represents the underlying filtering logic of indicator selection. Every indicator in this framework underwent a dual-filtering process: international universality ("n") and Chinese strategic adaptability ("n+1"). The indicator selection strictly adhered to three principles: (i) close alignment with China's core national strategies (e.g., Dual Carbon, Digital China, Common Prosperity, and Proactive Response to Population Aging); (ii) inclusion of metrics that may hold lower weights or be missing in mainstream international frameworks but are critical for Chinese urban governance; and (iii) availability of public, unified city-level statistical calibers.

Crucially, the selection of these 21 indicators is not arbitrary but strictly guided by the aforementioned theoretical paradigms. First, sustainability theory dictates the baseline environmental criteria, establishing the fundamental ecological boundaries for urban development. Second, urban resilience theory guides the selection of social indicators, emphasizing a city's adaptive capacity to provide equitable public services in the face of demographic transitions like aging. Third, collaborative governance theory informs the fiscal and administrative

metrics, capturing the multi-stakeholder coordination required for balanced growth.

Within the environmental dimension (E), the indicator system prioritizes measurable outcomes that directly reflect the synergy between ecological quality and public health. "Proportion of Days with Good Air Quality (E5)" and "Annual Average PM2.5 Concentration (E7)" serve dual roles. They are standard global environmental quality metrics, yet in the Chinese context they also function as indirect proxies for progress toward carbon peaking and carbon neutrality, given the strong empirical correlation between the combustion of fossil fuels – particularly coal – and both PM2.5 concentrations and sulfur dioxide emissions. Notably, direct municipal level carbon emission data derived using accounting methodologies that are consistent across cities remain unavailable; we therefore treat E5 and E7 as pragmatic proxies for energy structure transformation. Furthermore, "Industrial Sulfur Dioxide Emissions per Square Kilometer (E6)" serves as a vital proxy for assessing the environmental friction of industrial path dependence, capturing the urgent need for structural decarbonization in traditional manufacturing hubs. Within the social dimension, the framework emphasizes equitable resource allocation and social inclusiveness, moving beyond mere economic aggregation to address the tangible provision of public welfare. "Number of Licensed (Assistant) Physicians per 10,000 People (S1)" and "Per Capita Gross Regional Product (S4)" are foundational, capturing core dimensions of public welfare and economic vitality. However, particular scrutiny is warranted for "Number of Beds in Elderly Care Institutions (S7)," which, while directly responding to the national imperative of "actively responding to population aging", solely reflects hardware supply scale without accounting for occupancy rates, staffing ratios or service quality. To mitigate this limitation, we cross-reference S7 with broader public service expenditure (G3) and demographic pressure proxies. The governance dimension serves as the systemic driver of the framework, strongly characterized by digital transformation and institutional capacity. The "Government Online Transparency Index (G1)" serves as the digital backbone, bridging data openness and public responsiveness. "Judicial transparency index (G2)" and "Ratio of General Public Service Expenditure to GDP (G3)" complement G1 by addressing the rule of law and public investment intensity, together forming a "transparency-justice-service" triangle. Regarding "Number of Industrial Enterprises Above Designated Size / Population (G5)", we place it in the governance pillar because it reflects the cumulative outcome of local

Table 1. Urban ESG evaluation system

Goal Layer	Criterion Layer	Alternative Layer	Indicator Description	Identifier	Direction
Enhancing Urban ESG Development Standards	E	Recreational Green Space Coverage	Per Capita Park Green Space Area (m ²)	E1	+
		Residential Green Space Coverage	Greening Rate in Built-Up Areas (%)	E2	+
		Sewage Pollution Treatment	Sewage Treatment Rate (%)	E3	+
		Public Transportation Investment	Public Transport Share of Motorized Travel in Central Urban Areas (%)	E4	+
		Air Quality Monitoring	Proportion of Days with Good Air Quality (%)	E5	+
		Industrial Exhaust Pollution	Industrial Sulfur Dioxide Emissions per Square Kilometer (t)	E6	−
		Level of Haze Pollution	Annual Average PM2.5 Concentration (μg/m ³)	E7	−
	S	Allocation of Medical Resources	Number of Licensed (Assistant) Physicians per 10,000 People (persons)	S1	+
		Level of Communication Infrastructure	Mobile Phone Subscriptions per Capita (households)	S2	+
		Residential Gas Popularization	Gas Popularization Rate (%)	S3	+
		Level of Household Affluence	Per Capita Gross Regional Product (10,000 yuan)	S4	+
		Household Consumption Capacity	Per Capita Total Retail Sales of Consumer Goods (10,000 yuan)	S5	+
		Road Infrastructure Quality	Per Capita Road Area (m ²)	S6	+
		Elderly Care Service Resources	Number of Beds in Elderly Care (beds)	S7	+
	G	Level of Government Transparency	Government Online Transparency Index (points)	G1	+
		Level of Judicial Transparency	Judicial Transparency Index (points)	G2	+
		Public Service Expenditure	Ratio of General Public Service Expenditure to GDP (%)	G3	+
		Urban Unemployment Rate	Number of Registered Urban Unemployed Persons / Employed Persons at Year-End (%)	G4	−
		Scale of Industrial Output (Above-Designated Size)	Number of Industrial Enterprises Above Designated Size / Population (units / 10,000 people)	G5	+
		Fiscal Balance	Ratio of General Public Budget Expenditure to Revenue (%)	G6	+
		Fiscal Autonomy	Fiscal Self-Sufficiency Ratio (%)	G7	+

Source: own study

government efforts to attract firms and create jobs through industrial policies. In agglomeration economics, firm density is understood as an institutional output shaped by the business environment and administrative efficiency. Two fiscal indicators, “Ratio of General Public Budget Expenditure to Revenue (G6)” and “Fiscal Self-Sufficiency Ratio (G7)”, both measure fiscal health but from complementary angles: G6 captures the balance between spending commitments and revenue generation, while G7 assesses the city’s autonomous revenue-raising capacity relative to its expenditure needs. Although these two indicators are moderately correlated, they are not collinear in practice – a city may have a balanced budget (low G6) yet rely heavily on central transfers (low G7). Their coexistence captures distinct policy levers: expenditure discipline versus fiscal autonomy.

3.2. Case study

The empirical foundation of this research lies in selecting case studies that align with the study’s goals, prioritizing typological representativeness over economic scale or rankings. We chose China’s four municipalities (Beijing, Tianjin, Shanghai, Chongqing) as empirical subjects. These municipalities are selected as critical “frontier testbeds” to validate the proposed framework’s theoretical logic, providing a robust basis for refining a context-sensitive urban ESG evaluation system.

These municipalities transcend ordinary geographic or economic entities, embodying core national strategies in key regions; their ESG performance serves as a critical barometer of the nation’s sustainable development pathways (Table 2). Each exhibits distinct characteristics relevant to urban ESG assessment.

First, as the national political and technological innovation hub, Beijing’s ESG performance places strong emphasis on policy implementation efficacy and technology-driven governance. As a pilot zone

for major national strategies, metrics such as administrative transparency and the efficiency of translating research into application directly reflect the local execution of central policies. This aspect, often overlooked by international frameworks, requires local indicators. As a megacity, Beijing’s ESG framework must account for public service pressures from population concentration and cross-jurisdictional ecological coordination imperatives, introducing a regional synergy dimension that is absent in the single-organization focus of corporate ESG.

Second, as a global financial hub and China’s primary gateway to international markets, Shanghai requires an ESG assessment that integrates global standards with localized innovation. As a major recipient of foreign investment, the city must align with internationally recognized disclosure frameworks such as the Task Force on Climate-Related Financial Disclosures. Simultaneously, its digital governance initiatives, such as the “One-Net Administration” platform, and cross-border carbon trading pilots showcase unique local urban governance methods. However, existing evaluation systems struggle to quantify the dual requirements: the degree of international alignment and the tangible contributions of local innovation.

Meanwhile, as a traditional industrial base in Northern China and a strategic node in the Beijing–Tianjin–Hebei coordinated development strategy, Tianjin’s ongoing transformation positions its ESG priorities around transition risks and synergistic benefits. The city faces structural challenges stemming from its high concentration of energy-intensive industries and historical under-investment in public services. Thus, an effective ESG assessment must critically evaluate how the city balances industrial decarbonization with economic revitalization and measure its progress in bridging gaps in public services. Moreover, within the regional framework, the evaluation should include cross-jurisdictional ecological compensation mechanisms and ESG responsibility transfer during industrial relocation.

Table 2. Urban characteristics and research representativeness

Municipality	Research representation	Sample type
Beijing	A benchmark model for translating national strategies into megacity governance	Reduction-Innovation
Tianjin	A pioneering model for green transformation and regional coordination in legacy industrial bases	Transformation-Under Pressure
Shanghai	A fusion model for aligning international standards with local innovation	Open-Benchmarking
Chongqing	A distinctive model for balancing ecological conservation in the west with urban–rural development	Ecology-Coordination

Source: own study

These complex, dynamic processes are difficult for conventional urban assessments to capture.

And fourthly, in contrast, as the sole provincial-level municipality in Western China and an ecological shield for the Yangtze River Economic Belt, Chongqing orients its ESG priorities toward ecological conservation and urban–rural equity. It bears a national mandate to protect the Yangtze River’s ecosystem while tackling significant disparities in public service provision between urban and rural areas. Key challenges, such as monetizing ecological assets and using digital governance to reduce urban–rural ESG gaps, are crucial in the western region but remain largely unaddressed by existing frameworks modeled on eastern cities.

Thus, geographically and developmentally, the four municipalities cover the northern (Beijing, Tianjin), the eastern (Shanghai), and the south-western (Chongqing) parts of China and reflect a wide range of economic development and urbanization models. This diversity captures urban ESG differences under China’s “uneven regional development” context, overcoming the limitation of existing research that overemphasizes developed eastern cities. This selection criterion enhances the analytical relevance of the framework’s findings for high-administrative-rank urban contexts. Finally, the administrative status of these municipalities affords them greater policy autonomy, rendering their ESG practices critical testing grounds for major national initiatives. Analyzing these municipalities thus extends beyond urban performance assessment to serve as a systematic evaluation of how effectively national strategies are implemented at the local level. The resulting insights offer actionable input for refining national policy design and fostering context-sensitive development pathways.

It is crucial to clarify that choosing these four municipalities does not undermine the significance of other major urban centers like Shenzhen, Guangzhou or Chengdu. Instead, this selection is methodologically driven by the need to control for administrative rank. By restricting the sample to the four direct-administered municipalities, we eliminate the confounding variable of administrative hierarchy, enabling a more rigorously controlled comparison of regional ESG coordination across different macro-regions.

3.3. Data treatment and analysis

Data for this study were sourced from the 2024 Statistical Yearbooks of Chinese municipalities, government work reports, official departmental

releases, and research institution reports. All data are for 2023 (standardized to ensure temporal consistency). Raw indicator values were collected comprehensively; missing data were addressed using linear interpolation. To ensure comparability, the raw data were standardized to eliminate dimensional influences. Positive indicators, such as “Proportion of Days with Good Air Quality (E5)”, were normalized using Equation (1). Negative indicators, such as “Industrial SO₂ Emissions per Square Kilometer (E6)”, were processed using Equation (2).

Positive indicators:

$$X_{ij} = \frac{x_{ij} - \min[x_j]}{\max[x_j] - \min[x_j]} \quad (1)$$

Negative indicators:

$$X_{ij} = \frac{\max[x_j] - x_{ij}}{\max[x_j] - \min[x_j]} \quad (2)$$

Where x_{ij} is the raw value of the j^{th} indicator for the i^{th} evaluation object, $\max[x_j]$ and $\min[x_j]$ are the maximum and minimum values in the dataset, respectively. As shown in Figure 1, the resulting normalized value X_{ij} is bounded between 0 and 1.

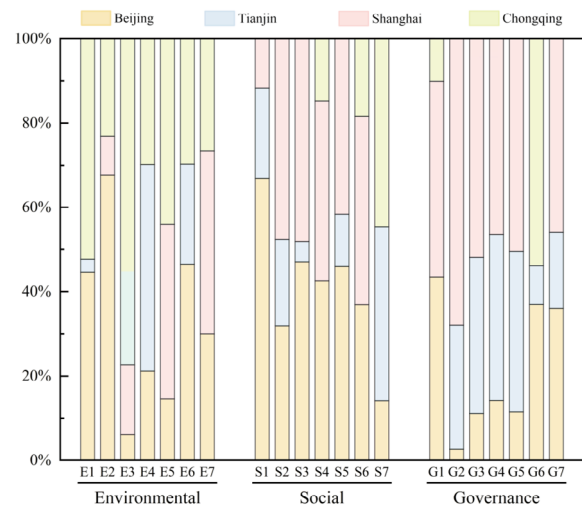


Fig. 1. Dimensionless data ratios

Source: own study

4. Urban ESG evaluation methodology

The selection of an appropriate weighting method is a pivotal methodological decision in urban ESG evaluation, as it directly affects the credibility and policy relevance of the assessment results. The extant literature on urban sustainability and ESG evaluation encompasses a broad spectrum of approaches, ranging from subjective expert-based methods (e.g., Delphi, Analytic Hierarchy Process) to objective data-driven

techniques (e.g., Entropy Weight Method, CRITIC, standard deviation [Criteria Importance Through Intercriteria Correlation]), and further to integrated multi-criterion decision-making frameworks such as TOPSIS and grey relational (Technique for Order of Preference by Similarity to Ideal Solution) analysis. Each method carries distinct assumptions and applicability conditions, and the choice of weighting scheme significantly influences evaluation outcomes. Notably, the AHP has been widely adopted in urban sustainability indicator studies for its ability to structure complex problems hierarchically and capture domain expertise, while the EWM is frequently used to exploit inherent data variation, minimizing subjective biases. However, single-method approaches face inherent limitations: purely subjective weights may overemphasize expert opinions and neglect empirical data patterns, whereas purely objective weights may overlook strategic policy priorities that are not yet reflected in historical data. This tension is particularly acute in the Chinese urban ESG context, where national strategies set explicit priorities that must be systematically integrated into the evaluation framework. Therefore, a combined weighting strategy that reconciles these two perspectives offers a more balanced and defensible pathway (Tian et al., 2020). The three-step procedure is as follows: first, derive subjective weights via AHP; second, calculate objective weights using EWM; third, synthesize the two sets of weights into a unified scheme to compute final ESG scores.

4.1. Determining subjective weights via AHP

Analytic Hierarchy Process, a subjective weighting method, was employed to convert expert judgments into quantifiable weights through structured decomposition and logical validation. We selected AHP for its strength in capturing domain expertise on indicator importance, which is critical for ESG metrics that lack fully mature quantitative benchmarks. First, we constructed a hierarchical structure with three levels – a goal layer (enhancing urban ESG development standards), a criterion layer (ESG dimensions) and an alternative layer (21 specific indicators). Next, to ensure the quality and representativeness of expert judgments, we designed a purposive expert panel comprising seven professionals with diverse yet complementary expertise. The panel consisted of: (i) three industry consultants (each with 12–20 years of experience in corporate sustainability reporting or ESG investment advisory, currently serving in leading consulting firms or financial institutions); (ii) two academic researchers (holding PhDs in urban

planning or environmental economics, with 8–15 years of research experience and multiple publications on urban sustainability assessment); and (iii) two urban strategic planners (chief planners from municipal development and reform commissions, with 10–18 years of practical experience in city-level policy formulation and project evaluation). All experts have direct involvement in urban governance or ESG-related decision-making, ensuring both theoretical depth and practical relevance. The consultation was conducted via a two-round Delphi iterative process. In the initial round, experts rated indicator importance using a 1–9 scale (1 = equal importance, 9 = extreme importance), forming pairwise comparison matrices. Subsequently, we calculated the Consistency Index (CI) and Consistency Ratio (CR) to verify logical consistency, with only matrices meeting $CR < 0.1$ deemed acceptable. In our empirical analysis, 100% of the second-round comparison matrices met the $CR < 0.1$ threshold, meaning no expert matrices were excluded as invalid. To verify that no major divergences existed among the panel, we calculated Kendall's coefficient of concordance (W) for the final expert ratings, yielding a highly consistent and statistically significant agreement level ($W = 0.85$, $p < 0.05$). Finally, we derived local weights for sub-criteria and synthesized them with criteria weights to obtain comprehensive subjective weights, as shown in Table 3.

4.2. Determining objective weights via EWM

Entropy Weight Method is an objective weighting method rooted in information theory, quantifying indicator importance based on data variability. Indicators with higher variability convey more information (lower entropy) and thus receive higher weights, ensuring alignment with empirical data patterns. We chose EWM to complement AHP because it avoids over-reliance on expert subjectivity, especially for indicators with robust historical data.

First, the value of P_{ij} was calculated based on the standardized matrix x_{ij} .

$$P_{ij} = \frac{x_{ij}}{\sum_{i=1}^m x_{ij}} \quad (3)$$

Next, the information entropy e_j for each indicator was computed, where $k = 1/\ln m > 0$ and $e_j \geq 0$.

$$e_j = -k \sum_{i=1}^m p_{ij} \ln p_{ij} \quad (4)$$

Finally, objective entropy weights w_{2i} for each indicator was determined.

$$w_{2i} = \frac{1 - e_j}{\sum_{j=1}^n (1 - e_j)} \quad (5)$$

Table 3. Weights of each indicator under AHP

Criterion layer		Alternative layer		Criterion layer × alternative layer
Indicator	Weight	Indicator	Weight	Weight
E	0.531	E1	0.045	0.024
		E2	0.070	0.038
		E3	0.185	0.100
		E4	0.027	0.015
		E5	0.345	0.186
		E6	0.095	0.051
		E7	0.233	0.126
S	0.297	S1	0.410	0.122
		S2	0.027	0.008
		S3	0.213	0.063
		S4	0.142	0.042
		S5	0.102	0.030
		S6	0.070	0.021
		S7	0.038	0.011
G	0.163	G1	0.344	0.056
		G2	0.263	0.043
		G3	0.102	0.017
		G4	0.045	0.007
		G5	0.025	0.004
		G6	0.066	0.011
		G7	0.155	0.025

Source: own study

4.3. Construction of a unified weighting scheme

The core goal of this study is to construct a general evaluation framework and realize horizontal comparability among cities. Therefore, a uniform weighting scheme is the fundamental prerequisite for cross-city benchmark comparisons; if differentiated weights were adopted, the inter-city scores would lose their objective basis for comparison. The final indicator weights were computed by integrating the

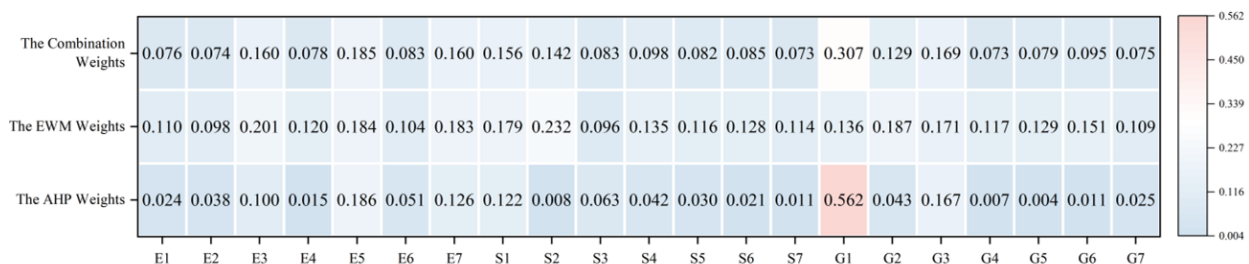
AHP and EWM weights using a weighted average method (formula below).

$$w_i = \mu w_{1i} + (1 - \mu)w_{2i} \quad (6)$$

Referring to the common value range of combined coefficients in similar urban evaluation studies (0.3–0.5) and considering that urban ESG evaluation must balance policy guidance (subjective) and data objectivity, experts determined the combination coefficient μ to be 0.4. This approach both avoids the arbitrariness of purely subjective weighting and prevents purely data-driven models from deviating from strategic guidance. The resultant composite weights were presented in Figure 2.

Utilizing the final composite weights, we computed the comprehensive ESG scores for the four municipalities from the normalized dataset. Their corresponding rankings were then determined based on these scores, and the complete results were summarized in Table 4.

To verify the robustness of the weighting scheme, we conducted a sensitivity analysis by adjusting the combination coefficient μ to 0.3, 0.5 and 0.6. The results show that, while the composite weight of the G1 fluctuated between 0.264 and 0.392, it consistently ranked highest among all 21 indicators. More importantly, based on the four sets of results ($\mu = 0.3, 0.4, 0.5$ and 0.6), we calculated the Spearman rank correlation coefficient. The results demonstrate that the correlation coefficients of the four municipalities' rankings across different μ values are all >0.9 , showing a highly significant positive correlation. This indicates that fluctuating the μ value within a reasonable range does not affect the core conclusions, and the ESG rankings of the four municipalities remained stable with no significant reversals. In terms of overall performance, Shanghai ranked first in total scores, followed by Beijing, Chongqing and Tianjin. This consistency with the order in the GYBrand China City Index preliminarily validates

**Fig. 2.** Distribution of composite weights for 21 indicators

Source: own study

Table 4. Urban ESG scores and rankings

Urban	Environmental	Social	Governance	Score	Ranking
Shanghai	0.378	0.509	0.833	1.720	1
Beijing	0.441	0.605	0.632	1.678	2
Chongqing	0.645	0.142	0.162	0.949	3
Tianjin	0.125	0.210	0.344	0.679	4

Source: own study

the scientific soundness of the proposed indicator system and weighting methodology.

The composite weights derived from the integrated AHP-EWM approach (as shown in Fig. 2) reveal the following distribution across the three ESG dimensions. The environmental dimension is anchored by “Proportion of Days with Good Air Quality (E5)” (weight = 0.185), the top ecological indicator. Beyond directly reflecting residents’ daily life quality, E5 serves as a benchmark for urban ecological health. Its high weighting underscores broad societal emphasis on atmospheric governance, aligning with China’s “Ecological Civilization” and “Dual Carbon Goals”. Within the social dimension, the indicator “Number of Licensed (Assistant) Physicians per 10,000 People (S1)” holds a significant position with a weight of 0.156. This weighting reflects the foundational role of accessible primary healthcare in meeting residents’ core needs: adequate medical resource allocation and convenient access safeguard basic health rights while enhancing overall social well-being, demonstrating the framework’s precise alignment with public welfare priorities under “Common Prosperity”. Within the governance dimension, “Ratio of General Public Service Expenditure to GDP (G3)” (weight = 0.169) and “Judicial Transparency Index (G2)” (weight = 0.129) act as dual pillars supporting governance effectiveness. G3 reflects the government’s investment intensity in public services, directly shaping urban infrastructure development and service quality; G2 embodies judicial

openness and transparency, a vital safeguard for social fairness, justice and public trust. Overall, the setting of these weights not only aligns with the practical needs of megacities in addressing complex and dynamic risks and enhancing comprehensive governance capabilities but also highlights the strategic direction toward modernizing urban governance systems and advancing digital governance capacity.

5. Discussion

This study identifies a clear hierarchical pattern of urban ESG performance among China’s four municipalities: Shanghai leads comprehensively, followed by Beijing, Chongqing and Tianjin. This ranking not only reflects systematic disparities across the three core ESG dimensions but also reveals underlying differences in development models and governance capabilities. To deepen causal analysis and derive targeted policy implications, we quantify each municipality’s ESG characteristics using indicator contribution values (Fig. 3), while linking performance variations to regional contexts and national strategic priorities.

Based on the final AHP-EWM composite weights presented in Fig. 2, the G1 within the governance dimension had a weight of 0.307, significantly higher than other indicators. Its instrumental role manifests through three key mechanisms: First, as a digital governance backbone, G1 underpins holistic urban ESG

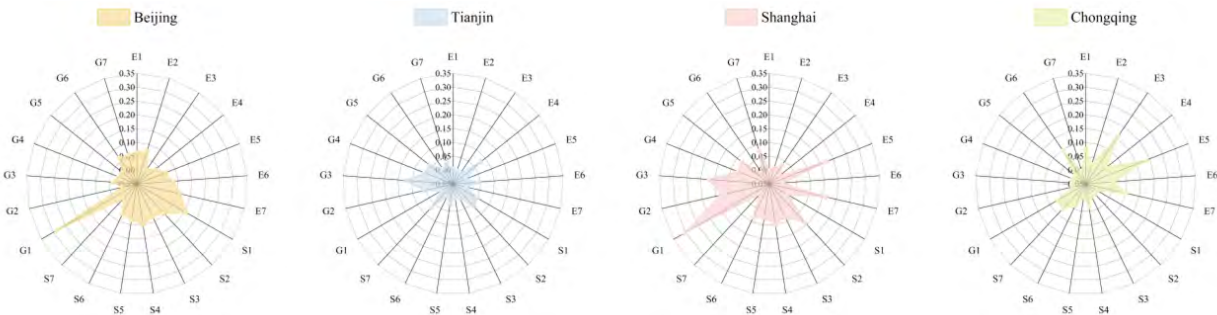


Fig. 3. Indicator contribution profiles of the Four Municipalities
Source: own study

coordination. Against the macro background of China's "Digital China" strategy and administrative reforms, government portals have emerged as the core nodes linking environmental monitoring, social service provision and administrative procedures. For example, an effective "Sewage Treatment Rate (E3)" depends on public environmental-data disclosure and civic oversight, while equitable distribution of the "Number of Licensed (Assistant) Physicians per 10,000 People (S1)" can be improved through online service platforms. The elevated weight of G1 therefore reflects a city's foundational capacity for synergistic governance in the digital era. Second, G1 acts as a reliable proxy for overall governance efficacy. In contexts where governance quality is difficult to observe directly, G1 offers a measurable substitute. A government that demonstrates strong performance in information disclosure, data openness and public responsiveness typically reflects higher internal management efficiency. It also indicates stronger adherence to the rule of law and more modern governance principles. This aligns with Sharifi et al. (2023), who emphasize that governance and policy issues warrant prominent attention in urban studies. The significant weight assigned to this indicator thus accurately captures a core feature of governance modernization in Chinese cities (Wang et al., 2021). Third, G1's prominence resonates with national top-level strategies. This empirical finding corresponds strongly with the "Digital China Development Indicator System", which lists "digital government services" as a primary metric. It also aligns with the "Action Plan for Digital China by 2025", which advocates for more intelligent and efficient digital governance. This not only validates the policy relevance of the proposed ESG framework but also highlights its ability to translate strategic priorities into measurable performance outcomes. It is important to clarify, however, that G1 does not fully capture the entirety of "digital governance capacity". Rather, G1 functions as a measurable proxy for a subset of digital governance, specifically the transparency and openness dimension of government digital services. Our emphasis on G1 is therefore pragmatic rather than conceptual.

Further examining inter-city disparities, the indicator contribution shown in Fig. 3 unpacks the strengths and weaknesses of each municipality, revealing context-specific barriers and enablers. Shanghai's overall leadership is substantially propelled by its remarkable performance in G1, which forms the digital foundation for efficient, transparent governance. It also enables high scores in other key indicators, reflecting a "digital governance-led" ESG model. Although Beijing lags slightly behind Shanghai in absolute transparency, it attains notable achievements. It does so by strictly controlling high-weight environmental indicators like "Annual Average PM2.5 Concentration (E7)",

supported by consistent public service provision. Its performance embodies a "policy implementation and ecological governance" model, aligned with its role as a national political and technological innovation hub. In comparison, G1 exhibits significantly lower contribution values in Chongqing and Tianjin, quantitatively highlighting weaker digital governance capacity as a key constraint on their overall ESG performance. Chongqing demonstrates strengths in ecological baseline indicators such as "Proportion of Days with Good Air Quality (E5)", leveraging its natural endowments as an ecological shield for the Yangtze River Economic Belt. However, its significant lag in critical governance and social indicators shows its inability to convert ecological assets into governance and social outcomes, with deficits in digital governance and public services largely offsetting its environmental gains. Tianjin's last-place ranking stems from intertwined environmental and governance pressures. It has a major shortcoming in "Proportion of Days with Good Air Quality (E5)", exacerbated by a low proportion of "Ratio of General Public Budget Expenditure to Revenue (G6)". These factors reflect structural transition challenges, where high emissions and low public investment mutually reinforce each other.

In summary, the ESG performance variations among the four municipalities mirror their distinct resource endowments, development stages, and effectiveness in implementing sustainability-oriented strategies. Shanghai and Beijing's leading outcomes demonstrate a strong synergy between digital governance capacity, environmental oversight and public service delivery – offering models for high-quality urban development (Gao, 2025). In contrast, Chongqing and Tianjin's lower performance highlights two typical challenges in Chinese urban sustainability. These are, respectively, the "blocked conversion of ecological assets into benefits" and "difficulties in transitioning from a conventional industrial pathway". This quantified assessment precisely identifies the sources of ESG disparities. It further underscores the critical importance of digital governance transformation and enhanced policy coordination between environmental and social objectives for China's high-quality urban development. Future policy formulation should leverage this granular causal understanding. Such a shift moves governance from a uniform approach toward a model of precision targeting.

6. Conclusion

This study develops a context-sensitive urban ESG evaluation system, offering theoretical innovations and practical guidance for advancing sustainable

urban development in China's four municipalities. Theoretically, it adapts the conventional ESG framework to the urban context while retaining the classic three-pillar (environmental, social, governance) structure. Notably, the empirical finding that the "Government Online Transparency Index (G1)" receives the highest weight underscores the critical role of information disclosure and public responsiveness within the governance dimension. Although G1 merely serves as a measurable proxy for the transparency aspect of digital governance, it also reflects, to a certain extent, the distinctive pathway adopted by China's local governments: advancing urban sustainable development through transparency-oriented digital tools. It also introduces a "G+" enhancement centered on digital governance capacity. This innovation stems from the empirical finding that G1 emerged as the top-weighted indicator, highlighting China's distinctive path of leveraging digital tools to accelerate urban sustainability. Unlike international models that often overlook digital governance's systemic role, our framework embeds this priority and bridges the gap between global ESG norms and Chinese policy realities. Notably, Shanghai's outstanding performance demonstrates that integrating digital governance into urban management creates strong cross-dimensional synergies. This validates the framework's ability to capture context-specific drivers of sustainability. However, we emphasize that digital governance advancement must avoid a "technology-first" trap. Its ultimate goal is to deliver tangible benefits.

Practically, the distinct ESG profiles and performance disparities among the four municipalities provide a scientific basis for tailored policy-making (Yao & Luo, 2019). Based on the empirical results and asymmetrical ESG characteristics discussed above, this study proposes actionable, phased policy designs for the four municipalities. These recommendations are divided into short-term (1–2 years), medium-term (3–5 years) and long-term (more than 5 years) implementation priorities. For Tianjin, the core objective is to overcome its industrial path dependence and public service deficits. In the short term, the city should establish an annual ESG assessment and accountability mechanism, specifically targeting its core weakness in air quality (E5). In the medium term, Tianjin should introduce independent third-party verification, utilizing differentiated pollution taxes and green subsidies to drive industrial transition. In the long term, it must optimize its fiscal balance (G6) to substantively increase foundational public service investments, particularly in healthcare and eldercare. For Chongqing, the priority is to unlock the market value of its ecological assets, addressing the imbalance of "strong ecology, weak society". Short-term efforts should focus on building a unified regional ESG data platform to accurately map ecological resources. In the medium

term, the city must accelerate the development of carbon trading mechanisms and ecological product certification systems to establish concrete marketization channels. In the long term, Chongqing should explore cross-regional ecological compensation and transfer payment systems to convert ecological dividends into social governance and public service benefits. For Beijing, the focus lies in alleviating public service bottlenecks caused by population concentration. In the short term, the government should establish refined performance evaluation systems targeting the specific supply gaps in medical resources (S1) and eldercare services (S7). In the medium to long term, Beijing must optimize its public service expenditure structure. This includes implementing urban micro-renewal projects to expand green and social infrastructure in high-density neighborhoods, thereby balancing supply and demand. For Shanghai, as the leading benchmark, short-term actions should pioneer a "Shanghai ESG Disclosure Protocol" that aligns with international standards while reflecting the Chinese context. In the medium to long term, the city should leverage platforms like South–South cooperation to export its successful digital governance and smart city solutions globally. At the regional level, we propose fostering ESG synergies. This includes establishing an industrial-ecological compensation mechanism in the Beijing–Tianjin–Hebei region (Guo et al., 2022). It also involves promoting digital governance collaboration between eastern and western cities via staff exchanges, technology transfer and platform interoperability (Zhang et al., 2024).

This study has several limitations alongside its contributions. First, although it is reasonable in both experience and theory to have a very high weight for a single governance indicator, there are potential risks. These include the possibility of incentivizing "superficial governance", where cities might prioritize improving their digital appearance over enhancing substantive offline service quality. Second, the AHP-EWM employed represents a fundamentally static assessment approach. We explicitly acknowledge that static uniform weights cannot fully adapt to the core contradictions of cities at different development stages. For instance, the "Industrial Sulfur Dioxide Emissions per Square Kilometer (E6)" indicator is far more crucial for Tianjin (in light of its industrial transition context) than for Shanghai, which is at a more advanced development stage. Future research could develop adaptive weight models to set differentiated weight systems tailored for different city types. Third, while the focus on the four municipalities is methodologically sound for framework development, it limits the generalizability of findings to less-developed urban areas, such as prefecture level cities in central and western China. Methodologically, this small sample size challenges the EWM, which is

intrinsically sensitive to data fluctuations. To address this, future research should expand the sample to include diverse city types nationwide. Fourth, as noted in the indicator design section, the absence of a direct carbon emission metric constitutes a data-driven limitation. While we employ E5 and E7 as indirect proxies for the “Dual Carbon Goals”, these indicators do not capture economy-wide carbon emissions or the full spectrum of decarbonization progress. Future research should incorporate direct carbon accounting as municipal-level data quality improves and reporting standards converge.

In summary, this paper contributes a localized, policy-aligned urban ESG evaluation tool and empirical evidence on inter-regional disparities among China's four municipalities. The findings underscore that high quality urban development in China necessitates balancing global sustainability norms with local contextual priorities – particularly through advancing digital governance transformation and strengthening cross-dimensional policy coordination. By addressing the identified limitations and refining the framework, thereby future research can further advance the theory and practice of urban ESG governance, supporting China's transition toward sustainable, inclusive and resilient cities.

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