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Readiness for smart sustainable urban development in Iraq using environmental, economic, and social indicators

Zainab Khalid [*,a], Tamara Mutaz [b]

Department of Architecture, College of Engineering, University of Baghdad, Baghdad, Iraq

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Abstract

Assessments of smart city preparedness usually compare cities against predefined indicators at a single point in time and do not account for how urban development changes over time. This study takes a longitudinal view of readiness for smart, sustainable urban development in Iraq, focusing on Baghdad, the capital and main urban core. Sixteen World Bank indicators for Iraq (1960–2024) were grouped into economic, environmental, and social dimensions following the United for Smart Sustainable Cities (U4SSC) framework. We examined trends using stationarity tests, principal component analysis, and forecasting models, comparing them with a simple no-change forecast. Fewer than half of the yearly values were recorded, so the analysis focuses on 2000–2024, when the records are most complete. Access to safe water, sanitation, electricity, and mobile and internet services improved steadily and together, largely as a shared trend over time. Environmental indicators such as air pollution, water stress, and renewable energy followed their own paths and did not improve alongside these services. The forecasting models rarely did better than assuming that the latest value would continue. Readiness is therefore uneven across dimensions, and a single combined score would hide the gap between improving services and lagging environmental conditions. The findings are relevant to smart urban design in other resource-constrained cities and point to the need for city-level data for Baghdad.

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1. Introduction

Over the last two decades, urban development discourse has increasingly revolved around two dominant paradigms: the smart city and sustainable urban development [1,2]. Although one is based on technological progress and the other on social and ecological awareness, they converge into a hybrid agenda that combines digitalization with long-term urban resilience [3]. However, the analytical tools for assessing urban progress still lag behind this convergence [4]. This challenge is more evident in Global South cities, where contradictions, inconsistent institutional capacities, and asymmetrical infrastructure provision shape development pathways [4]. In this context, Baghdad is a key example [5]. It represents both the liberties and the limitations of postwar urban development in a capital city with a concentrated demographic share and economic centrality [6]. Through phases of disruption and reconstruction, its infrastructure systems, governance structures, and environmental conditions have evolved over time in ways that frameworks assessing development at a specific point in time can only partially capture [7–9]. This is compounded by the current heavy reliance on composite indices [10]. It assumes that technological, social, and environmental dimensions change according to the same temporal logics and are thus more or less interchangeable when pooling heterogeneous indicators into a common score. This assumption is analytically problematic. Distinct causal mechanisms dominate urban subsystems: digital infrastructure is built cumulatively, social development tends toward

*Corresponding author: zainab.khalid@coeng.uobaghdad.edu.iq
[a]orcid.org/0000-0003-2622-964X; [b]orcid.org/0000-0002-2160-8272
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haphazard maturity (or immaturity), and environmental conditions are exogenously driven by locally unfamiliar factors [2,4].

Based on a dataset compiled from the World Bank's World Development Indicators [32], the researchers examine the temporal structure of several key indicators associated with the economic, environmental, and social dimensions of smart sustainable development, using Augmented Dickey-Fuller testing, time-series modeling, and Principal Component Analysis. Because these indicators describe Iraq as a whole, they reflect the national conditions within which Baghdad, the capital and main urban core, develops, as do other Arabian capital cities.

2. Literature Review

Table 1 reviews global and local literature on smart city research, which has increasingly converged with sustainable urban development, particularly in areas focused on livability, resilience, and resource use [12]. Concurrently, the global and local literature on smart city preparedness has relied primarily on static assessment models of urban indicators [13]. The local literature examines development in our cities, which helps develop the digital technologies needed to leverage urban features and facilitate the transition toward smart and sustainable cities [18-19]. These indicators also help evaluate strategies for achieving the United Nations' goals for smart cities and sustainability (U4SSC) in the new era of development [18].

Many studies use indicators that classify cities by local conditions, administrative readiness, or basic infrastructure availability. These comparisons are useful, but they treat preparedness as a static state rather than a dynamic trajectory [14]. Where development is discontinuous, conflict has recently ended, and institutions or infrastructure are weak [15], it can be especially tempting to make such an assumption. Integrated modeling approaches have tried to combine political, regional, and environmental aspects of Iraq [13,16]. Technology diffusion has a financial lag; social indicators can be sluggish, and environmental pressures follow their own drivers. Compressing many measures into a single index can give an appealing result that does not represent the urban environment well [10,11,30,35,36]. Examining development in our cities helps advance the digital technologies needed to leverage urban features and facilitate the transition toward smart and sustainable cities [18-19].

To keep these dimensions distinct, this study follows the United for Smart Sustainable Cities (U4SSC) key performance indicators, based on Recommendation ITU-T Y.4903 [33,34]. The framework groups its indicators into three dimensions: economic, environmental, and social. Digital services such as internet and mobile access are not a separate dimension; they belong to the economic dimension as the infrastructure that supports the other two. This grouping is used throughout the paper and is reflected in its title.

Table 1. Summary of the reviewed literature

Authors. year	Literature	Scope of impact	Focusing	Indicator
Younis et al. [24], 2015	Local	Smart Urban Development & Management.	The study examines digital technologies and engineering in electronic governance applications that facilitate daily transactions and digital services, thereby replacing paper-based processes and reducing time and effort.	Technology
Mao et al. [17], 2015	Global	Smart Sustainable Development.	The study proposes a smart renewal model that includes smart system applications and services, digital urban management, digital infrastructure platforms, protection measures, and an integrated city management system.	Technology & Environment
Abdul Wahab [23], 2016	Local	Smart Sustainable Development.	The study integrates smart systems and technologies, including sensors, with traditional architecture to create sustainable, locally rooted architectural models that preserve local affiliations while keeping pace with the modern era.	Technology & Environment
Erzaij and Obaid [22], 2017	Local	BIM	The study highlights the importance of information in construction projects locally and presents a three-dimensional digital model	Technology

			linked to a timetable for its application in the local building, architecture, and construction sectors.	
Akande et al. [26], 2019	Global	Smart Sustainable Development.	The study classifies 28 smart cities in European capitals according to four main components and 32 sustainability and smartness indicators.	Technology, Economic, Social & Environment
Al-shukri and Al-Majidi [21], 2020	Local	Smart Sustainable Development.	The study focuses on the creative possibilities of smart generative digital design programs and the shift from traditional to innovative design enabled by these tools and smart digital design environments.	Technology
Makieła et al. [27], 2022	Global	Smart Sustainable Development.	The study shows how innovation and new tools improve citizens' access to smart city services and affect municipal authorities, citizens, and city behavior in ways that support sustainable development.	Technology
Javidroozi et al. [29], 2023	Global	Smart Urban Development & Management.	The study uses digital data and smart technology to improve urban life systems and increase efficiency in addressing different challenges.	Technology
Khalid Z. 2023	Local	Sustainable Development.	The study adopts feasible urban roof solutions for local city buildings, including solar cells and green roofs, to reduce urban burdens in existing local cities.	Technology & Environment
Liu and Wu [20], 2023	Global	Smart Sustainable Transformation.	The study presents information technologies and digital urban transformation as solutions to environmental, economic, and urban deterioration, as well as to overpopulation challenges in contemporary cities. It also presents the challenges Chinese cities face during their transformation.	Technology, Economic & Environment
Jassim et al. [25], 2024	Local	Smart Urban Network.	The study examines how GPS systems and satellite imagery enhance navigation in urban areas and shape perceptions of the urban landscape. It also reveals the relationship between residents, their social interactions, and their experiences in Iraqi cities.	Technology & Social
Yang and Zhen [28], 2024	Global	Smart Sustainable Development.	The study presents methods and standards for developing smart cities worldwide and provides a theoretical basis for smart, sustainable development. IndiTeCultural is proposed to meet urban development requirements in smart cities worldwide, grounded in individuals, technology, and culture.	Technology & Socio- Culture
Abaas and Khalid [31], 2023	Local	Sustainable Development.	The study assesses local outdoor urban spaces, simulates scenarios to improve the outdoor environment, and develops an urban model that revitalizes outdoor urban activities.	Technology, Social & Environment
Khalid, Z. 2025	Local	Smart Sustainable Development.	The research compiles a table of core smart city indicators from global smart city initiatives to guide urban transformation.	Technology & Environment

3. Evidence Toward a New Era of Urban Development in Iraq

The evidence and measurements confirm the need for future transformation and strengthen several indicators. Our cities, especially Baghdad, are moving toward urban development and require stronger cooperation agreements and partnerships with major companies in information and communication technologies and electronics, as shown in (Fig. 1). It illustrates the following:

- Ur electronic platform for government services. This formal Iraqi government platform provides electronic services, including decision-making, loan applications, and inquiries. It also collects residents' opinions on matters and decisions related to their cities.

- Use clean, renewable energy sources, such as solar cells, and distribute them under state supervision in various regions to cover energy expenditure in kiosks and areas where electricity supplies are difficult to extend. The Central Bank of Iraq launched an initiative to help cover part of the cost of equipping solar systems and to grant loans supporting investment in clean energy.
- In addition to using solar energy units in public buildings, Baghdad Traffic has begun using solar cells to monitor traffic on public streets, light the streets, and supply radar devices and surveillance cameras with renewable energy.
- Smartphone services linked to the satellite system provide knowledge of weather and climate conditions. In addition, they provide weekly weather information, 24-hour forecasts, and air quality data.
- Temporary parking is smartly utilized with an activation card system and automated parking facilities. Some parking locations are in malls and shopping centers, although this organization is primitive because it is not linked to sensors or parking-sensing devices, but rather to the electronic parking information system.
- The icon shows electronic shopping applications for various life needs. The smartphone interface is supported by the government to localize employees' salaries in government and private banks, encourage electronic payments at gas stations and for government fees, enable shopping through electronic payment, and support smart, secure marketing.
- The adoption of electronic payment cards and smartphone applications, direct deposit of employee salaries into banks, and digital data entry from home for issuing electronic driver's licenses, passports, ID cards, ration cards, renewing ID cards, and other e-government services all show a continued commitment to e-governance.
- According to the Ur electronic portal for government services, the Iraqi Ministry of Health and the National Electronic Data Center launched the electronic medical examination initiative for government jobs, driving licenses, and other procedures that require a medical examination. The transaction is processed electronically, sent to examination centers, and paid for electronically there, including all Iraqi state employees in the health insurance program.
- The population's use of street navigation applications such as Waze and Google Maps provides information on road movement, direction, flow, congestion, maintenance operations, road safety, and paving quality. This information results from connecting Iraqi cities to the geographic information system. (Fig. 1(i)) shows icons of one of the road navigation programs.
- A smart, self-sufficient cabinet in pedestrian walkways near gathering spaces in Baghdad, set by the Ministry of Communications and Posts, supports smart communication and postal services. It uses renewable solar energy and operates via voice and motion commands, providing Wi-Fi, air conditioning, and an electrical outlet. (Source: Ministry of Communications and Posts) & (baghdad-live4).
- Electronic aircraft reservation and hotel reservation interfaces on smartphones allow booking and payment through smartphone applications without cash, with options for various alternatives and discounts.
- The Ministry of Higher Education launched an educational system that provides IQ learning, an electronic educational platform for all university students. It helps them keep up with curricula, assignments, and course materials and provides a digital repository for research by undergraduates, postgraduates, and academic faculty.
- Baghdad Municipality implemented a law to number and protect trees, marking some mature trees to be left uncut. The Ministry of Agriculture and the Ministry of Environment organized tree-planting campaigns to restore vegetation lost to urban expansion and designated a day to encourage tree-planting.
- The street coding system and regions linked with the geographical information system provide opportunities to use car navigation and taxi booking applications on smart devices. Applications like Baly, Obr, and Careem Taxi ensure customer satisfaction.

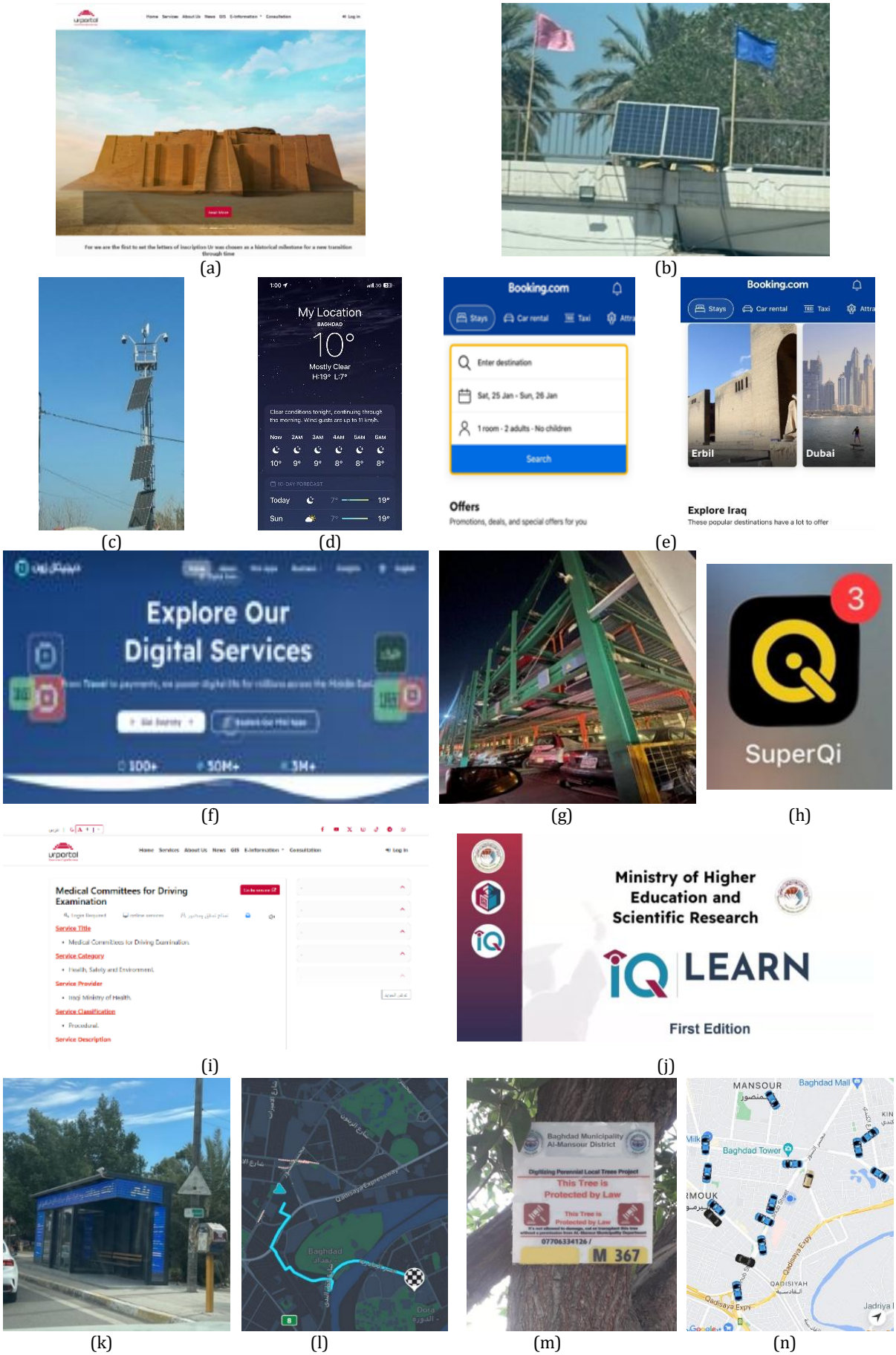


Fig. 1. Urban evidence of smart preparedness in Iraq

4. Methodology

4.1 Magnitude of the Analysis

The indicators used in the study are drawn from World Bank open data and cover economic, environmental, and social aspects at the national level. Therefore, we assessed a set of national conditions that enable the establishment of smart, sustainable urban development in Iraq. This is because many of the chosen indicators are managed by the central government, such as electricity, mobile and internet access, and national research outputs. These national figures describe the conditions within Iraq. We focus on Baghdad, Iraq's capital, as the primary site of interpretation because it is the country's main urban core, with a high-density population of nearly eight million residents. These national figures describe the conditions within which Baghdad develops; they do not measure the city itself, and district-level data would be needed to assess Baghdad directly.

4.2 Data Collection and Coverage

The selected indicators are sixteen and cover the period 1960-2024. The dataset includes 1,040 indicator-year cells; only 47.4% were observed, while the remaining were absent from the source database. Indicators of urban population and population growth are complete, while only five observed values are shown for account ownership. Other indicators recorded six for adult literacy and twelve for slum population. Coverage is highest from 2000 to 2024, at 78.5%, reflecting expanded international statistical reporting on Iraq in recent years. We therefore adopted this period as the primary analytical window, using the full period for sensitivity analysis. Each indicator was assigned to one of the three U4SSC dimensions used in the title: economic (including digital and basic services), environmental, or social (Table 2). A twenty-five-year window gives the statistical tests less power than the full period, and we account for this when interpreting the results.

Table 2. Data availability by indicator, 1960–2024

Indicator	Dimension	Values observed	Years covered	Filled between	Filled beyond
UrbanPop	Social	65	1960-2024	0	0
UrbanGrowth	Social	64	1961-2024	0	1
Mobile	Economic	53	1960-2024	12	0
WaterStress	Environmental	48	1975-2022	0	17
Renewable	Environmental	32	1990-2021	0	33
PM25	Environmental	31	1990-2020	0	34
SciArticles	Economic	27	1996-2022	0	38
SecEnrol	Social	27	1971-2007	10	28
Internet	Economic	25	1990-2024	10	30
Water	Economic	25	2000-2024	0	40
Sanitation	Economic	25	2000-2024	0	40
CleanFuels	Environmental	24	2000-2023	0	41
Electricity	Economic	24	2000-2023	0	41
Slums	Social	12	2000-2022	11	42
Literacy	Social	6	2000-2021	16	43
AccountOwn	Economic	5	2011-2024	9	51

4.3 Treatment of Missing Values

Missing values are filled by linear interpolation between adjacent observed values. Moreover, the first and last observed values are carried backward and forward to the ends of each series. The interpolation between two observed values is a reasonable approximation for indicators that

change slowly. In contrast, values outside the observed range are treated as constant over periods with no measurements, and the dataset-generated constant runs for nearly four decades. This has two consequences. First, the unit root tests are not meaningful on filled values, because straight interpolated segments look to the tests like strong mean reversion; they were therefore computed only on the observed years. Second, filling a sparse series can make it almost identical to another series. This happened with slum population and safely managed drinking water, which move identically (r = 1.000), even in the years in which both were actually recorded, because both are estimated by international agencies from simple trends [37]. Keeping both would count the same information twice. Slum population therefore remains one of the sixteen study indicators, in (Table 2 and Fig. 2), but is left out of the principal component analysis, which uses the other fifteen. Running that analysis with all sixteen gives the same results (Table 4, row E).

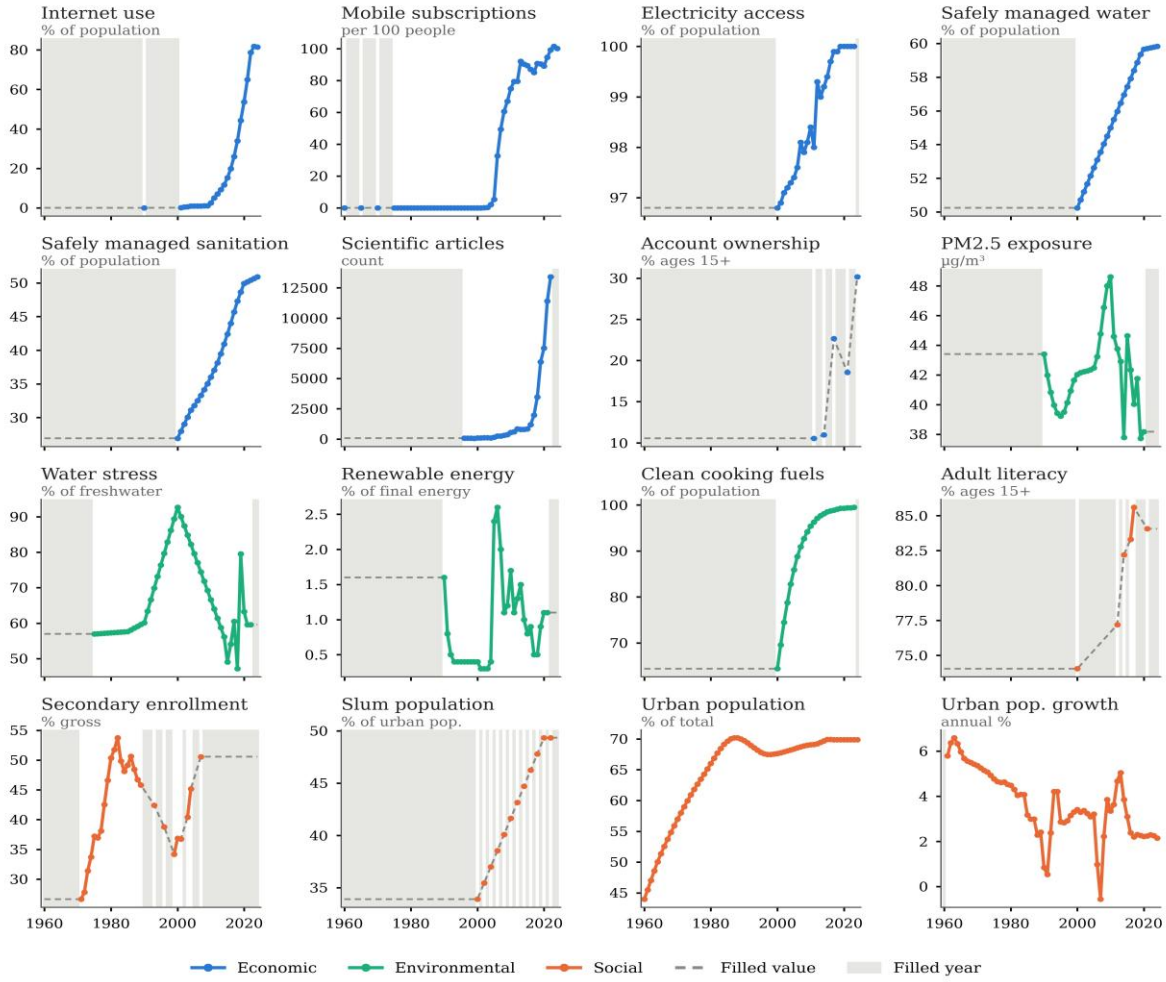


Fig. 2. Observed and estimated values of the sixteen indicators, 1960–2024

In (Fig. 2), solid-colored lines with dots show observed values, and grey shading with dashed lines shows estimated values. The long-shaded stretches show the estimated record rather than the measured one; they are most pronounced for the scientific articles' indicators: cooking fuels, safely managed water, and safely managed sanitation series.

4.4 Standardization and Dimensionality Reduction

Indicators are measured in various ways, for example, as percentages, counts, and rates. Standardization is calculated by subtracting the mean value and dividing by the standard deviation. This prevents any indicator from dominating the component proportions relative to its raw scale. Principal component analysis (PCA) is applied to the resulting standardized matrix; it determines whether measurement sets move in a small number of coordinated ways rather than independently. The summary variables capture the shared movement, loadings, and range between -1 and +1. They describe the strength, direction, and relationships among indicators and their

related components. The technique is assessed using two tests: the Kaiser-Meyer-Olkin measure and the Bartlett test. Kaiser [38] assesses whether indicators share sufficient common variance to be summarized. Bartlett [39], on the other hand, proposes the sphericity test that examines whether each indicator is related to the others. We also inspected the determinant and condition number of the correlation matrix for near singularity.

Thirteen of the sixteen indicators rise or fall steadily over the study period. When such trending series are analyzed together, the first component can simply reflect the passage of time. We therefore repeated the analysis with year-to-year changes (first differences) as well as with the original values, over the full and primary windows. We also checked whether the main patterns change when we remove the long-term trend, fill the missing values differently, or leave out the sparsest indicators [40,41].

4.5 Forecasting and Stationarity

We test for unit roots using the augmented Dickey-Fuller test [42]. We also applied the complementary KPSS test elaborated by Kwiatkowski et al. [43]. We did not test series with fewer than twenty observations and report them as untested. This test assesses whether differencing is required for valid time series modeling. We compared three approaches: ARIMA, simple exponential smoothing, and Holt's linear trend method. ARIMA is taken with the order selected by the corrected Akaike information criterion over p and q of at most three and d of at most two. The evaluation uses a holdout design in which each series is divided into a training window and a held-out final segment of about a quarter of its observations, bounded at four years and ten years. We also compared the models with a naive forecast that simply repeats the last observed value [44]. We apply the estimated models only to the training window and project them across the holdout horizon. In addition, we measured accuracy against the withheld actual values using root mean squared error, mean absolute error, and mean absolute percentage error, and tested the difference between methods with the Diebold-Mariano test [45].

4.6 Tools and Software

We performed principal component analysis, time series modeling, and diagnostic testing in JMP Pro 16. We computed the holdout evaluation, adequacy diagnostics, and predictive-accuracy tests adopted in Section 5 in Python 3.12 using statsmodels on data extracted from the World Bank open data.

5. Results and Discussion

5.1 Temporal Structure

Table 3 shows the unit root results. Six indicators are integrated of order one, and two are trend stationary in levels, while the remaining five indicators are unresolved because neither the level nor the first difference rejected the unit root null. The unresolved cases are short series of between twenty-four and forty-eight observations, for which the Dickey-Fuller test has low power. We interpret them accordingly rather than as evidence of second-order integration. Three indicators had too few observations to test. The substantive reading is that most indicators are non-stationary in levels, which is the condition under which principal component analysis applied to levels produces spurious common factors.

5.2 Covariance Structure of The Indicators

Overall, the level diagnostics are satisfactory. For instance, the sampling adequacy equals 0.766 over the full period and 0.760 over the primary window. These are above the 0.600 threshold, and the sphericity test is rejected at $p < 0.001$ in every specification. The first component captures about 60.3 percent of the variance over the full period and 66.8 percent over the primary window, and three components exceed the unit eigenvalue. Taken alone, these values would suggest a strong solution. However, the correlation matrix is very close to singular (determinant 1.45×10^{-20}, condition number 2.61×10^{5}), so the sphericity test carries little weight on its own. When year-to-year changes are analyzed instead of the original values, sampling adequacy falls from 0.760 to 0.282 for 2000–2024, the share of the first component falls from 66.8 to 26.0 percent, and six

components exceed an eigenvalue of one. The first component rises steadily from 2000 to 2024 and follows the calendar year almost exactly r = 0.996; (Fig. 3). In plain terms, it captures the general improvement that most indicators share over time rather than a separate quality of readiness. It is therefore read throughout the paper as a common time trend and is not used as a readiness score. The more informative patterns lie in the second and third components.

Table 3. Unit root and stationarity tests on observed years

Indicator	Years tested	ADF (level)	p	KPSS	ADF (change)	p	Conclusion
Urban Pop	1960-2024	-2.21	0.484	0.267	-1.953	0.3076	I(1)+ (unresolved)
Urban Growth	1961-2024	-3.149	0.095	0.182	-8.498	0.0	I(1)
Mobile	1960-2024	-1.521	0.822	0.255	-4.297	0.0004	I(1)
Water Stress	1975-2022	-2.287	0.441	0.207	-1.784	0.3884	I(1)+ (unresolved)
Renewable	1990-2021	-2.901	0.162	0.104	-4.9	0.0	I(1)
PM25	1990-2020	0.106	0.995	0.149	-0.402	0.9098	I(1)+ (unresolved)
SciArticles	1996-2022	1.874	1.0	0.171	4.426	1.0	I(1)+ (unresolved)
SecEnrol	1971-2007	-2.76	0.212	0.14	-3.125	0.0247	I(1)
Internet	1990-2024	-3.221	0.08	0.194	-4.6	0.0001	I(1)
Water	2000-2024	-6.408	0.0	0.153	-7.327	0.0	I(0) trend-stationary
Sanitation	2000-2024	-3.422	0.048	0.107	-2.516	0.1116	I(0) trend-stationary
Clean Fuels	2000-2023	-2.58	0.289	0.186	-1.548	0.5096	I(1)+ (unresolved)
Electricity	2000-2023	-1.106	0.928	0.132	-8.534	0.0	I(1)
Slums	–	–	–	–	–	–	Not tested (fewer than 20 values)
Literacy	–	–	–	–	–	–	Not tested (fewer than 20 values)
Account Own	–	–	–	–	–	–	Not tested (fewer than 20 values)

Note: The Dickey-Fuller test includes a constant and trend for levels and a constant for first differences.

Table 4. Sampling adequacy and variance explained under five specifications

Specification	Years	KMO	Bartlett chi-sq	df	p	Comp. 1	% var	Comp. 2	% var	Top 3 %	Comp. > 1
A. 1960-2024, levels	65	0.766	2417.2	105	<0.001	9.038	60.3	2.250	15.0	86.2	3
B. 2000-2024, levels	25	0.760	829.8	105	<0.001	10.017	66.8	2.303	15.4	91.0	3
C. 1960-2024, first differences	64	0.427	553.3	105	<0.001	3.504	23.4	2.237	14.9	48.9	6
D. 2000-2024, first differences	24	0.282	186.1	105	<0.001	3.903	26.0	2.273	15.2	52.6	6
E. 2000–2024, levels, 16 indicators	25	0.808	998.1	120	<0.001	11.008	68.8	2.304	14.4	91.5	3

In (Fig. 3), the dashed grey line describes a simple linear trend through time. The two series track one another almost exactly, and the only departures are the slight flattenings around 2008-2009 and 2019, which correspond to periods of political and fiscal disruption. The second component, about 15.4 percent of the variance, includes the research output, internet use, account ownership, and water stress series at 0.462, 0.441, 0.423, and 0.405, respectively, while the air pollution, secondary enrollment, and renewable energy series are at −0.679, −0.601, and −0.599. The third component, about 8.9 percent, places the renewable energy share at 0.656, while urban population growth is −0.832. Consequently, the environmental indicators do not move as a group, since the water stress series accompanies the connectivity measures, whereas the air quality and renewable energy series oppose them. (Table 5) presents the full loading pattern, and (Fig. 4) shows it.

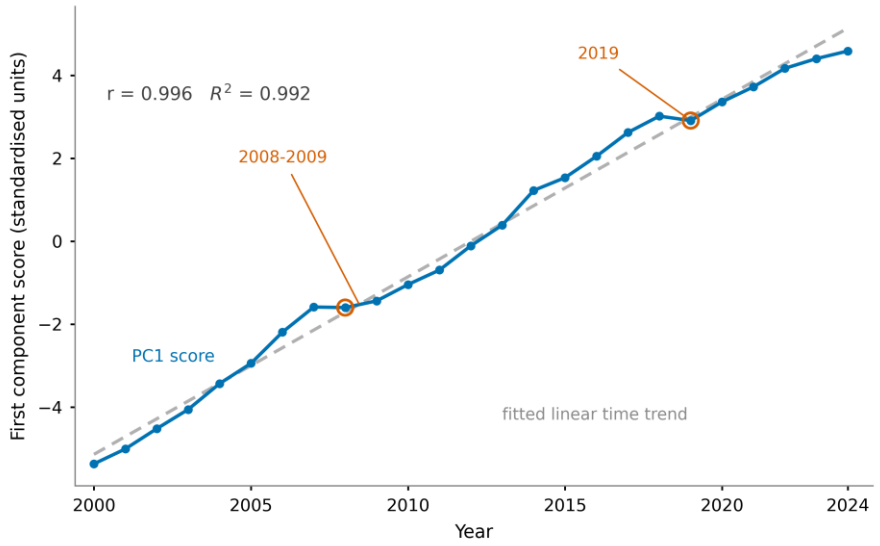


Fig. 3. First component (common time trend) against calendar year, 2000–2024

Table 5. Component loadings, 2000–2024, with the first component under first differences

Indicator	Comp. 1	Comp. 2	Comp. 3	Comp. 1 (changes)
CleanFuels	+0.879	-0.446	-0.006	+0.582
Electricity	+0.980	-0.028	-0.096	+0.418
AccountOwn	+0.840	+0.423	+0.093	+0.255
Internet	+0.848	+0.441	+0.143	+0.520
WaterStress	-0.814	+0.405	+0.242	-0.147
Literacy	+0.951	+0.137	-0.117	+0.509
Mobile	+0.920	-0.292	-0.134	+0.443
PM25	-0.554	-0.679	-0.033	-0.094
Water	+0.995	-0.020	-0.058	+0.940
Sanitation	+0.991	+0.106	-0.021	+0.938
Renewable	+0.062	-0.599	+0.656	+0.068
SecEnrol	+0.764	-0.601	+0.135	+0.089
SciArticles	+0.770	+0.462	+0.211	+0.362
UrbanPop	+0.968	-0.198	-0.106	-0.504
UrbanGrowth	-0.225	-0.126	-0.832	-0.085

The loadings are component-variable correlations. Indicators with the same sign move together, and opposite signs indicate movement in opposite directions.

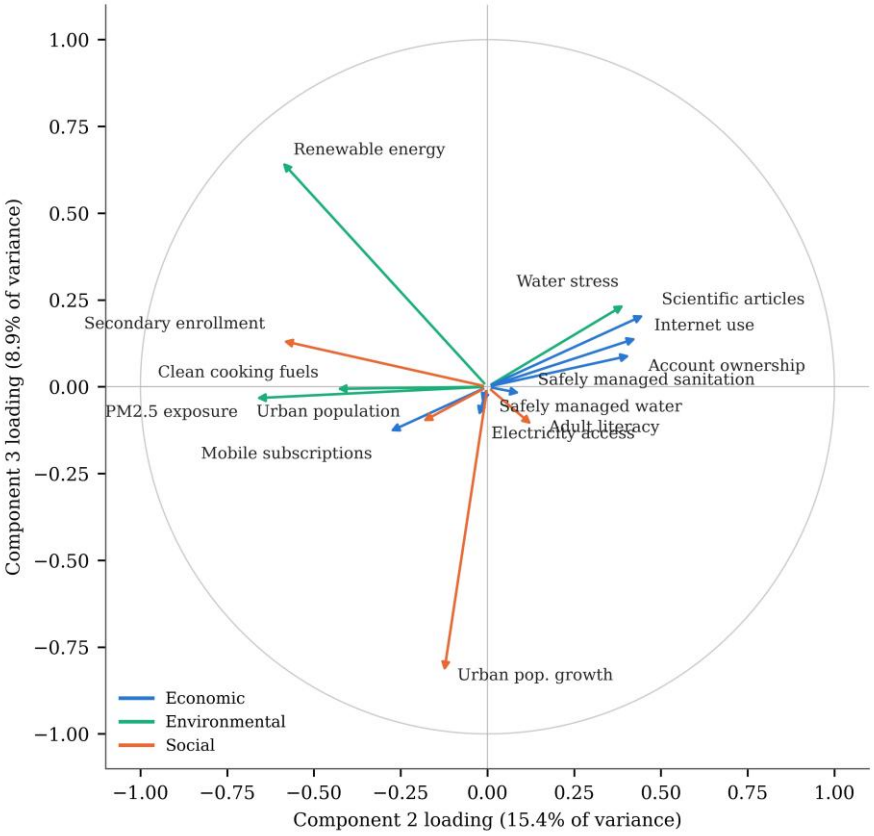


Fig. 4. Second and third component loadings by dimension

In (Fig. 4), each indicator is drawn as a line from the center of the plot. Indicators pointing in similar directions move together, while those pointing in opposing directions move against one another. The environmental measures, shown in green, do not cluster.

5.3 How Stable are These Patterns

Because many values are estimated and the series are short, we tested whether these patterns hold under different assumptions. The second and third components reappear when the long-term trend is removed from each indicator, when the gaps are filled with a different method, when the three sparsest indicators are dropped, and when the analysis is repeated on resampled years, with a similarity to the original pattern between 0.79 and 0.99 on a scale where 1 means identical. The most stable result is the contrast between internet use, research output, and water stress on one side and air pollution and clean cooking fuels on the other. The positions of account ownership and secondary enrollment, which have the most estimated values, are less certain and are not interpreted. The detailed results of these checks are available from the authors.

5.4 Forecast Accuracy

The smoothing parameter of simple exponential smoothing reached its upper bound, alpha = 1.000, for twelve of the thirteen indicators with sufficient data, and it stood at 0.815 for the thirteenth. Moreover, at alpha = 1, the smoothed forecast reduces to the last observed value, so that the model is numerically identical to the naive random walk and performs no smoothing. Any apparent superiority of exponential smoothing over ARIMA in these series is therefore the superiority of a no-change benchmark.

The formal comparison test favors ARIMA overall ($p = 0.006$), but this result rests mainly on one indicator, internet use, whose rapid growth ARIMA captured, and the no-change forecast missed; without it, the difference is no longer significant ($p = 0.106$). Indicator by indicator, ARIMA was

more accurate than the no-change forecast for only five of the thirteen indicators. The two findings therefore agree: ARIMA helps for a few fast-changing indicators, but no method improves reliably on the simple assumption that the latest value continues.

This finding is consistent with how the series were constructed. Many are administrative or modeled estimates updated at multi-year intervals and interpolated by the source agency before publication, and such series carry limited genuine year-to-year dynamics for a time series model to recover.

Table 6. Out-of-sample forecast accuracy (root mean squared error on held-out years)

Indicator	Tested on	Years	ARIMA order	ARIMA	Smoothing	Holt	No-change	Alpha	Best
UrbanPop	2015-2024	10	(1,2,1)	0.424	0.217	1.198	0.217	1.000	Naive
UrbanGrowth	2015-2024	10	(1,1,2)	0.308	1.532	1.325	1.532	1.000	ARIMA
Mobile	2015-2024	10	(1,2,1)	18.121	5.988	15.988	5.988	1.000	SES
WaterStress	2013-2022	10	(0,2,0)	17.600	8.845	17.600	8.845	1.000	Naive
Renewable	2014-2021	8	(0,1,0)	0.670	0.687	0.670	0.687	1.000	ARIMA
PM25	2013-2020	8	(0,2,0)	2.330	3.949	4.018	3.949	1.000	ARIMA
SciArticles	2016-2022	7	(0,2,1)	6,872	7,104	6,869	7,104	1.000	Holt
SecEnrol	1999-2007	9	(0,2,1)	16.069	8.439	15.931	8.439	1.000	Drift
Internet	2016-2024	9	(0,2,0)	25.000	44.909	25.000	44.909	1.000	ARIMA
Water	2019-2024	6	(1,1,1)	1.116	0.818	1.121	0.818	1.000	Naive
Sanitation	2019-2024	6	(0,2,0)	3.520	2.919	3.520	2.919	1.000	Drift
CleanFuels	2018-2023	6	(2,2,0)	0.772	0.451	0.351	0.451	1.000	Holt
Electricity	2018-2023	6	(0,1,1)	0.501	0.137	0.501	0.091	0.815	Naive

5.5 Readiness as a Multidimensional Condition

The central argument of this study is that readiness for smart sustainable urban development cannot be adequately represented by a single composite score. The first component, the only dimension behaving as a general factor, accounts for 66.8 percent of the variance. It mainly reflects the passage of time and largely disappears when year-to-year changes are analyzed. Within the economic dimension, the basic service and connectivity indicators improve together. Moreover, the electricity, water, sanitation, and mobile penetration series load at 0.92 or above on the first component. The social indicators improve alongside them with weaker, less consistent loadings, and the secondary enrollment series has no observations after 2007, so its recent trajectory is

estimated rather than measured. The environmental indicators neither follow the service indicators nor cohere among themselves, as shown in (Fig. 4).

The policy implication is dimension-specific rather than aggregate. Improvements in service provision and connectivity are real and measurable at the national scale, whereas environmental pressure is not improving alongside them and is not amenable to the same instruments. The social indicators are the least well measured of the three, which points to a finding about Iraq's statistical infrastructure rather than Iraqi society. A composite index averaging these dimensions reports steady improvement and conceals the divergence that is material for planning. The criticism applies to the composite method generally, although the effect is likely moderated where the underlying indicators are collected at the scale that the index describes. For Baghdad, these national gains in services and connectivity set the conditions for the capital's smart city initiatives (Section 3), while city-level data are needed to show whether Iraq, especially Baghdad, shares the lag in environmental conditions. The correlation r = 0.996 between the first component and the calendar year, shown in (Fig. 3), reminds us that the indicators share a national history of conflict, reconstruction, and oil-revenue cycles; the associations reported here are not causal.

6. Conclusions

This study assessed readiness for smart, sustainable urban development in Iraq using sixteen World Bank indicators from 1960 to 2024, grouped into economic, environmental, and social dimensions. It combined stationarity testing, principal component analysis, and out-of-sample forecast evaluation. Readiness for smart, sustainable urban development is best understood as a sequential, multidimensional process: an ongoing path rather than a fixed goal. The indicators do not move like one. Basic services and digital connectivity, including safe water, sanitation, electricity, and mobile and internet access, improved steadily and together over the last twenty-five years. Environmental conditions did not follow this trend; air pollution, water stress, and the share of renewable energy took their own paths. A single average index would report steady progress and hide this gap. This is the study's main conceptual contribution, and it aligns with critical reviews of smart city assessment tools.

Many of the indicators show only improvement over time. The first component follows the calendar year almost exactly, so it should not be read as a readiness score. The more useful information lies in the differences between dimensions, and these differences remained when we removed the time trend and treated missing values differently. These series are not well suited to short-term statistical forecasting. Exponential smoothing reduced to repeating the last value for twelve of the thirteen indicators, and ARIMA did better than that simple forecast for only five. Projections should therefore be presented as trend extensions with clear assumptions rather than as model forecasts. The main constraint on evidence-based urban policy in Iraq, and in Baghdad as its main urban core, is measurement. Fewer than half of the yearly values were recorded, and district-level, annually updated data for Baghdad is still unavailable. Iraq has built digital connectivity faster than the environmental and statistical foundations a smart city depends on. Even so, the initiatives documented in Section 3 show that Baghdad is taking steps toward a new stage of urban development and building the data to follow that path is a precondition for smart city investment, not a step after it.

6.1 Recommendations

Baghdad should be treated as a physical base for sustainable urban projects, supported by qualitative and quantitative indicators of urban intelligence and sustainability. Statistical agencies should collect annual city- and district-level data for the U4SSC core indicators, starting with air quality, water, and energy. Smart city investment should be paired with environmental measures rather than assumed to deliver them. Future readiness assessments should report data gaps openly, check whether their patterns remain once the time trend is removed, and compare forecasts with the simple no-change forecast.

6.2 Limitations of The Study

The data are national, so they describe the conditions within which Baghdad develops rather than the city itself. The 2000–2024 window has only twenty-five yearly values, and fewer than half of all indicator-year values were observed. We could not include several U4SSC indicators because consistent series for Iraq are not available.

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