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Assessing Service Delivery Gaps in Urban Water Supply and Sanitation Services in Mumbai Using CAG Audit Reports

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Abstract—Urban water supply and sanitation are essential public services that influence public health, environmental sustainability, and urban quality of life. Mumbai, as a densely populated metropolitan region, continues to face challenges related to service reliability, sewerage coverage, sewage treatment, infrastructure, governance, and financial management. This study assesses service delivery gaps in Mumbai using evidence from Comptroller and Auditor General of India (CAG) audit reports, Brihanmumbai Municipal Corporation (BMC)-related documents, government publications, and scholarly literature. The study follows a qualitative descriptive approach based primarily on secondary data. Service-performance indicators are extracted, classified, and compared with available benchmarks to identify major gaps. A Looker Studio dashboard is used for data visualization and comparative analysis. The analysis highlights substantial gaps in sewage treatment adequacy, collection efficiency, and metering, while reported water-supply connection coverage is high. The study provides an evidence-based framework for interpreting service performance and identifying areas requiring governance, financial, infrastructure, and monitoring improvements.

Index Terms—urban water supply, sanitation services, service delivery gaps, CAG audit reports, Mumbai, urban governance, data visualization

I. INTRODUCTION

Urban water supply and sanitation constitute fundamental components of urban public service delivery. Reliable access to water, effective wastewater collection, adequate treatment capacity, and sound financial and administrative systems are essential for healthy and sustainable cities. Mumbai faces continuing challenges associated with infrastructure ageing, service management, sewerage coverage, wastewater treatment, and governance.

This study focuses on assessing service delivery gaps in Mumbai's urban water supply and sanitation services using CAG audit evidence and supporting secondary data. The research examines service-performance indicators, compares observed values with available benchmarks, and identifies operational, governance, administrative, financial, and infrastructure-related deficiencies.

The study aims to assess the current status of urban water supply and sanitation services, identify major service deliv-

ery gaps, and develop evidence-based recommendations for improving efficiency and sustainability.

A. Problem Statement

Mumbai continues to face challenges in providing reliable and efficient water supply and sanitation services despite substantial investment in infrastructure. Service delivery is affected by issues including inadequate sewerage coverage, sewage treatment limitations, leakages, ageing infrastructure, weaknesses in metering and revenue collection, and institutional constraints. There is therefore a need for a systematic, evidence-based assessment of these gaps using audit and government records.

B. Research Objectives

The study has the following objectives:

- 1) To assess the current status of urban water supply and sanitation services in Mumbai.
- 2) To identify the major service delivery gaps in Mumbai's water supply and sanitation services.
- 3) To recommend measures for improving the efficiency and sustainability of urban water supply and sanitation services in Mumbai.

C. Research Questions

The study addresses the following questions:

- 1) What is the current status of urban water supply and sanitation services in Mumbai based on available audit and government evidence?
- 2) What are the major service delivery gaps and the governance, administrative, and financial factors affecting these services?
- 3) What measures can improve urban water supply and sanitation services in Mumbai?

II. LITERATURE REVIEW

Existing research indicates that Mumbai's water and sanitation challenges cannot be understood only through physical infrastructure. Governance, institutional coordination, policy

choices, maintenance, financial management, access, and user-level conditions also affect service outcomes.

Tiwale and Wagle examine the framing of Mumbai's urban water problem and emphasize that policy attention can become concentrated on water scarcity and augmentation while distribution, leakage, reliability, and governance problems receive comparatively less attention [1].

Haridasan, Parker, and Sule examine water-service provision in rapidly urbanising areas around Mumbai and Chennai and highlight the importance of governance structures and institutional coordination for reliable service provision [2].

Biswas et al. examine disparities in access to water, sanitation, and hygiene services across India and identify regional differences in infrastructure and service access, reinforcing the importance of geographically focused assessment [3].

The CAG performance audit on implementation of the 74th Constitutional Amendment in Maharashtra identifies deficiencies relating to planning, financial management, accountability, monitoring, staffing, and institutional capacity within Urban Local Bodies [4].

Biswas et al. investigate sanitation conditions in informal settlements in Mumbai and demonstrate that increasing toilet infrastructure alone does not necessarily eliminate open defecation or guarantee effective sanitation outcomes; maintenance, accessibility, behaviour, and governance also matter [5].

The literature therefore demonstrates a need for an integrated, evidence-based assessment that combines service-performance indicators with audit observations. The present study addresses this gap by using CAG evidence together with BMC-related and government data to examine water and sanitation service delivery in Mumbai.

III. RESEARCH METHODOLOGY

A. Research Approach and Design

The study adopts a **qualitative research approach** with a **descriptive research design**. The analysis relies primarily on secondary documentary evidence and focuses on interpreting service-performance indicators, audit observations, and recurring governance and implementation issues. No experimental intervention or manipulation of variables is undertaken.

A descriptive design is appropriate because the study seeks to systematically document and assess existing conditions rather than establish causal relationships through controlled experimentation.

B. Data Sources

The principal data source is CAG audit evidence concerning Urban Local Bodies and municipal service delivery in Maharashtra. Supporting evidence is obtained from BMC-related documents, government publications, policy reports, and peer-reviewed research literature. The selected materials are restricted to information relevant to Mumbai's urban water supply and sanitation services.

C. Data Collection and Selection

The study uses purposive document selection to identify sources directly relevant to the research objectives, geographic scope, and service domains. Relevant observations are extracted into a structured dataset containing fields such as indicator, value, unit, benchmark, year/period, source document, source page, geographic scope, and status.

D. Data Processing and Analysis

The extracted information is classified into water-supply, sanitation, governance, financial, infrastructure, and implementation themes. Quantitative indicators are retained with their original units. Where an appropriate benchmark exists, the service-delivery gap is computed as the difference between the benchmark and the observed performance in percentage-point terms. Qualitative audit findings are examined through content and thematic analysis.

IV. MEASUREMENT CONCEPTS

A **variable** is a characteristic that may take different values. In the present study, examples include water availability, sewerage coverage, and collection efficiency.

An **indicator** is a measurable variable representing a specific aspect of service performance. Examples include Water Supply Coverage, Sewerage Network Coverage, and Sewage Treatment Adequacy.

A **metric** is the numerical measure used to quantify an indicator. For example, a sewerage network coverage value of 80.9% is the observed metric for that indicator.

A **unit of measurement** specifies how a value is expressed. The dataset uses units such as percentage (%), litres per person per day (L/person/day), and million litres per day (MLD).

A. Actual Value, Benchmark, and Gap

The **actual value** represents the observed or reported service performance. The **benchmark** represents the target or expected performance. The **service-delivery gap** represents the difference between these values.

For a percentage indicator, the shortfall magnitude can be represented as

$$G = B - A, \quad (1)$$

where G is the shortfall, B is the benchmark, and A is the actual performance. For example, an actual sewage-treatment adequacy of 43.8% against a 100% benchmark corresponds to a shortfall of 56.2 percentage points.

V. DATASET ANALYSIS AND FEATURE IDENTIFICATION

The structured dataset contains service-performance indicators relating to water supply, sewerage, sewage treatment, and financial efficiency. It combines observed service values with benchmark information and gap calculations where comparable benchmarks are available.

A. Numerical Features

The principal numerical fields are:

- *Value* – observed service performance;
- *Benchmark* – expected or target performance;
- *Gap* – difference between actual performance and benchmark.

B. Categorical Features

The principal categorical fields include:

- Indicator;
- Sector;
- Geographic Scope;
- Status;
- Unit;
- Data Period Type.

C. Key Performance Indicators

Selected key performance indicators used in the dashboard include:

- Water Supply Coverage: 100%;
- Per Capita Water Availability: 135.5 L/person/day;
- Sewerage Network Coverage: 80.9%;
- Sewage Treatment Adequacy: 43.8%;
- Collection Efficiency: 12.1%;
- Cost Recovery: 74.1%.

VI. DATA ANALYSIS AND VISUALIZATION

A Looker Studio dashboard was developed to convert the structured indicators into visual evidence. It includes KPI scorecards, actual-versus-benchmark comparisons, service-delivery shortfall analysis, water-supply comparisons, wastewater indicators, sanitation performance, and financial-efficiency measures.

A. Actual Performance versus Benchmark

Figure 2 compares observed service performance with the corresponding benchmark for selected percentage-based indicators. The comparison shows that water-supply connection coverage is aligned with the benchmark, whereas collection efficiency, sewage treatment adequacy, metering, and sewerage network coverage exhibit larger deficiencies.

B. Major Service Delivery Gaps

Figure 3 ranks the magnitude of selected percentage-point shortfalls. The largest shortfall is observed for collection efficiency, followed by sewage treatment adequacy and metering.

C. Current Water Supply versus Demand

The dashboard compares total raw water yield from sources with reported water demand. The values are 4,548 MLD and 4,505 MLD, respectively.

D. Wastewater Generation and Untreated Discharge

Normative sewage generation is approximately 2,003 MLD, while untreated sewage discharge is approximately 552 MLD. These values illustrate the scale of wastewater requiring collection and treatment.

E. Sanitation Service Performance

Selected sanitation indicators include Sewage Treatment Quality (85.7%), Sewerage Network Coverage (80.9%), and Sewage Treatment Adequacy (43.8%). The large difference between treatment quality and treatment adequacy indicates that service coverage and capacity remain important concerns even where treated effluent quality is comparatively stronger.

F. Financial Efficiency

Cost recovery is reported at 74.1%, whereas collection efficiency is substantially lower at 12.1%. The contrast indicates a major revenue-collection and financial-management weakness within the service-delivery system.

VII. STATISTICAL ANALYSIS PRESENTATION

Because the present dataset is a structured collection of reported service indicators rather than a large respondent-level sample, the statistical presentation is primarily descriptive. Comparable percentage-based indicators are summarized using their observed values, benchmarks, and shortfalls.

TABLE I
SELECTED SERVICE-PERFORMANCE INDICATORS

Indicator	Actual	Benchmark	Shortfall
Water Supply Coverage	100.0	100.0	0.0
Sewerage Network Coverage	80.9	100.0	19.1
Sewage Treatment Adequacy	43.8	100.0	56.2
Extent of Metering	45.9	100.0	54.1
Collection Efficiency	12.1	90.0	77.9

The descriptive comparison indicates that collection efficiency has the largest shortfall among the selected indicators, followed by sewage treatment adequacy and the extent of metering. The statistics are interpreted within the definitions and reporting periods associated with each source.

VIII. RESEARCH PAPER ANALYSIS

The literature review identifies several recurring themes. First, governance and institutional coordination influence the quality and reliability of water services. Second, infrastructure availability alone does not guarantee effective sanitation outcomes. Third, regional and local disparities require city-specific assessment. Finally, CAG audit evidence provides a governance and accountability perspective that complements conventional infrastructure-focused studies.

Table II summarizes the contribution of the principal studies considered in this research.

IX. MACHINE LEARNING EVALUATION METRICS

Machine-learning evaluation metrics are included as a conceptual component of the assignment. The current Mumbai water and sanitation study does not claim to have trained a predictive machine-learning model. Therefore, no model-performance results are reported.

Mumbai Urban Water & Sanitation Service Delivery Dashboard

Assessing Service Delivery Gaps Using CAG Audit Reports and BMC Data

Water Supply Converage

Value
100

Per Capita Water Availability

Value
135.5

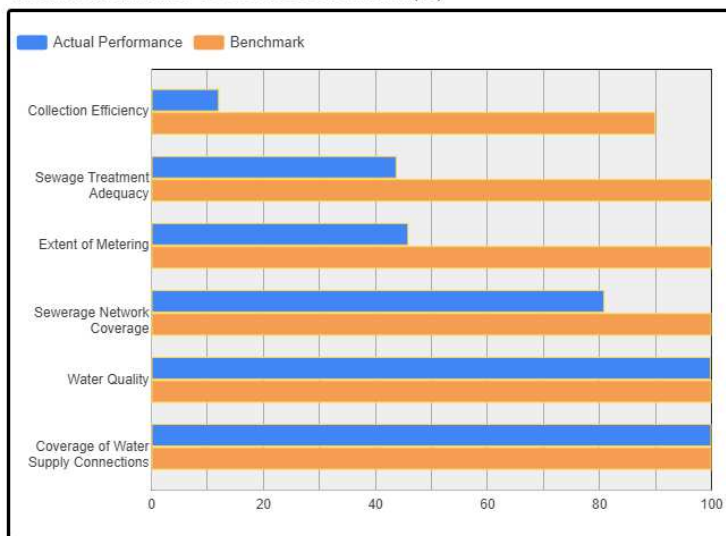
Sewerage Network Coverage

Value
80.9

Sewage Treatment Adequacy

Value
43.8

Actual Performance VS Service Benchmark (%)



Major Service Delivery Gaps

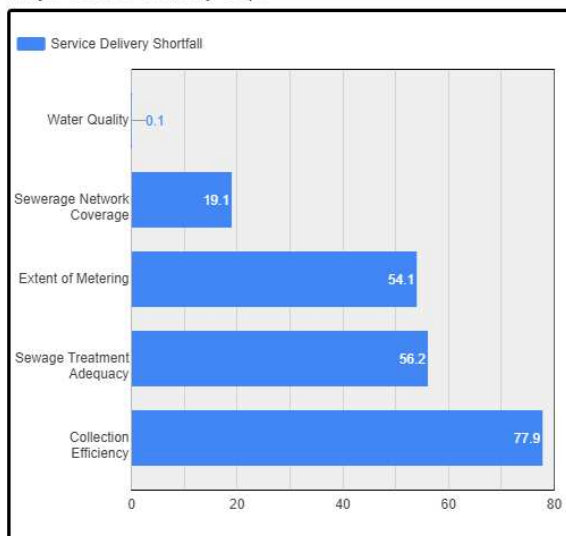


Fig. 1. Overview of the Mumbai urban water and sanitation service delivery dashboard.

Actual Performance VS Service Benchmark (%)

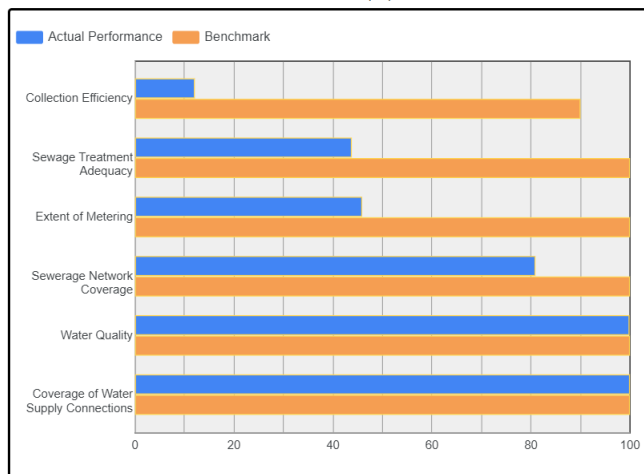


Fig. 2. Actual service performance versus benchmark.

TABLE II
SUMMARY OF SELECTED RESEARCH LITERATURE

Study	Main Focus	Relevance/Gaps
Tiwale and Wagle (2025)	Urban water problem framing and governance in Mumbai	Highlights distribution, reliability, leakage and governance; does not provide a CAG-based service-gap framework.
Haridasan et al. (2026)	Governance of water services in rapidly urbanising regions	Shows the role of institutional coordination; does not provide an integrated Mumbai water-sanitation audit analysis.
Biswas et al. (2024)	WASH disparities across India	Establishes broader access disparities; lacks a focused Mumbai audit-based assessment.
CAG (2022)	Governance and implementation of ULB functions in Maharashtra	Provides audit evidence on planning, funds, accountability and monitoring.
Biswas et al. (2020)	Sanitation and open defecation in Mumbai settlements	Shows that infrastructure alone is insufficient; broader financial and audit perspectives remain limited.

Major Service Delivery Gaps

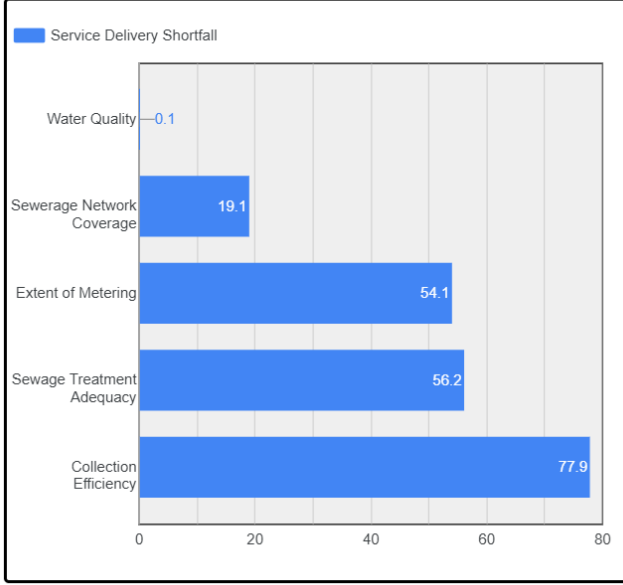


Fig. 3. Major service-delivery shortfalls.

Current Water Supply vs Demand

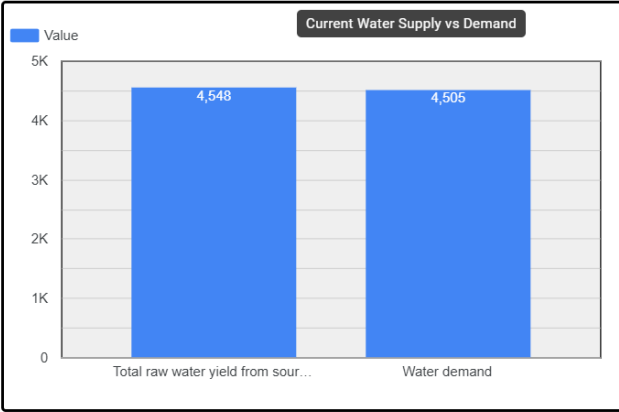


Fig. 4. Current water supply resource availability versus water demand.

A. Accuracy

Accuracy measures the proportion of all predictions that are correct:

$$\text{Accuracy} = \frac{TP + TN}{TP + TN + FP + FN}. \quad (2)$$

B. Precision

Precision measures the proportion of predicted positive observations that are actually positive:

$$\text{Precision} = \frac{TP}{TP + FP}. \quad (3)$$

Wastewater Generation, Discharge & Treatment Adequacy

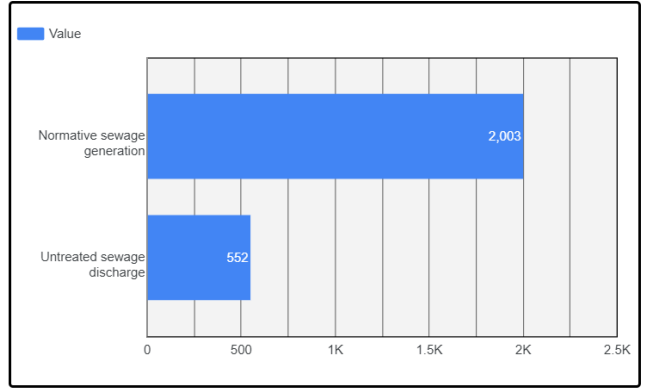


Fig. 5. Wastewater generation and untreated sewage discharge.

Financial Efficiency of Water Supply Services (%)

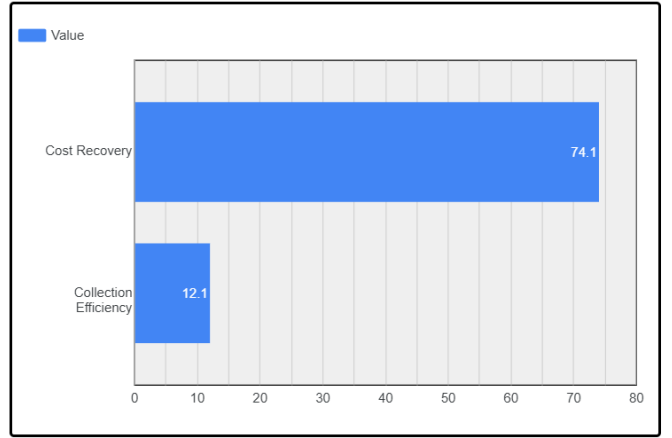


Fig. 6. Financial efficiency indicators for water-supply services.

C. Recall

Recall measures the proportion of actual positive observations correctly identified:

$$\text{Recall} = \frac{TP}{TP + FN}. \quad (4)$$

D. F1-Score

The F1-score is the harmonic mean of precision and recall:

$$F1 = 2 \frac{\text{Precision} \times \text{Recall}}{\text{Precision} + \text{Recall}}. \quad (5)$$

E. ROC-AUC

ROC-AUC measures the ability of a classifier to distinguish between classes over different decision thresholds. Higher AUC values indicate better class discrimination.

F. Applicability to the Present Study

The present research uses qualitative analysis and descriptive comparison of secondary documentary data. Consequently, training, validation, and test datasets are not required for the current study. ML metrics are presented only as

concepts required for the assignment and are not presented as empirical findings.

X. RESULTS AND KEY FINDINGS

The dashboard indicates that reported water-supply connection coverage is 100%, while sewerage network coverage is 80.9%. Per capita water availability is 135.5 L/person/day. Sewage treatment adequacy is substantially lower at 43.8%, indicating a major capacity-related service gap.

The service-gap analysis identifies collection efficiency as the largest selected percentage shortfall at 77.9 percentage points, followed by sewage treatment adequacy at 56.2 percentage points and metering at 54.1 percentage points. Sewerage network coverage has a smaller but still material shortfall of 19.1 percentage points.

The wastewater analysis also indicates approximately 2,003 MLD of normative sewage generation and 552 MLD of untreated sewage discharge. These results indicate that service delivery assessment should consider the full chain from water provision through sewerage collection, treatment, and financial management.

XI. DISCUSSION

The findings demonstrate that overall water-supply coverage does not necessarily imply uniformly effective urban water and sanitation service delivery. The comparatively high connection coverage coexists with lower performance in metering, revenue collection, sewerage coverage, and sewage treatment adequacy.

The findings are consistent with the literature's emphasis on governance, institutional coordination, maintenance, accessibility, and management alongside infrastructure. The CAG evidence further supports the relevance of planning, financial management, monitoring, and accountability in understanding service outcomes.

The dashboard should therefore be interpreted as an evidence-synthesis and service-performance assessment tool rather than as a causal model. Reported differences across indicators describe performance conditions and gaps but do not independently establish causal relationships.

XII. DATA COLLECTION, ETHICS, AND DATASET BIAS

The study uses secondary information obtained from CAG audit reports, BMC-related documents, government publications, and scholarly literature. Source documents and relevant pages are recorded to support data provenance and verification.

Potential data-quality limitations include missing information, differences in reporting periods, changing definitions, and inconsistent measurement procedures. Government-reported indicators may also be influenced by reporting practices and availability of administrative data.

The geographic and temporal scope of the dataset limits its generalization beyond the documented Mumbai service context and reporting periods. Indicators measured in different units should not be directly compared numerically. For example, 135.5 L/person/day and 80.9% represent different constructs.

The study uses publicly available or academically accessible secondary information and does not collect personal data from human participants. Data are presented transparently and are not intentionally manipulated to exaggerate service gaps.

XIII. RECOMMENDATIONS

Based on the identified service-delivery gaps, the following measures are recommended:

- 1) Strengthen planning, monitoring, and institutional accountability for water and sanitation services.
- 2) Improve metering coverage and meter maintenance to support accurate billing and revenue collection.
- 3) Strengthen wastewater collection and treatment capacity, with priority to areas with inadequate network or treatment coverage.
- 4) Improve financial management and collection mechanisms for municipal water services.
- 5) Use CAG findings and service-performance indicators as inputs to evidence-based monitoring and policy review.

XIV. REPRODUCIBILITY

The research is designed to support reproducibility through explicit documentation of data sources, document-selection criteria, extracted indicators, units, benchmarks, and analysis procedures. Future researchers can access the underlying public reports and repeat the indicator extraction and benchmark comparison process.

The structured dataset and dashboard framework also provide a reproducible path for updating the analysis when new government or audit reports become available. Reproducibility is improved by maintaining consistent definitions, recording source pages, preserving original units, and documenting all derived calculations.

XV. CONCLUSION

This study presents a structured assessment of urban water supply and sanitation service delivery gaps in Mumbai using CAG audit evidence and related secondary data. The combination of documentary analysis, indicator measurement, descriptive statistics, and dashboard visualization provides an integrated view of service performance.

The results indicate that while reported water-supply connection coverage is high, important deficiencies remain in sewerage coverage, sewage treatment adequacy, metering, and collection efficiency. The findings support the need for coordinated improvements in governance, infrastructure, financial management, monitoring, and accountability.

The research demonstrates how audit evidence and data visualization can be combined to support transparent assessment of urban public-service delivery. Future work may extend the dataset with additional time periods and city-level observations and, where a sufficiently large and appropriately structured dataset becomes available, evaluate predictive approaches separately.

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