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Systems-Based Approach to Improving Urban Water Access in Low-Income Communities

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THE PROBLEM

A city-scale water gap, sharpest for the poor

2.1 bn

people worldwide lacked safely managed drinking water in 2024 [1]

179 m

Nigerians without a safely managed water service (WASH NORM 2021) [2]

2.39 vs 0.93

million m³/day: Lagos State demand vs public supply (2015) [3]

44%

of Lagos residents have physical access to the LWC network [30]

up to 60%

of distributed water reported lost to leakage and inefficiency [31]

41–74%

of Lagos residents rely on wells or boreholes; only 8.9% safely managed [32]

WHY A SYSTEMS APPROACH

More pipes alone have not fixed it

- **Conventional response:** more treatment capacity, pipes and pumps.
- **What it leaves out:** feedback between utility performance, household demand, vendor markets, tariffs and maintenance.
- **Result:** repaired systems fail again because the conditions that caused the failure remain.

AIM

A framework for resilient, equitable water service in low-income settlements (Lagos as reference)

- Define water access as a system-of-systems problem
- Identify the reinforcing loops that lock in poor supply
- Propose a four-module intervention architecture
- Define five pilot metrics and test the kiosk buffer by simulation

Methodology: a four-step systems engineering workflow

1

Problem scoping

System boundary and stakeholders

2

Systems analysis

Bottlenecks, dependencies, feedback loops

3

Architecture design

Modules mapped to leverage points

4

Evaluation design

System-level metrics for a pilot

TOOLS

- Stakeholder mapping
- Root-cause (Ishikawa) analysis
- Causal-loop diagramming
- Model-based systems engineering

EVIDENCE

- Published studies, utility statements, national survey data and recent reports
- Field questionnaire (KoboCollect) with residents of the Bariga–Ilaje axis (n ≈ 62–65)
- Monte Carlo scenario simulation (Yaba and Lagos Island)

SYSTEM BOUNDARY

Who shapes the service, and how it fails

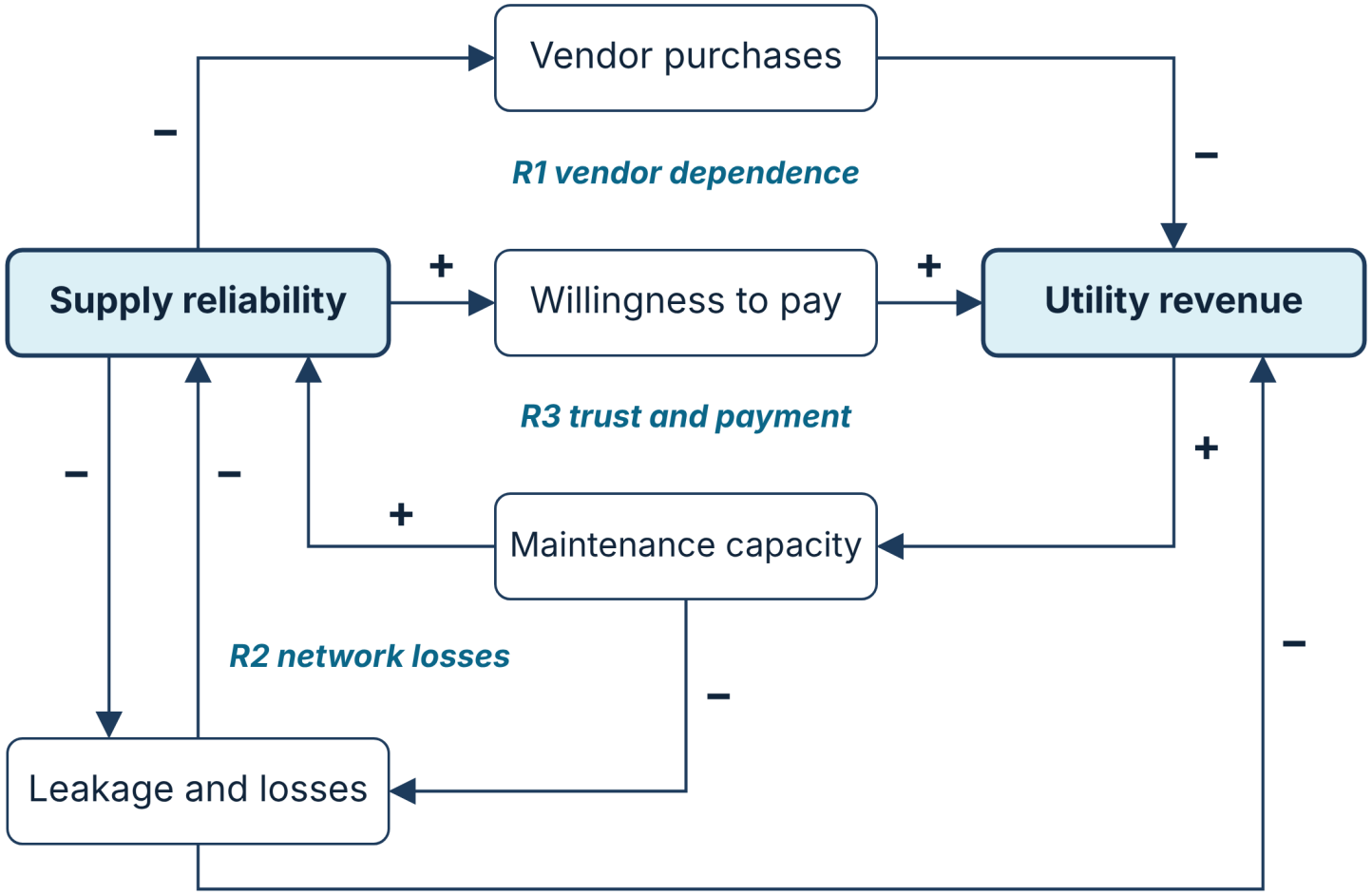
Stakeholder	Main lever
State govt. & regulator	Pricing, quality, vendor licensing
Water utility (LWC)	Operations and maintenance spending
NGOs and donors	Capital for pilots, technical support
Informal vendors	Price, availability, source of water
Households & communities	Demand, willingness to pay, oversight

FIVE RECURRING FAILURE MODES

- **Intermittent supply:** rationing forces storage and alternatives
- **Hydraulic imbalance:** low pressure at the network edge
- **Non-revenue water:** leaks, illegal connections, metering gaps
- **Fragmented governance:** unclear repair responsibility
- **Vendor dependence:** high price, uncertain quality

FEEDBACK STRUCTURE

Three coupled loops keep supply poor and costly



- **R1 Vendor dependence:** unreliable supply → vendor purchases → lower utility revenue → less maintenance.
- **R2 Network losses:** deferred maintenance → leakage → rationing → more losses and lost revenue.
- **R3 Trust and payment:** poor service → lower willingness to pay → less revenue.

Shared variables: supply reliability and utility revenue. Fixing one alone is absorbed by the others.

BASELINE EVIDENCE

Current state: two Lagos settings

Lagos Island (Itafaji, Onola, Adeniji Adele)

₦1,500

per vendor truck of 8 × 25 L kegs (≈ ₦7,500 per m³), current price

- Published 2025: ₦100–150 per 25 L jerrycan [33]
- Residents report never having had public water
- Groundwater TDS above 8,500 mg/L [33]

Makoko, Yaba

₦100

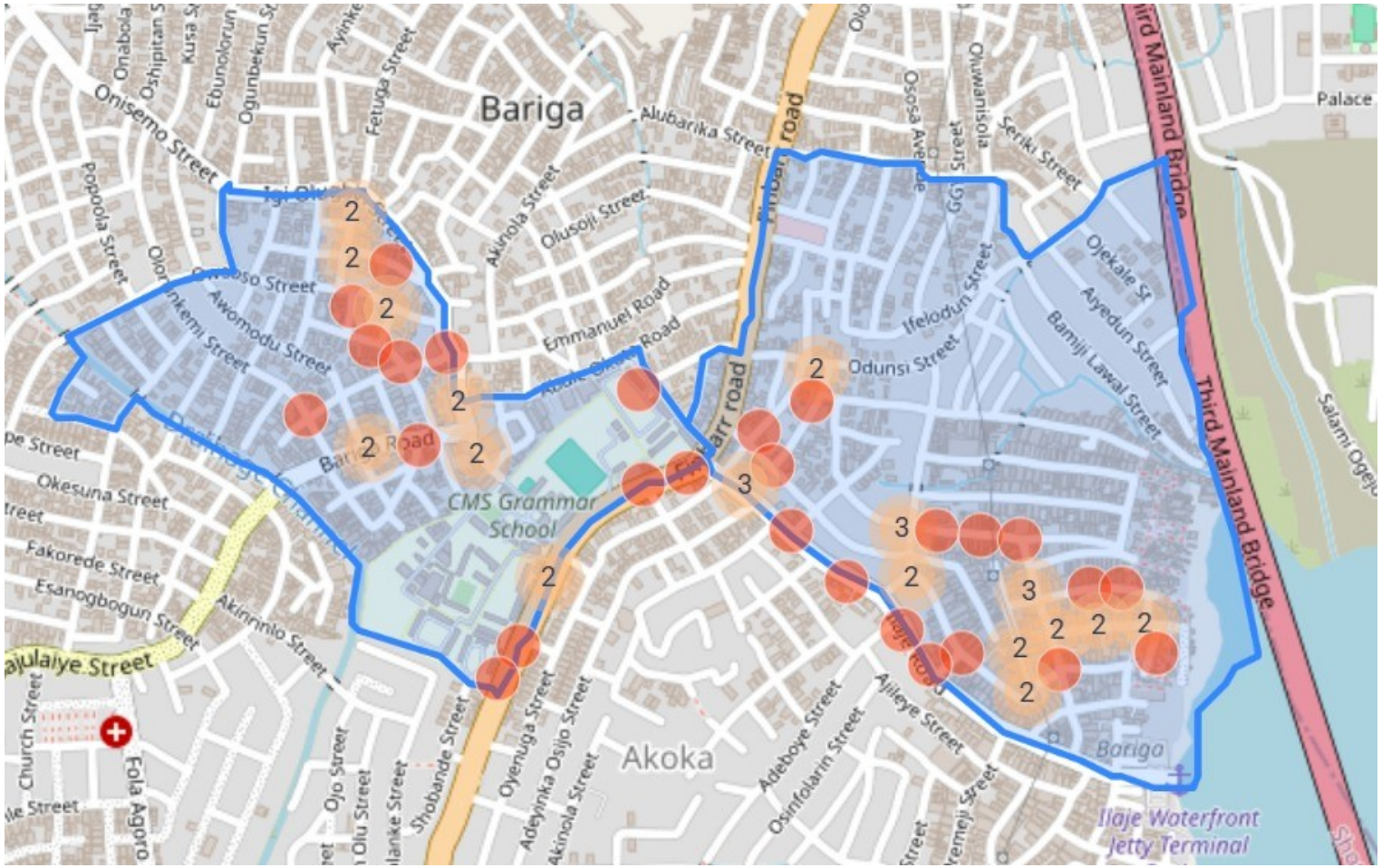
for 3 buckets at borehole points, current price

- Published 2021: ₦10 per bucket [34]
- Household of six spends ₦100–200 a day [34]
- E. coli and acidic water found in tests of 20 water points [34]

Current prices: author's field observation, November 2026. Bracketed numbers are published sources.

PRIMARY DATA

Field questionnaire: residents of the Bariga–Ilaje axis



Surveyed area (blue) and respondent locations (red; numbers = respondents at the same point). Base map © OpenStreetMap contributors.

- **Area:** Bariga–Ilaje axis, between CMS Grammar School and Third Mainland Bridge
- **Method:** structured questionnaire administered to residents in the area using the KoboCollect mobile app (geotagged responses)
- **Respondents:** about 62–65 residents surveyed
- **Asked about:** main water source, how water is obtained from that source, and household water use

QUESTIONNAIRE RESULTS

Most households in this axis rely on water vendors

MAIN HOUSEHOLD WATER SOURCE (n ≈ 62–65)

1 — Water vendors

Majority of respondents

2 — Boreholes

A minority

3 — Wells

Very few

Ranked by number of respondents naming each as their main source. Field questionnaire, Bariga–Ilaje axis, 2026.

WHY NOT BOREHOLES?

- **Electricity:** pumping depends on power supply or fuel for a generator
- **Water quality:** residents reported concerns about borehole water quality

Consistent with loop R1: household spending flows to vendors, not to the utility.

INTERVENTION ARCHITECTURE

Proposed framework: four interacting modules

01

INFRASTRUCTURE

Kiosk nodes

Local storage, treatment and metered dispensing buffer supply from trunk failures

Weakens R1

02

INFORMATION

Digital monitoring

Pressure, flow, level and quality sensing with simple anomaly detection

Weakens R2

03

INSTITUTIONAL

Adaptive governance

Utility–community agreement on roles, fault escalation and response times

Weakens R3

04

ECONOMIC

Market integration

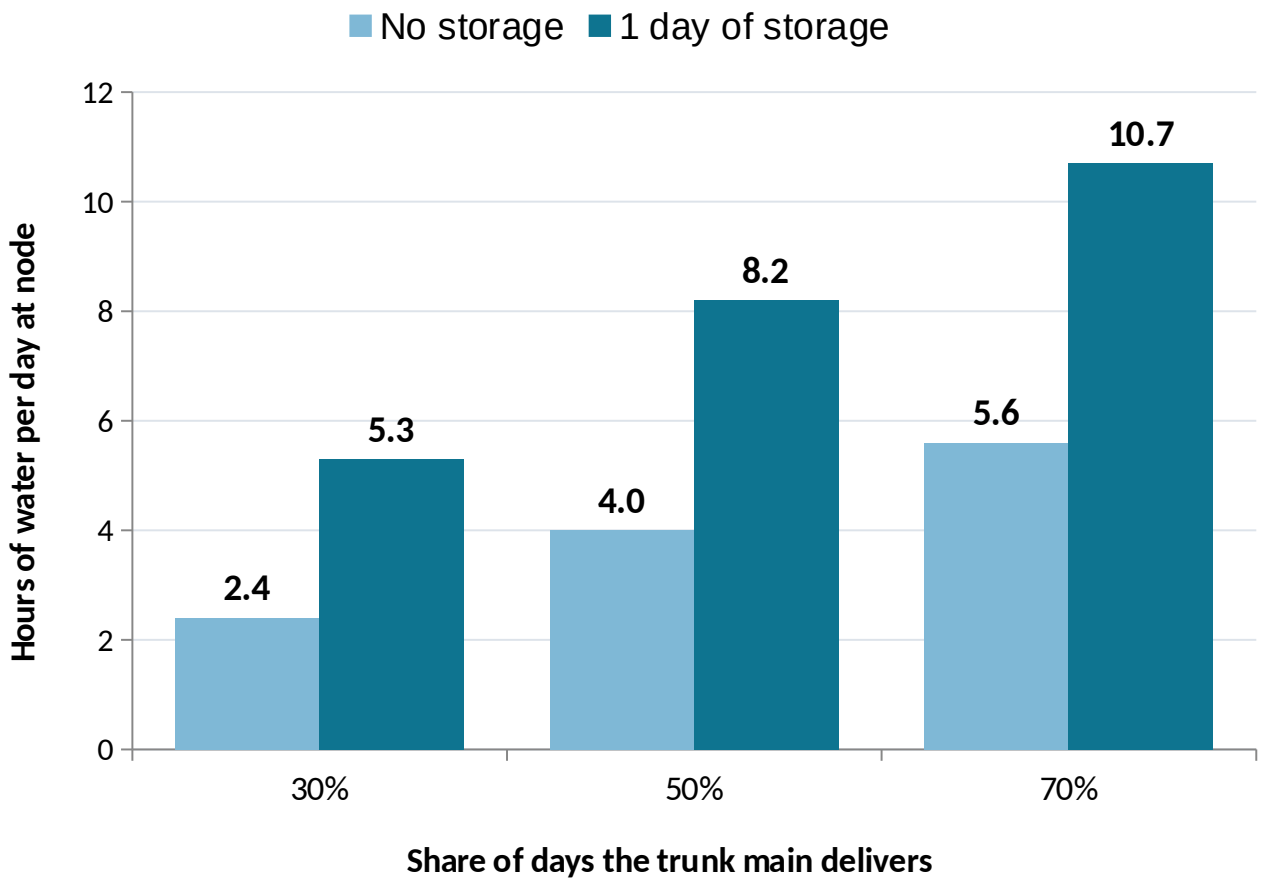
Registered vendors buy at bulk rate from nodes, resell under a price ceiling

Weakens R1

Nodes → sensor data → monitoring → fault alerts → governance → pricing rules → market → sales revenue → node maintenance

SCENARIO RESULTS (SIMULATED, NOT MEASURED)

Simulation: storage roughly doubles hours of water



2× Storage roughly doubles daily water hours at every supply level.

−60% Lagos Island: cost of water falls from about ₦5,000 to ₦1,935 per m³.

Cap Supply volume limits the gain: size storage to outage length, feed to average demand.

Safe Yaba: cash cost rises slightly (₦750 → ₦900/m³); the gain is safe water.

Means of 2,000 one-year runs; cluster of 5,000 residents; node open 14 h a day.

EVALUATION METRICS

How success will be measured in a pilot

Metric	Baseline	Pilot target
Reliable service hours / day	2.4–5.6 h (simulated, no storage)	**≥ 12 of 14 opening hours**
Water quality compliance	To be measured	**All samples within NIS and WHO limits**
Household cost per m³	₦4,000–6,000 (Lagos Island); ₦500–1,000, unsafe (Yaba)	**≤ ₦1,500 from a safe source**
Non-revenue water	To be measured (IWA water balance)	**20–30% reduction**
Fault response time	Days to weeks	**Under 24 h**

Mixed-methods before-and-after design with a comparison cluster; surveys and sampling at 0, 3 and 6 months.

TAKE-AWAYS

Conclusion and next steps

- Urban water access in low-income communities is a systems problem: infrastructure, governance, markets and households.
- Three coupled reinforcing loops explain why infrastructure-only projects underperform.
- Four modules (kiosk nodes, monitoring, governance, market integration) each target a loop.
- Field responses in the Bariga–Ilaje axis and published evidence both point to heavy reliance on vendors.
- Limitations: no deployment data yet; baselines partly indicative; needs sustained stakeholder cooperation.

NEXT STEPS

1. Costed design for one community cluster
2. Baseline measurement of all five metrics
3. Six-month pilot against a comparison cluster

Fix the loop, not just the pipe.

Thank you

Questions and discussion

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