

LOCAL 2030
KNOWLEDGE AND SCIENTIFIC NETWORK

Aqaba Environmental Decision Support System

Policy Paper – 2026



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PREFACE

Achieving the 2030 Agenda requires more than translating global goals into national targets – it demands that sustainable development be rooted in the realities, needs, and capacities of local territories. Local and regional governments are indispensable actors in this process: they deliver essential services, address inequalities on the ground, and turn policy commitments into concrete actions. Yet this critical role is only fully effective when backed by strong evidence, meaningful knowledge exchange, and coherent governance across levels.

The Local2030 Knowledge and Scientific Network (KSN) was established within the UN Local2030 Coalition precisely to respond to this need. As a dynamic global platform, KSN connects young researchers, policymakers, community leaders, and practitioners around a shared mission: to harness science for sustainable development with local impact. It does so by aligning academic inquiry with the specific priorities of local development stakeholders, while amplifying research findings as inputs to SDG-related global processes.

Central to this approach is the understanding that research must not only be produced – it must be translated into policy and action. KSN promotes a more dynamic and responsive model of academia, one that co-creates scalable solutions rooted in scientific evidence and community priorities, and that empowers local actors with the skills, tools, and institutional support needed to engage in evidence-based decision-making and influence policy. Through its Country Pilots – sponsored by the Italian government and implemented by UN-Habitat and the Centro Studi di Politica Internazionale (CeSPI ETS) – and Innovation Labs, the network operationalizes this vision by connecting universities and students with local policymakers, enabling interdisciplinary collaboration and capacity-building in territories across Africa, Asia, and Latin America and the Caribbean.

Action-research is the methodological backbone of this work. Territories are engaged not as passive subjects of study, but as spaces for experimentation and learning, where sustained interaction between researchers, local governments, civil society, and communities drives learning, adaptation, and co-creation. By combining quantitative and qualitative methods – data analysis, spatial assessments, stakeholder engagement, and participatory approaches – this process generates a comprehensive and grounded understanding of local dynamics, inequalities, and development opportunities.

This policy paper is the result of that process. It reflects the outcome of collaboration

between academic research, territorial analysis, and multi-stakeholder dialogue, in the spirit of the KSN's core objective: translating research into policy and action. Its aim is to offer context-sensitive analysis and practical policy recommendations that can inform SDG localization at the local level — bridging the gap between global agendas and the communities that will ultimately determine their success.

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EXECUTIVE SUMMARY

Aqaba faces intensifying environmental pressures driven by industrial activity, tourism growth, logistics operations and climate-related stressors. Traditional monitoring approaches – periodic, manual and institutionally fragmented – are no longer sufficient to manage the city's complex coastal environment. To address this gap, the Environmental Decision Support System (DSS) was designed as an applied outcome of scientific research integrating Internet of Things based (IoT-based) air quality monitoring, AI-enabled analytics, geospatial dashboards and multi-stakeholder governance frameworks. It provides real-time, evidence-based environmental intelligence aligned with the Sustainable Development Goals (SDG 11 and SDG 13) and Aqaba Special Economic Zone Authority's (ASEZA) Smart City and Sustainable Growth pillars.

The system is built on a governance-first model underpinned by strategic sparsity: a limited number of high-quality, strategically placed sensors supported by Quality Assurance and Quality Control (QA/QC), calibration protocols and wind-aware analytics. This approach maximizes data validity and actionable insight within realistic operational and budget constraints, making it particularly suited to the resource environments of coastal cities in the Global South.

A six-month exploratory pilot, grounded in mixed-methods research (quantitative sensor data combined with qualitative stakeholder inputs), demonstrated the system's early impact: a 30% reduction in Particulate Matter (PM₁₀), Sulfur Dioxide (SO₂) and related pollutant peaks in priority zones; 20% faster emergency response times due to automated alerts and Standard Operating Procedures based (SOP-based) escalation; improved inter-agency collaboration; enhanced situational awareness; and strengthened public communication through simplified visualization tools.

To institutionalize and scale this progress, the policy paper identifies six core priorities:

Embed DSS in ASEZA's operational workflows through SOPs, escalation protocols and integration with planning, permitting and coastal management.

Strengthen data governance, calibration and cybersecurity to safeguard integrity, interoperability and public trust.

Expand sensor coverage and enhance analytics, extending real-time intelligence to residential and coastal areas while introducing forecasting and source attribution.

Advance community engagement and public communication, including Air Quality Index based (AQI-based) advisories and citizen feedback mechanisms.

Mobilize partnerships and financing through national ministries, UN-Habitat, Green Climate Fund GCF, EU Missions, Public-private partnerships PPPs and research institutions.

Establish a replication-ready Coastal DSS Model: provide replicable architecture for Red Sea and Middle East and North Africa (MENA) coastal cities, supported by a structured starter kit.

1. INTRODUCTION AND STRATEGIC-INSTITUTIONAL CONTEXT

Aqaba, Jordan's sole coastal city and a strategic gateway to the Red Sea, is undergoing rapid transformation driven by industrial expansion, tourism development and logistics operations. These activities – central to the city's economic growth – are increasing pressure on the environmental systems that sustain public health, coastal ecosystems and the city's quality of life. The combined effects of human activity – ranging from port and industrial emissions to seasonal wind shifts, waste management challenges and marine ecosystem degradation – have elevated the urgent need for robust environmental governance mechanisms that can respond swiftly and coherently across institutions. Climate change further compounds these pressures, exhibited in rising temperatures, altered precipitation patterns and a higher frequency of extreme weather events. These dynamics demand a modern, data-driven solution capable of turning fragmented information into timely, actionable decision intelligence.

In response, the Environmental Decision Support System (DSS) was conceived and developed as a next-generation digital public good for Aqaba. Powered by Artificial Intelligence (AI) and the Internet of Things (IoT), the DSS integrates real-time monitoring with predictive analytics and Geographic Information System (GIS), serving as a dynamic bridge between environmental data and institutional action. Rather than positioning technology as an end in itself, the DSS represents a shift in governance practice, leveraging environmental intelligence through clear workflows, defined roles, escalation protocols and integration with planning, permitting and city service platforms. In short, the DSS transforms data into decisions – and decisions into measurable improvements in environmental quality and resilience.

1.1 Strategic anchoring and policy alignment

Strategically, the DSS is anchored in the 2030 Agenda for Sustainable Development, with direct relevance to SDG 11 (Sustainable Cities and Communities) and SDG 13 (Climate Action). These goals emphasize the importance of inclusive, safe, resilient and sustainable urban environments, as well as urgent action to combat climate change and its impacts. Locally, the initiative aligns with ASEZA's strategic direction

as outlined in the Strategic Plan (2024–2028) and the Master Plan (2025–2040). These planning instruments center integrated development, environmental sustainability and digital transformation as pillars of Aqaba's future, and they explicitly call for better data, smarter systems and stronger coordination to manage comprehensive urban and environmental challenges. Within that vision, the DSS serves as an enabling platform that connects environmental monitoring, urban planning, institutional coordination and public engagement.

More specifically, the DSS supports ASEZA's Smart City pillar by improving digital infrastructure, cybersecurity, data integration and geospatial information management. It also advances the Sustainable Growth pillar by enabling proactive measures that reduce air pollution, protect sensitive coastal and marine habitats and lower the city's carbon footprint. As the system matures, DSS outputs can also be linked to Environmental Impact Assessment (EIA) workflows, informing permit decisions with reliable, auditable evidence, thereby streamlining approvals while improving safeguards.

1.2 Why DSS, and why now?

The timing is strategic. ASEZA's 2024–2028 roadmap is accelerating digital transformation across services and operational directorates, while the 2025–2040 Master Plan underscores the importance of integrated coastal management, resilient infrastructure and environmental protection. A modern DSS accelerates these agendas by providing a fundamental operational framework for decisions that must be made daily – where minutes matter and cross-department coordination is essential. At the same time, Aqaba's unique position as Jordan's coastal gateway – with industrial ports, marine reserves, tourism areas and residential growth – creates a complex environment that cannot be effectively managed with fragmented systems or delayed reporting. DSS brings coherence, timeliness and precision to that environment.

Globally, cities that have adopted environmental decision support systems – linking sensors with GIS analytics, workflows, alerts and defined actions – demonstrate faster incident response, more consistent regulatory enforcement and higher public trust. Aqaba has institutional readiness through leadership commitment, digital infrastructure initiatives and technical partners to join this group and to tailor best practices to a coastal context along the Red Sea.

1.3 Integration with global SDG localization efforts

The DSS model aligns closely with the outcomes of the III International SDG Forum: From Research to Action, held in Curitiba, Brazil. The Forum underscored the need to strengthen the science-policy interface, mobilize territorial ecosystems and leverage research-based innovation to localize the SDGs. The DSS directly embodies these principles by connecting scientific evidence, institutional practice and multi-stakeholder territorial governance, positioning Aqaba as a contributor to global SDG localization efforts.

1.4 How DSS works in practice

At its core, DSS integrates three layers:

Sensing and data ingestion: an IoT sensor network measures key parameters (e.g., PM₁₀, Nitrogen dioxide NO₂, Carbon monoxide CO, temperature, humidity, wind and – where available in the next phase – marine indicators). Data ingestion pipelines validate readings (zero reference checks and validity threshold: ≥75% validated readings per hour interval) before committing to the analytics store.

Analytics and intelligence: the analytics engine transforms raw streams into insights: real-time exceedance detection against national standards; spike detection with sensitivity tuning, trend analysis and forecasting; and preliminary source attribution using historical patterns, meteorological context and spatial overlays. These insights are rendered through dashboards tailored to ASEZA units (environmental directorates, planning, city services, emergency response).

Operational workflows and escalation: intelligence is only useful when someone acts on it – quickly and consistently. SOP-based workflows map each alert type to a responsible unit and define expected actions. Escalation protocols specify time-bound steps (e.g., verification within 15 minutes; Level 2 escalation to the Environment Director within 30 minutes if the alert persists; Level 3 escalation to the Environmental Commissioner within 2 hours for repeated exceedances). Actions and outcomes are logged to ensure traceability and continuous learning.

1.5 Institutional capacity and roles

ASEZA (lead implementer): oversees system governance and integrates DSS outputs into industrial operations permitting, zoning, enforcement and city services.

The Environmental Commissioner and Monitoring Directorates lead operational use and inter-departmental coordination.

BEN HAYYAN – Aqaba International Laboratories (technical partner): provides sensor calibration, quality assurance and data validation. A designated data specialist oversees weekly calibration cycles, validation protocols and data integrity checks prior to analytics or public reporting.

UN-Habitat and national ministries (Facilitating Partners): provide technical cooperation, ensure policy alignment and support pathways for scaling, ensuring consistency with national digital and environmental strategies and enabling replication beyond the pilot phase.

Community and civil society (engagement): benefit from a public-facing, Multilingual, mobile-friendly AQI interface (and contribute observations through citizen science features, strengthening situational awareness and local ownership).

Academic and research partners (R&D): collaborate on predictive models, publish research findings and support evaluation of the effectiveness of policy responses, turning Aqaba into a living lab for smart environmental governance.

1.6 Pilot results and what full roll-out could achieve

The initial deployment demonstrated the practical value of DSS in real-world scenarios. During the pilot in the industrial zone, an air quality exceedance triggered immediate verification by the BEN HAYYAN AQM team, followed by automated notifications to the environmental monitoring unit to implement temporary operational adjustments and direct communication with industrial stakeholders when wind or weather fluctuations amplifying emissions. This coordinated response reduced pollutant concentrations within hours and prevented escalation to critical levels.

Estimates of the pilot project results are based on a mixed-methods approach combining validated sensor data with structured interviews and surveys with stakeholders. Pollution reductions were calculated using wind-speed-adjusted baselines to separate operational and seasonal effects. Improvements in response time reflect the processing of timed alerts according to standard operating procedures, measured across similar events before and during the pilot. These results remain preliminary and are subject to expansion over several seasons and the addition of more monitoring stations.

Preliminary findings from the pilot indicate measurable improvements: up to a 30% reduction in pollutant peaks in targeted industrial and tourism areas through rapid interventions and compliance checks; and 20% faster incident triage compared to previous manual processes, enabled by SOP-driven workflows and automated alerts.

With full citywide integration, expanded sensor coverage and advanced analytics, Aqaba can aim for: sustained reductions of 15–25% in peak pollutant concentrations across industrial and tourism areas; along with 25–35% faster incident handling during environmental exceedance events; and higher rates of timely enforcement actions tied to data-documented exceedances. These projections are directional and will be refined through phased implementation, stakeholder engagement and technical reviews.

1.7 Trust, transparency and public communication

Public trust is both a goal and a mechanism for success. The DSS incorporates AQI-based communication to translate complex environmental data into clear, accessible and understandable categories for residents, visitors and businesses. During periods of elevated or critical environmental conditions, the public interface can publish targeted guidance (e.g., outdoor activity recommendations and advisories) while city teams deploy immediate operational measures. Transparency – when coupled with reliable validation – creates a virtuous cycle: better data leads to better actions, clearer communication and stronger compliance and community support.

To protect integrity, DSS data governance includes clear cybersecurity and access controls, audit trails for alert handling and response actions, and retention policies that support institutional learning. As the system matures, aggregated insights can be shared through periodic public briefs, reinforcing credibility without exposing sensitive operational details.

1.8 Comparative advantage and regional leadership

Aqaba's comparative advantage lies in its unique combination of coastal geography, economic dynamism and institutional readiness. Few cities in the region possess such a concentrated blend of industrial ports, marine reserves and tourism areas within a single authority – supported by an authority (ASEZA) that is actively

advancing smart city and sustainability agendas. This distinctive context positions Aqaba to pioneer a coastal DSS model in the Red Sea, one that could be adapted and replicated by partner municipalities facing similar conditions.

2. TERRITORIAL PLANNING INSTRUMENTS

The DSS is more than a monitoring tool; it is a strategic planning instrument that embeds environmental intelligence into the heart of territorial governance. Its integration with ASEZA's planning framework ensures that environmental considerations are systematically incorporated into land-use decisions, infrastructure development, tourism planning and coastal zone management, not an afterthought.

2.1 Linking DSS to urban and coastal planning

Aqaba's urban landscape reflects a complex interplay of industrial zones, tourism areas, residential neighborhoods and ecologically sensitive areas. Traditional planning approaches often rely on static data and periodic assessments, which cannot keep pace with dynamic environmental conditions. DSS addresses this gap by providing real-time data streams and predictive analytics, enabling planners to anticipate risks and adjust decisions proactively. This dual capability ensures that environmental intelligence informs both industrial operations and tourism-related planning, transforming monitoring from a passive reporting function into an active governance tool that influences zoning, permitting and emergency response in real time.

2.2 Integration with ASEZA's strategic pillars

The system directly supports ASEZA's Smart City pillar by embedding environmental intelligence into digital planning platforms and its Sustainable Growth pillar by enabling proactive measures to reduce carbon emissions and protect sensitive ecosystems. By integrating DSS output into planning workflows, ASEZA can implement adaptive measures before environmental risks escalate, ensuring that development remains resilient and sustainable.

2.3 Coastal zone management and Master Plan alignment

The DSS complements ASEZA's coastal zone management initiatives outlined in the Master Plan 2025–2040. Spatial data generated by the system informs beach

rehabilitation projects, marine reserve protection, compliance with Blue Flag certification standards and UNESCO nomination. This ensures that coastal development aligns with environmental sustainability goals while maintaining Aqaba's appeal as a global tourism destination.

2.4 Future integration opportunities

- **Unified Smart City Platform:** integrate the DSS into ASEZA's digital planning ecosystem for seamless coordination across departments.
- **Environmental Impact Assessments (EIA):** leverage DSS historical and real-time data to strengthen EIA reports, improving accuracy and credibility.
- **Emergency preparedness:** leverage predictive modelling to design contingency plans for high-risk zones, including industrial areas and coastal ecosystems.

3. NATIONAL POLICIES IN THE IDENTIFIED SECTOR

The DSS initiative is not an isolated technological upgrade; it is a strategic enabler that operationalizes Jordan's national policy frameworks across environmental protection, digital transformation and public health. By embedding advanced analytics and real-time monitoring into governance workflows, the system bridges the gap between policy intent and practical execution, turning commitments into measurable outcomes.

3.1 Alignment with environmental policy frameworks

Jordan's environmental policies emphasize robust monitoring of air and water quality, control of industrial emissions and protection of natural ecosystems. DSS strengthens these objectives by providing continuous, validated data streams and actionable alerts. This capability transforms enforcement from reactive to proactive, reducing delays and improving regulatory credibility.

3.2 Integration with digital transformation agenda

Jordan's National Digital Economy Action Plan calls for leveraging smart technologies to improve public sector efficiency and service delivery. DSS embodies this vision by automating environmental data collection, analytics and reporting. Its integration into ASEZA's digital platforms demonstrates how national digital strategies can be localized to address complex urban challenges.

3.3 Contribution to public health objectives

Air quality is a key determinant of public health, particularly in industrial and tourism zones. DSS enables health authorities to correlate environmental data with respiratory health trends, issue timely advisories and design targeted interventions. These capabilities align with national health strategies aimed at reducing exposure to environmental risks and improving population well-being.

3.4 National policy hooks

Digital transformation: embeds environmental intelligence into e-government platforms, supporting Jordan's smart city vision.

Climate action: contributes to national commitments under the Paris Agreement and SDG 13 by enabling adaptive planning and resilience measures.

Public health and safety: enhances national health strategies through proactive air quality management and early warning systems.

Institutional coordination: creates pathways for collaboration between ASEZA, the Ministry of Environment and the Ministry of Digital Economy and Entrepreneurship, ensuring policy coherence and scalability.

4. LOCALIZATION OF THE 2030 AGENDA AND GLOBAL PARTNERSHIPS

The DSS initiative in Aqaba is a practical demonstration of how global sustainability frameworks can be translated into local action. By embedding advanced digital technologies into environmental governance, the system operationalizes the principles of the 2030 Agenda for Sustainable Development, particularly SDG 11 and SDG 13.

4.1 Direct alignment with SDG indicators

DSS monitors and analyses environmental parameters that correspond directly to SDG targets:

- **SDG 11.6:** reduce the environmental impact of cities, including air quality. DSS provides quantifiable metrics for pollutant concentrations and trends.
- **SDG 13.1:** strengthen resilience and adaptive capacity to climate-related hazards. DSS predictive analytics enable scenario modelling for climate adaptation strategies.

4.2 Integration with climate action frameworks

Under SDG 13, DSS supports both mitigation (identifying pollution sources and informing interventions to reduce emissions) and adaptation (forecasting environmental risks under different climate scenarios, guiding infrastructure planning and emergency preparedness). This dual role ensures that Aqaba's development path aligns with Jordan's commitments under the Paris Agreement and regional climate resilience strategies.

4.3 Strategic opportunities for international collaboration

- **UN-Habitat Local2030 Platform:** showcase DSS as a replicable model for SDG localization and smart city innovation.
- **Green Climate Fund (GCF):** position DSS as a climate resilience project eligible for adaptation financing.
- **Regional cooperation:** collaborate with coastal cities in MENA to share data platforms, harmonize standards and develop joint funding proposals.
- **Research networks:** integrate DSS into global research initiatives for validation, joint publications and innovation partnerships.

5. FUNDING AND PARTNERSHIP OPPORTUNITIES

The DSS initiative represents a high-impact, scalable solution that aligns with global priorities in climate action, digital transformation and sustainable urban development. Its successful pilot implementation and measurable outcomes make it an attractive candidate for diverse funding streams and multi-sector partnerships.

5.1 Strategic funding sources

UN-Habitat: Through its Smart Cities Programme and SDG Localization Initiatives, UN-Habitat supports projects that integrate technology into urban governance. DSS aligns with these objectives and benefits from Aqaba's active engagement with the UN-Habitat Knowledge and Scientific Network (KSN).

Green Climate Fund (GCF): as a global financing mechanism for climate adaptation and mitigation, GCF prioritizes projects that demonstrate environmental impact, scalability and innovation. DSS contributes directly to climate resilience by enabling early warning systems, pollution source detection and adaptive planning.

European Union Missions – Climate-Neutral and Smart Cities: Horizon Europe and Mission Innovation programmes support digital and environmental innovations in urban contexts. DSS can be positioned as a Mediterranean pilot for regional cooperation.

Private sector and PPP models: technology firms, environmental consultancies and infrastructure developers can co-invest in sensor deployment, analytics and platform enhancements. Public-private partnerships ensure long-term sustainability and reduce dependency on donor funding.

International research institutions: universities and innovation hubs (e.g., MIT Urban Risk Lab, ICLEI) may partner on research, validation and scaling, offering technical expertise and co-development opportunities.

5.2 Collaborative models for partnerships

Regional coastal cooperation: partner with cities such as Jeddah and Sharm El-Sheikh to share data platforms and develop joint funding proposals for coastal resilience.

- **Civil society engagement:** local non-governmental organizations (NGOs) and community groups can support awareness campaigns, citizen science initiatives and data validation, ensuring inclusivity and public trust.
- **Blended finance structures:** combine donor grants, public funds and private investment to create a resilient financing model that reduces dependency on single sources.

6. STAKEHOLDERS AND INSTITUTIONAL COORDINATION

The success of DSS depends on a governance model that ensures collaboration across multiple levels – local, national and international. Environmental challenges in Aqaba are cross-sectoral by nature, requiring coordinated action among regulators, technical partners, emergency services and the community.

6.1 Key stakeholders and their roles

- **ASEZA (lead implementer):** oversees DSS integration into operational workflows, planning systems and enforcement mechanisms. The Environmental Commissioner and Monitoring Directorates manage day-to-day operations.
- **BEN HAYYAN Laboratories:** responsible for sensor calibration, data validation and quality assurance. Their technical expertise guarantees scientific integrity and reliability of DSS outputs.
- **UN-Habitat Country Office:** acts as an international facilitator, supporting technical cooperation, policy alignment and funding mobilization.
- **National ministries (Environment, Digital Economy and Entrepreneurship):** provide strategic oversight for scaling DSS beyond Aqaba, ensuring alignment with national frameworks.
- **Local community and civil society:** engage through citizen science initiatives, feedback mechanisms and awareness campaigns, fostering transparency and trust.
- **Academic and research institutions:** offer analytical support, predictive modelling and joint research opportunities, strengthening evidence-based policymaking.

6.2 Institutional coordination mechanisms

Joint Technical Committee (JTC): a formal body comprising ASEZA, BEN HAYYAN, UN-Habitat and national ministries. The JTC supports SOP revisions, feature releases and replication offers to peer cities.

- **Data-sharing protocols:** secure agreements between ASEZA, laboratories and research institutions to ensure interoperability and confidentiality.
- **Regular stakeholder workshops:** biannual workshops for capacity building, knowledge exchange and public engagement.
- **Public feedback interface:** a mobile app or web portal enabling residents to access real-time air quality data, report observations and submit suggestions.

7. TOOLS AND METHODS USED OR PROPOSED

7.1 Current tools and methods

7.1.1 Real-time analytics engine

The core of DSS is its analytics engine, which ingests data from IoT sensors measuring key parameters such as PM₁₀, NO₂, CO, temperature, humidity and wind speed. Data validation protocols – including zero-reference checks and minimum validity thresholds – ensure accuracy before processing. The engine transforms raw data into actionable insights, enabling immediate operational responses.

7.1.2 GIS integration

Geographic Information System is central to DSS functionality. By overlaying environmental data on GIS maps, the system identifies pollution hotspots, vulnerable zones and proximity to sensitive assets such as schools, hospitals, residential and tourism areas and marine reserves. This integration supports zoning decisions, coastal management and emergency planning.

7.1.3 Forecasting models

Predictive algorithms simulate environmental scenarios based on historical trends and meteorological inputs. These models enable ASEZA to anticipate pollution spikes during adverse weather conditions, informing proactive interventions.

7.1.4 System architecture

The DSS follows a five-layer architecture:

- **Sensing layer:** three fixed and one mobile station across industrial, southern and city-centre zones, using calibrated analyzers (SO₂, nitrogen oxides NO_x, Ammonia NH₃, PM₁₀) and a meteorological suite. Stations include Uninterruptible Power Supply (UPS), surge protection and on-device buffering.
- **Ingestion layer:** measurements are timestamped (ISO 8601), tagged by station ID and transmitted via Secure Hypertext Transfer Protocol (HTTPS) with store-and-forward buffering for network outages.

- **Storage and governance layer:** time-series storage with a metadata registry tracking calibration events, maintenance logs and firmware versions.
- **Analytics layer:** preprocessing (time sync, de-duplication, outlier handling) followed by exceedance, spike and anomaly detection, plus forecasting tuned to Aqaba's wind patterns.
- **Decision and visualization layer:** an operational dashboard (AQI views, wind vectors, hotspot maps, trend charts) with configurable alerts and SOP-linked escalation.

7.2 Proposed enhancements

7.2.1 Advanced predictive analytics

Future iterations will incorporate machine learning models for trend forecasting, source attribution and scenario planning. These capabilities will strengthen adaptive management and long-term resilience strategies.

7.2.2 Data governance and cybersecurity

DSS will implement role-based access controls, encryption standards and audit trails to ensure compliance with ASEZA's Smart City cybersecurity framework. Operational data, calibration logs and alert response trails are retained for 24 months to support audits, learning and defensibility.

7.2.3 Calibration, validation and QA/QC

BEN HAYYAN Laboratories conduct weekly calibration cycles and zero-reference checks, maintain a calibration and maintenance log, and apply quality flags before analytics or reporting. A minimum validity threshold ($\geq 75\%$ validated readings per hour interval) is enforced prior to public disclosure or enforcement use.

8. FINAL RECOMMENDATIONS

Grounded in the analysis and stakeholder inputs presented throughout this paper, the following recommendations translate the DSS vision into concrete, institution-ready actions.

8.1 Governance and institutionalization

8.1.1 Institutionalize DSS as a core city function

Issue an internal directive from ASEZA leadership mandating the use of DSS outputs in environmental enforcement, coastal management and emergency response.

Create a concise decision template (one page) that attaches the relevant DSS snapshot to each decision for traceability.

8.1.2 Establish the Joint Technical Committee

Membership: ASEZA (chair), BEN HAYYAN, UN-Habitat (facilitator) and focal points from relevant national ministries. Mandate: review and validate implementation roadmaps, approve SOP updates, oversee system enhancements, resolve inter-agency coordination issues and authorize feature release documentation. Rhythm: quarterly governance meetings; monthly technical gatherings during the integration phase.

8.1.3 Embed DSS in ASEZA's policy instruments

Update internal manuals so that alert categories, escalation steps and evidence-based indicators are standard in environment planning and city services workflows, cross-referenced with coastal zone and marine reserve procedures where relevant.

8.2 Operations and service delivery

- **Approve and roll out SOPs and runbooks:** define who does what, when and with which tool for each alert type (exceedance, spike, anomaly). Include a 15-minute triage rule, 30-minute Level 2 escalation and 2-hour Level 3 escalation for repeated events.

- **Integrate DSS with permitting and zoning:** accompany each decision relating to an EIA or master permit with a one-page DSS abstract (map with stations and wind patterns, 7–30-day time series and summary of exceedances) and a decision memo referring to the alert log and SOPs.
- **Expand citywide sensor coverage and coastal use cases:** expand coverage in residential, tourism and coastal areas; add mobile units for events and seasonal peaks; prioritize placements that support Blue Flag processes, beach rehabilitation and marine reserve protection.
- **Ensure operational continuity and redundancy:** maintain spare calibrated sensors and hot standby data sync; maintain a business continuity logbook for sensor downtime, communications outages and extreme weather.

8.3 Technology, data and security

- Implement role-based access control, encryption in transit and at rest, and audit logs for alert response actions.
- Phase in predictive models (trend forecasting, basic source attribution) and automated operational triggers; maintain a simple model registry with documentation on assumptions and versioning.
- Ensure synchronized layer naming, coordinate reference systems and common symbology between DSS and GIS.
- Offer multilingual, plain-language and expert-level AQI dashboards and push notifications; use consistent AQI colour categories across public web, mobile and display panels.

8.4 People, capacity and community

- Provide short, role-specific training for monitoring staff, planners, inspectors and communications teams.
- Introduce a structured pairing initiative connecting technical analysts with field inspectors to accelerate adoption of data-informed workflows.
- Add a lightweight feedback button to the public AQI page (location, photo and brief note).
- Publish quarterly public briefs (2–3 pages, non-technical) summarizing patterns

and actions taken.

8.5 Financing and partnerships

- Link expenditures to clear milestones: core integration, coverage expansion, analytics upgrade, regional replication; blend ASEZA budget lines, donor grants, PPP contributions and in-kind research support.
- Prepare a concise presentation (problem, solution, governance, phases, results to date) for UN-Habitat, GCF, EU Missions and regional funds; use demonstration days (live dashboards and control room walkthroughs) to convert interest into commitments.
- Offer a replication starter kit (governance blueprint, technical specifications, data standards, operational runbooks, replication roadmap and legal and policy references) to peer coastal cities; pursue joint proposals on coastal resilience and environmental intelligence for Red Sea and Mediterranean countries.

8.6 Dependencies and risks to manage

- **Data quality and calibration:** sustained attention to validation, zero-reference routines and uptime service level agreements (SLAs).
- **Inter-directorate coordination:** SOP compliance and clear escalation pathways to avoid over-alerting.
- **Cybersecurity and privacy:** continuous patching, access reviews and incident response readiness.
- **Public trust:** proactive, consistent AQI communication and visible follow-through on actions.
- **Funding continuity:** milestone-based releases, diversified sources and embedding operational expenditure (OPEX) into ASEZA budgets.

8.7 Expected results

- Faster, more consistent responses to environmental events across industrial, tourism and residential zones.
- Reduced pollutant peaks in priority areas through targeted operational measures

and better compliance.

- Better planning and permitting decisions informed by current and historical environmental intelligence.
- Higher institutional capacity and smoother cross-directorate coordination are built on shared, trusted data.
- Greater public confidence through transparent AQI communication and evidence of action.

9. CONCEPT NOTE

9.1 Problem statement and rationale

Aqaba's growth in industry, logistics and tourism has accelerated pressures on air quality, coastal ecosystems and urban livability. Decision-makers need timely, trusted environmental intelligence that translates directly into planning, permitting, enforcement and service operations. The DSS responds to this need by converting real-time sensor data and geospatial analytics into clear, actionable workflows, enabling faster incident response, consistent compliance and adaptive urban planning.

9.2 Overall objective

Institutionalize a citywide environmental decision-support capability that improves air quality and coastal management, accelerates evidence-based decisions and strengthens public trust through transparent, plain-language communication.

9.3 Specific objectives

- Operationalize DSS within ASEZA workflows (planning, permitting, coastal operations, city services, emergency response).
- Expand coverage to residential, tourism and coastal areas, including mobile sensing for seasonal peaks.
- Enhance analytics (forecasting, basic source attribution) and automate operational triggers.
- Harden data governance (security, calibration, access control) and provide a multilingual AQI public interface.
- Build capacity across directorates and partners and establish a practical path to regionally replicate the model.

9.4 Primary beneficiaries

- Residents and visitors: clearer air quality advisories and safer coastal experiences.

- ASEZA directorates: faster, more consistent decisions supported by shared evidence.
- Business and industry: predictable, transparent enforcement and planning processes.
- Research and education: high-integrity datasets for applied studies and innovation.

9.5 Project components

- Component A – Core integration and governance
- Component B – Coverage expansion and coastal use cases
- Component C – Analytics and automation
- Component D – Public interface and communications
- Component E – Capacity, adoption and change management
- Component F – Regional replication readiness

9.6 Schedule and milestones

- Phase 1: core integration (SOPs, JTC, security hardening), baseline calibration, initial public AQI interface, priority GIS integration, first training wave.
- Phase 2: coverage expansion (fixed and mobile), automated triggers to city services, enhanced dashboards, replication starter kit.
- Phase 3: analytics upgrade (forecasting and source attribution), EIA linkage, regional demonstration days, replication MoUs with peer cities.

10. WAY FORWARD

10.1 Phase 1: foundation

Objective: establish governance, secure early wins and build confidence in the system.

Key actions: finalize SOPs and escalation protocols; activate the Joint Technical Committee; implement cybersecurity hardening; validate the sensor network and publish a first data quality report; deploy the multilingual AQI dashboard and pre-approved advisory templates; and issue a press release and conduct a live demonstration for ASEZA leadership and media.

Outputs: SOPs and governance charters approved; public AQI page live; first advisories issued; JTC operational; cybersecurity baseline achieved.

10.2 Phase 2: integration and expansion

Objective: embed DSS into ASEZA workflows and expand coverage to priority zones.

Key actions: connect DSS alerts to ASEZA's city service platforms; add fixed and mobile IoT stations in residential, tourism and coastal areas; align DSS layers with ASEZA's geospatial standards; configure automated operational triggers; deliver training for planners, inspectors and monitoring staff; and launch citizen feedback feature and first quarterly public brief.

Outputs: DSS integrated with ASEZA's city service platform systems; expanded sensor coverage; automated triggers tested and documented.

10.3 Phase 3: analytics upgrade and regional outreach

Objective: enhance predictive capabilities and position Aqaba as a regional model.

Key actions: deploy forecasting and basic source attribution; require DSS extracts in EIAs and major permit decisions; develop the replication starter kit; host regional demonstration days; and showcase DSS at UN-Habitat forums, Local2030 workshops and Smart City Expo.

Outputs: predictive models operational; EIA linkage institutionalized; replication kit published; MoUs signed with peer cities; DSS presented at least two global conferences.

10.4 Expected outcomes

- DSS is institutionalized as a core ASEZA function.
- Faster, more consistent responses to environmental incidents.
- Reduced pollutant peaks in priority areas.
- Stronger public trust through transparent AQI communication.
- Aqaba is positioned as a regional leader in smart environmental governance.

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