Executive Summary

Jeel Engineering LLC, in exclusive partnership with SuperMap Software Co., Ltd., proposes the development of an integrated Waste Infrastructure Digital Twin Platform that combines geospatial data integration, 3D modeling, analytics, and IoT connectivity.

SuperMap is a global leader in GIS and Digital Twin technologies, with over 30 years of innovation in 3D GIS, spatial data management, and AI-driven analytics. Leveraging this collaboration, Jeel will deliver a robust, scalable, and future-ready platform to enhance waste infrastructure planning, operations, and monitoring across Muscat Municipality.

Our approach emphasizes:

- Seamless integration of existing datasets into a unified geospatial repository.
- 3D visualization of waste assets and operational environments.
- Real-time data exchange through APIs and IoT gateways.
- Capacity building through comprehensive training and support.

Through this partnership, Jeel Engineering brings local expertise, implementation capacity, and compliance with Oman's regulatory, linguistic, and cybersecurity frameworks, while SuperMap contributes its globally proven technology stack.

Together, they deliver a localized, future-ready, and scalable platform for be'ah aligned with Oman Vision 2040 and national digital transformation objectives.

- Understanding of Scope and Objectives
- Data Integration, Cleaning, Validation & 3D Modeling
- Consolidate and validate existing waste infrastructure datasets.
- Develop 3D asset models and visualization environments.
- Establish standardized data storage and management structure.
- Integrate analytics dashboards for operational insights.
- API Gateway Design & IoT Integration
- Design and implement an API Gateway for secure data exchange.
- Integrate, test, and synchronize data from IoT sensors (software interface only; no hardware procurement).
- Enable interoperability with legacy waste systems and data streams.
- Training, Documentation & Support
- Deliver on-site and remote training sessions.
- Provide user and system administration manuals.
- Offer technical support during system handover and initial operation.

Methodology and Technical Approach

Jeel Engineering LLC, in partnership with SuperMap Software Co., Ltd., will employ a systematic, phased, and outcome-oriented methodology for the successful implementation of the Waste Infrastructure Digital Twin Platform for be'ah.

The approach focuses on data integrity, interoperability, visualization accuracy, and sustainable knowledge transfer, ensuring that the platform not only meets be'ah's technical requirements but also empowers its internal teams to maintain and enhance the solution independently.

Methodological Framework

The project will follow a four-phase engineering framework:

- Assessment and Planning – Establish requirements, review existing systems, and define integration specifications.
- Data Engineering and System Development – Clean, standardize, and integrate data; develop digital-twin components.
- Integration and Validation – Configure APIs, connect IoT feeds, and verify interoperability and security.
- Capacity Building and Deployment – Conduct training, prepare documentation, and transition to full operations.

This framework ensures transparency, traceability, and phased quality validation throughout the project lifecycle.

Technical Workflow

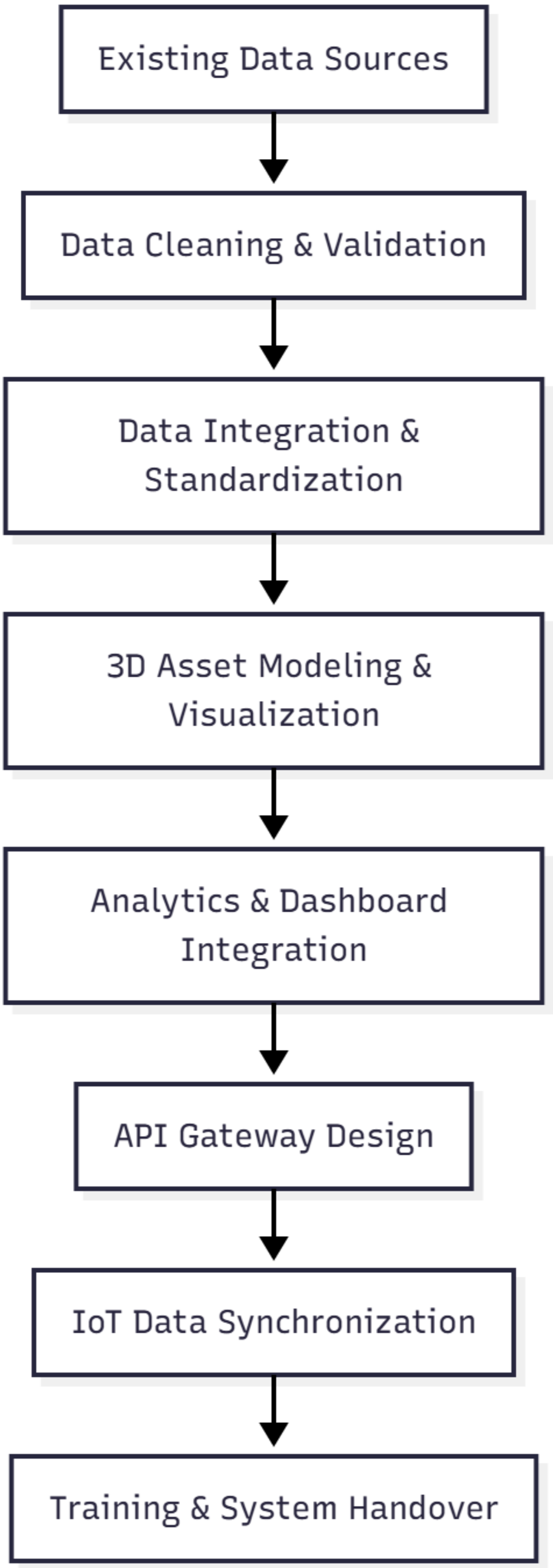


Figure 1: Methodological Workflow for Digital Twin Platform Implementation

Stepwise Workflow:

- Data Audit & Profiling: Review data formats, completeness, and spatial accuracy.
- Data Cleaning & Standardization: Use FME and SuperMap tools to harmonize datasets.
- 3D Asset Modeling: Create detailed 3D representations of waste facilities and infrastructure.
- Visualization & Analytics: Develop operational dashboards for performance monitoring.
- API Integration: Establish data exchange layers with IoT systems.
- Training & Knowledge Transfer: Ensure sustainability through staff capability development.

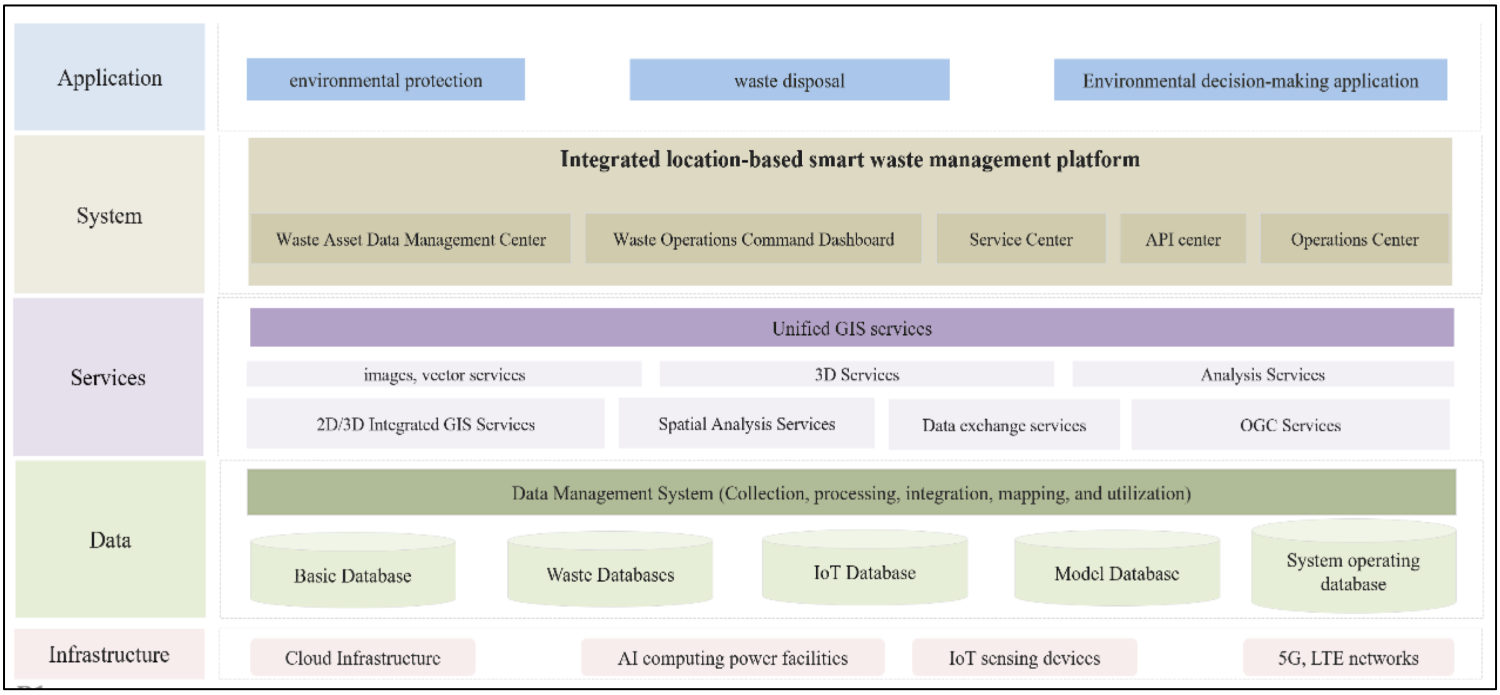


Figure 2: Layered Architecture of the Integrated Smart Waste Management Platform

Detailed Methodology Steps

Step 1 – Assessment and Data Audit

- Requirements Workshops: Conduct kickoff sessions with be'ah's operational, GIS, and IT teams to define objectives and deliverables.
- System Mapping: Document current data sources—GIS, SCADA, IoT feeds, and waste-management systems—to identify integration points.
- Data Profiling and Gap Analysis: Evaluate completeness, spatial accuracy, and attribute consistency; define missing datasets.

Deliverables:

Project Implementation Plan | Data Assessment Report | System Architecture Blueprint

Step 2 – Data Cleaning, Integration and Standardization

- Unified Data Access: Establish a single ingestion layer to collect real-time data from landfills, transport vehicles, treatment plants, and smart bins.
- Data Cleaning and Pre-Processing: Format conversion, denoising, outlier removal, and completion of missing values; harmonize coordinate systems and time series.
- Standardized Data Model: Develop a unified schema covering waste types, treatment processes, asset status, and sensor parameters to ensure structural consistency.

- Secure Data Storage: Build a highly available cloud database and data warehouse supporting large-scale time-series storage and rapid retrieval.
- Data Governance: Implement encryption, role-based access control, logging, and automated backups in line with be'ah's cybersecurity policies.

Deliverables:
Validated Database Repository | Geospatial Data Model Document | Metadata Catalog & Access Protocols

Step 3 – 3D Asset Modeling and Visualization

- Digital Twin Generation: Create 3D models of waste facilities, transfer stations, and vehicles using SuperMap 3D Engine integrated with IoT data layers.
- Visualization Configuration: Deploy 2D/3D map scenes and OCC dashboards capable of real-time spatial interaction and operational monitoring.
- Spatial and Predictive Analytics: Incorporate training datasets to enable AI/ML processes for waste prediction, route optimization, and anomaly detection.
- Scenario Simulation: Provide what-if analysis for capacity forecasting, network load balancing, and emergency response planning.

Deliverables:
Operational 3D Digital Twin Environment | Analytics-Enabled Dashboard | Simulation Tools and Reports

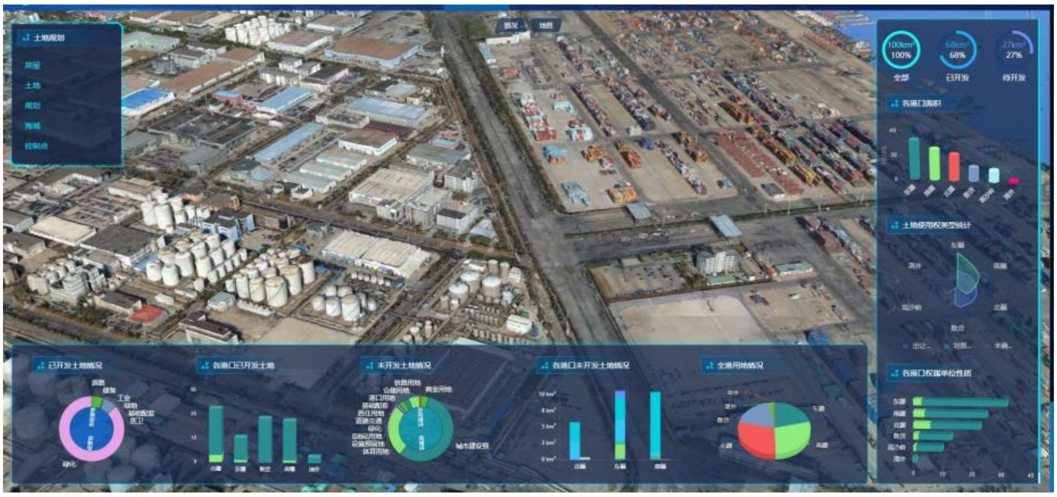
Figure 3: 3D Mesh Models of Infrastructure in Oman

Figure 4: 3D Mesh Models of Infrastructure in Oman

Figure 5: 3D Modeling is Sur Industrial Area

Figure 6: 3D Modeling is Sur Industrial Area


Overall Park Effect Display
Economic and Social Benefits
Indoor and Outdoor Intelligence
Park Evolution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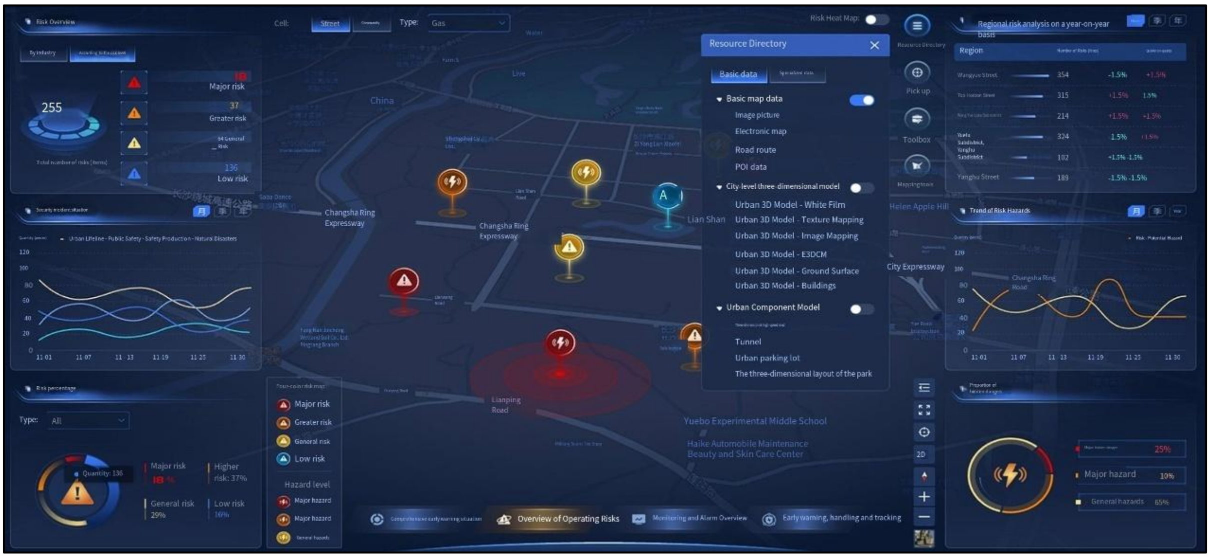
Step 4 – API Gateway and IoT Integration

- API Gateway Design: Develop a secure, standards-based interface for data exchange among GIS databases, IoT devices, and enterprise applications.
- IoT Device Docking: Integrate sensors measuring temperature, gas, vibration, leachate, meteorology, and PPE compliance using MQTT, Modbus, and RESTful API protocols.
- AI Algorithm Integration: Connect pre-trained recognition models for fire detection, illegal dumping, PPE compliance, and waste-flow optimization.
- Real-Time Data Synchronization: Ensure bidirectional communication between physical sensors and the digital-twin models for live asset-status updates.

Deliverables:

API Gateway Documentation | Integration Testing Report | AI/ML Algorithm Configuration

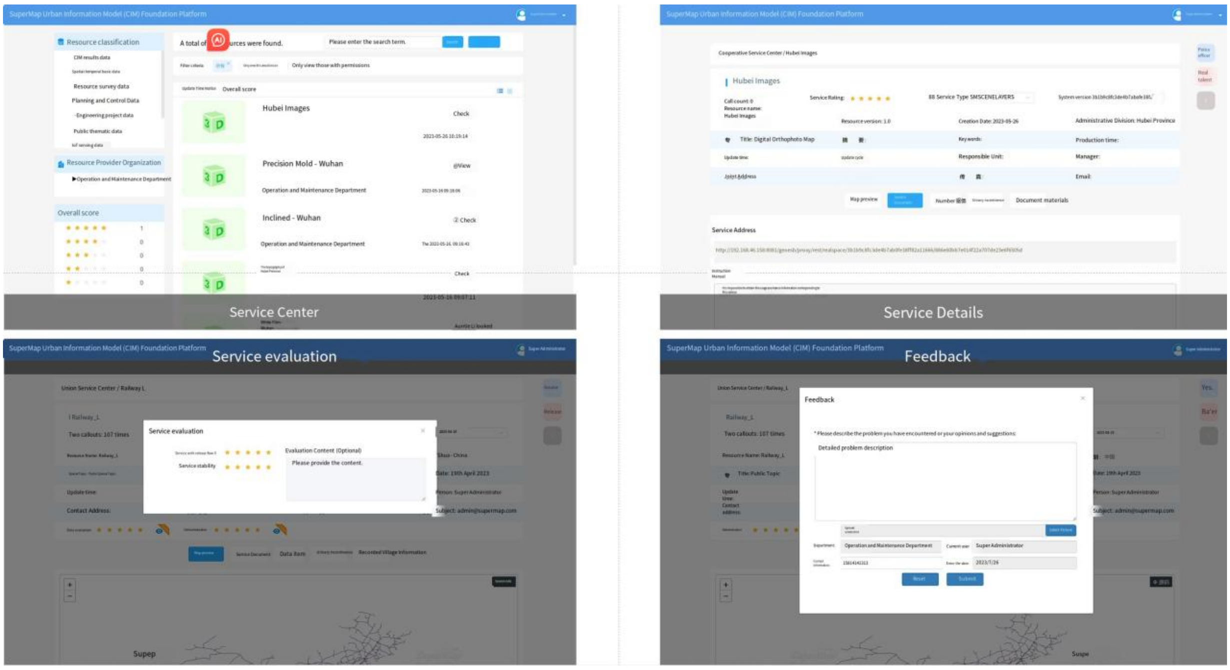


Step 5 – System Validation, QA and Security Testing

- Functional Testing: Validate feature completeness, 3D interactivity, and dashboard responsiveness.
- Integration Testing: Verify end-to-end data flow between GIS, IoT, and analytics components.
- Security Audit: Implement HTTPS encryption, device authentication, and access control; perform penetration testing.
- Monitoring and Alarms: Configure automated health-check and alerting mechanisms to detect interface failures and ensure high availability.
- Performance Benchmarking: Test throughput, latency, and scalability under simulated loads.

Deliverables:

QA Compliance Report | Security Audit Summary | System Performance Benchmarks

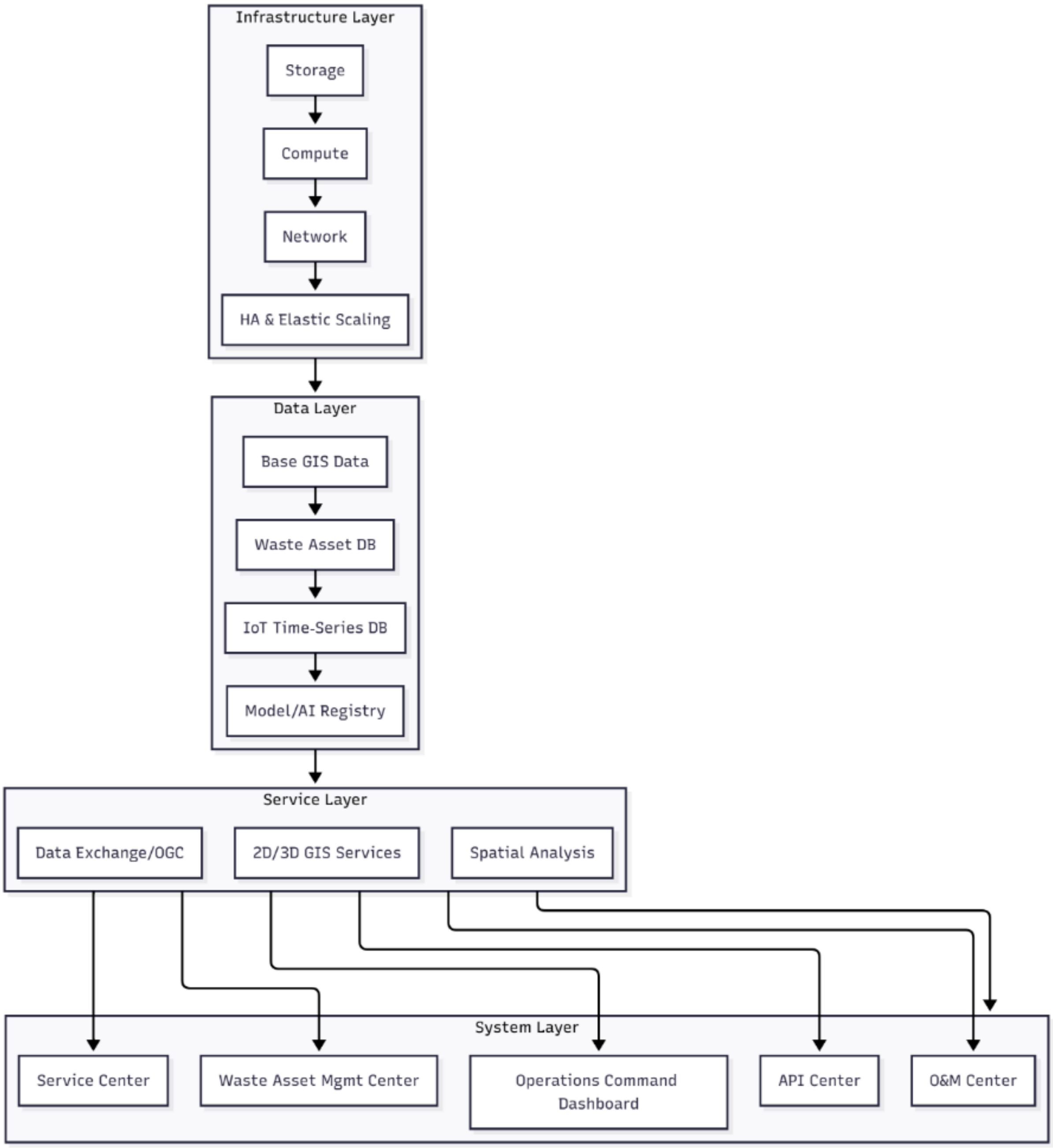


Step 6 – Training, Documentation and Handover

- Training Program: Conduct on-site and remote training for OCC operators, data analysts, and IT administrators in both Arabic and English.
- Documentation: Deliver comprehensive user, administrator, and API manuals detailing configuration, maintenance, and troubleshooting procedures.
- User Acceptance Testing (UAT): Facilitate live testing with be'ah teams to confirm operational readiness.
- System Transition & Support: Transfer ownership formally and provide 12 months of post-handover technical support.

Deliverables:

Training Mat



erials | UAT Sign-Off Documents | System Handover Certificate

Figure 7: our-Layer System Architecture of the be'ah Digital Twin Platform

Tools, Technologies and Standards

Domain	Primary Tools / Technologies	Standards & Frameworks
Geospatial Data	SuperMap iServer / iEdge / iObjects	ISO 19115 • OGC WMS/WFS
Database	PostgreSQL + PostGIS • MongoDB	SQL / JSON / S3M data standard
ETL & Processing	FME Workbench • Python (pandas/geopandas)	OGC Simple Features
3D Modeling	SuperMap 3D Engine • BIM Integration	IFC • S3M formats
API & IoT	RESTful API • MQTT • Modbus	OpenAPI 3.0 • ISO/IEC 30141
Analytics & AI	SuperMap Big Data GIS • Python ML	TensorFlow • scikit-learn
Security	HTTPS • JWT • OAuth2	ISO 27001 • be'ah IT Policy

Quality Control and Review Mechanism

- Weekly Progress Reviews with be'ah PMO team.
- Milestone-Based QA Checkpoints for each implementation phase.
- Formal Change Management Process for all scope adjustments.
- Requirement Traceability Matrix linking every client requirement to implemented features and test cases.

Expected Outcomes

- A unified, validated digital database for all waste-infrastructure assets.
- An operational 3D Digital Twin environment connected to live IoT streams.
- AI-driven analytics enabling predictive maintenance and optimized operations.
- Empowered be'ah personnel capable of sustaining and extending the platform.
- Through this methodology, Jeel Engineering and SuperMap ensure that the delivered system is technically sound, secure, scalable, and aligned with be'ah's digital transformation vision.
- System Architecture and Technology Stack

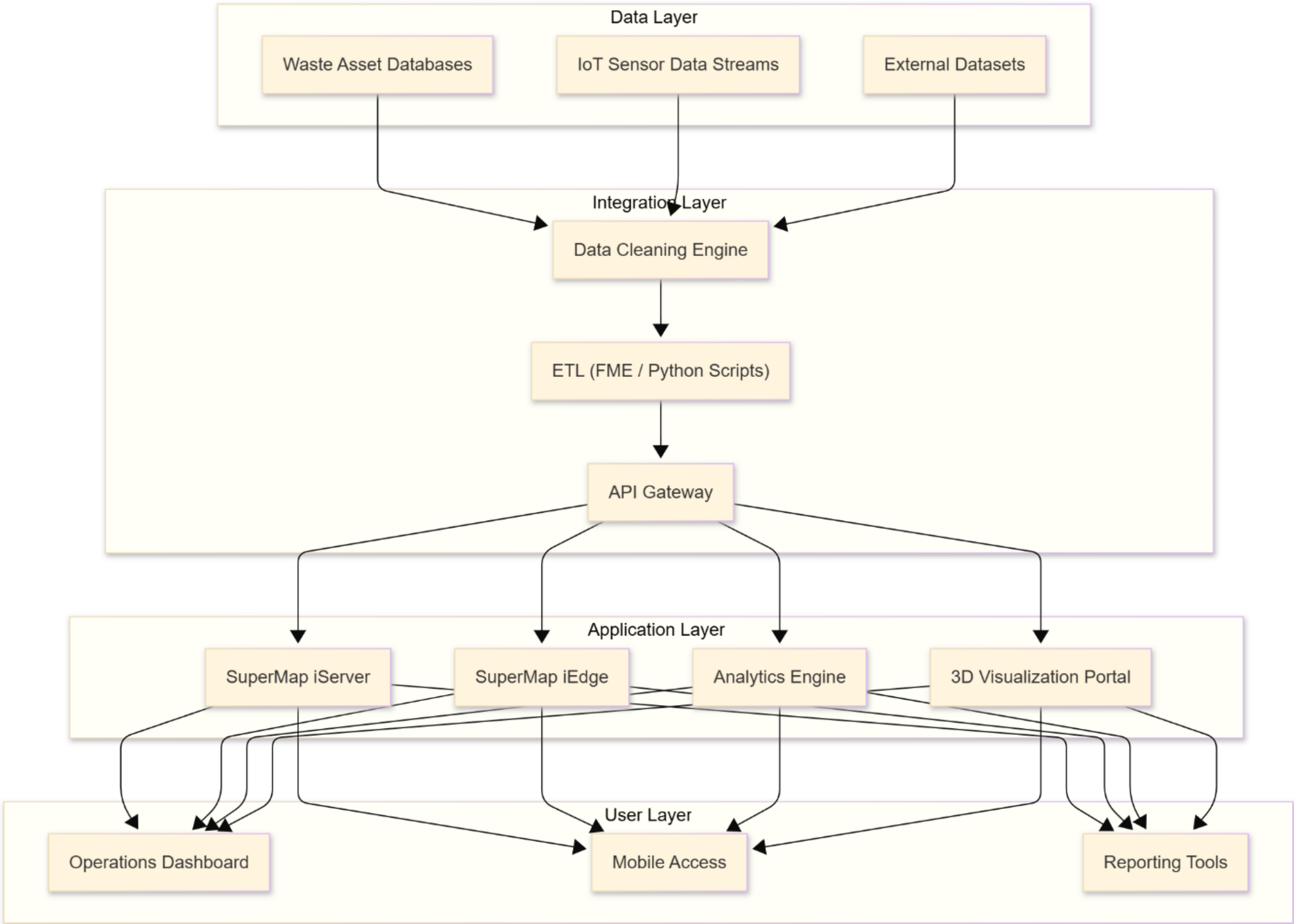


Figure 8: Integrated System Architecture Workflow

The proposed Waste Infrastructure Digital Twin Platform for be'ah is built on a modular, microservice-based, and cloud-ready architecture designed to ensure scalability, reliability, interoperability, and high performance.

It follows SuperMap's proven four-layer architectural model—Infrastructure Layer, Data Layer, Service Layer, and System Layer—integrated with a User Interaction Layer that delivers intelligent visualization and analytics to decision-makers.

Infrastructure Layer

- Adapted from SuperMap's scalable cloud architecture, this layer provides the foundational computing environment for the digital twin platform.
- Computing Resources: High-performance virtualized servers or physical clusters supporting parallel geoprocessing, AI computation, and 3D rendering.
- Storage Facilities: Redundant storage arrays (NAS/SAN) or cloud object storage for large raster, vector, LiDAR, and 3D datasets.
- Network & Security: Secured VPN access, HTTPS encryption, and segmented VLAN design ensuring protected data transit and rapid system response.
- Deployment Flexibility: Supports multiple configurations—on-premise, private cloud, public cloud, or hybrid—depending on be'ah's data-governance requirements.

- ➢ High Availability: Load-balanced servers and failover clustering to guarantee continuous uptime.

Data Layer

- ➢ The Data Layer is responsible for aggregating, storing, and standardizing multi-source spatial and non-spatial data.
  Drawing from SuperMap's "Data Construction" framework, this layer ensures that all environmental and operational datasets are integrated into a unified, secure repository.
- ➢ Multi-Source Integration: Combines imagery, vector data, 3D models, IoT sensor feeds, and AI model outputs into a unified geospatial schema.
- ➢ Data Standardization: Utilizes SuperMap's 2D/3D integrated data management and OGC-compliant data services (WMS, WFS, WMTS).
- ➢ Database Technology: Built on PostgreSQL/PostGIS for structured spatial data and MongoDB or HDFS for large unstructured or time-series datasets.
- ➢ Security & Access Control: Enforces encryption, user authentication, logging, and multi-level permission management.
- ➢ Data Lifecycle Support: Enables full lifecycle management—acquisition → cleaning → storage → sharing → archival—ensuring traceability and data provenance.

Service Layer

- ➢ The Service Layer exposes the core geospatial and analytical services that power all upper-level applications.
  It aligns with the SuperMap distributed-GIS framework, ensuring flexible service orchestration and dynamic scalability.

Service Category	Description
GIS Core Services	2D and 3D spatial data query, visualization, and analysis services (buffer, overlay, network, terrain, and volumetric analysis).
Spatial Analysis Engine	Supports over 600+ spatial algorithms including routing, hot-spot analysis, and coverage optimization.
Data Exchange Services	Handles REST/JSON/XML data exchange between external systems, IoT devices, and analytics modules.
AI & Big Data Services	Integrates ML models for prediction, anomaly detection, and route optimization; supports Python and TensorFlow pipelines.
OGC & Interoperability Services	Ensures full compliance with OGC standards (WMS, WFS, WMTS, GeoJSON) for cross-system compatibility.

System Layer

This layer hosts the functional applications and digital-twin modules customized for be'ah. Each module interacts with the service layer to deliver its designated operational functions:

- ➢ Waste Asset Management Center: Integrates geospatial, environmental, and sensor data into 2D/3D asset visualization dashboards.
- ➢ Operations Command Dashboard (OCC): Provides real-time situational awareness, KPI tracking, and performance analytics.

- Service Center: Manages map resources, style layers, and permission control; ensures seamless multi-departmental collaboration.
- API Center: Acts as the gateway for developers—offering SDKs (JavaScript, Python, Java), sample code, and API documentation for integration.
- Operation & Maintenance Center: Supports log monitoring, role-based access control, and bilingual (Arabic/English) interface management.
- User Interaction Layer
- At the top of the stack, the User Interaction Layer provides the visualization, monitoring, and reporting tools used by be'ah operators, analysts, and managers.
- Operations Dashboard: Web-based OCC interface showing real-time collection, transportation, and landfill operations.
- Mobile & Field Access: Responsive design allowing field teams to update or view operational data via mobile devices.
- Reporting and Analytics Tools: Enable ad-hoc queries, trend analysis, and data exports for planning and policy development.
- Bilingual Interface: Fully supports Arabic/English environments with right-to-left (RTL) formatting for Arabic users.

Technology Stack Summary

Category	Technologies / Tools	Key Features
GIS Platform	SuperMap iServer, iEdge, iObjects, iPortal	2D/3D integration, spatial analysis, distributed services
Database	PostgreSQL/PostGIS, MongoDB, HDFS	Spatial + unstructured data management, scalability
ETL / Integration	FME Workbench, Python (geopandas, pandas)	Automated data import, cleaning, transformation
3D Engine	SuperMap 3D Engine, BIM Integration	High-performance 3D rendering and analysis
API / IoT Layer	RESTful APIs, MQTT, Modbus, WebSocket	Real-time data exchange and synchronization
Web / Mobile Interface	SuperMap iClient JS/3D, ReactJS, HTML5	Cross-platform UI with dynamic rendering
Analytics / AI	SuperMap Big Data GIS, Python ML (TensorFlow, scikit-learn)	Predictive analytics, waste forecasting
Security Framework	HTTPS, OAuth2, JWT, Role-based Access	End-to-end data protection and secure authentication
Deployment	Docker, Kubernetes, Nginx	Containerization, auto-scaling, load balancing

Key Architectural Strengths

Drawing directly from SuperMap's enterprise platform advantages:

- Massive Environmental Data Management: Efficient storage and visualization of multi-source heterogeneous datasets (vector, imagery, BIM, LiDAR).
- 2D/3D Integrated Visualization: Unified management of 2D and 3D data models for real-time spatial analytics.

- Cross-Platform Flexibility: Runs seamlessly on Windows/Linux and x86/ARM architectures.
- Microservice Scalability: Containerized deployment using Kubernetes + Docker enables horizontal scaling and continuous delivery.
- AI and Big-Data Integration: Built-in support for machine learning frameworks and real-time IoT analytics.
- Bilingual, Localized Interface: Arabic/English support with RTL layout compliance for local usability.
- High-Performance Service Publishing: Load-balanced GIS services guarantee high concurrency and system responsiveness.
- Alignment with be’ah IT and Cybersecurity Policies
- Data Sovereignty: Supports on-premises or Oman-based private-cloud deployment to comply with local data-residency laws.
- Encryption Standards: Implements HTTPS/TLS 1.3 for all communications and AES-256 for data storage.
- Identity & Access Control: Multi-factor authentication and granular permissions for administrators, operators, and API consumers.
- Audit & Monitoring: Centralized logging and real-time system health dashboards to ensure accountability and up time.

Expected Benefits

- Unified architecture enabling real-time digital-twin operations and AI-driven analytics.
- Simplified data exchange and integration through standardized APIs.
- Scalable, cloud-native infrastructure supporting future expansion to other environmental domains.
- Strong alignment with Oman’s Vision 2040 and national digital-governance principles.

Implementation Plan

The implementation of the be’ah Digital Twin Platform will be carried out through a phased, milestone-based delivery approach spanning 12 months.
The plan ensures parallel progress across data integration, platform development, IoT interfacing, testing, and capacity building — with continuous coordination between Jeel Engineering (implementation partner) and SuperMap Software Co., Ltd. (technology provider).

Implementation Strategy

The overall strategy follows five major phases:

Phase	Name	Duration	Objective
Phase 1	Inception and Detailed Design	Month 1	Defining scope, requirements, and architecture; finalize design and data model.
Phase 2	Data Engineering and Repository Setup	Months 2–4	Acquire, clean, validate, and integrate waste datasets and IoT data feeds.
Phase 3	Platform Development and 3D Modeling	Months 5–7	Develop system modules, dashboards, and 3D visualization environment.

Phase 4	Integration, Testing, and Optimization	Months 8–10	Integrate APIs, perform QA, validate IoT connectivity, and optimize performance.
Phase 5	Training, Handover, and Support	Months 11–12	Deliver training, documentation, final testing, and commence warranty support.

Work Breakdown Structure (WBS)

The following WBS defines hierarchical activities and deliverables:

WBS ID	Phase / Activity	Deliverables / Outputs	Responsible Team / Role
1.0	Project Management & Coordination		Project Manager (Jeel Engineering)
1.1	Project initiation & kick-off	Kick-off report, project charter	PM / APM
1.2	Stakeholder coordination & communication plan	Communication matrix	PM / APM
1.3	Project scheduling, monitoring & reporting	Weekly & monthly progress reports	PM / APM
1.4	Quality control & risk management	QA checklist, risk register	QA Engineer
1.5	Change management & documentation control	Change log, versioned documentation	PM
2.0	System Design & Data Assessment		System Architect / GIS Lead
2.1	Requirement gathering & gap analysis	Requirements specification document	PM / System Architect
2.2	Review of existing GIS, IoT & operational data	Data audit report	GIS Lead
2.3	Define system architecture & technical design	System Design Document (SDD)	Architect / SuperMap Advisor
2.4	Develop conceptual & logical data models	Data model diagrams (ERD)	GIS Team
2.5	Finalize project plan & implementation schedule	Approved implementation plan	PM / be'ah PMO
3.0	Data Preparation & Integration		Data Integration Lead
3.1	Establish unified data access mechanism	Data access framework	Data Engineer

3.2	Perform data cleaning & validation	Validated dataset report	GIS / Data Engineer
3.3	Standardize schema & coordinate systems	Unified schema definitions	GIS Lead
3.4	Integrate GIS, IoT & AI datasets	Consolidated enterprise geodatabase	Data Engineer / API Specialist
3.5	Implement data security, backup & recovery	Security configuration, backup policies	IT Admin
4.0	Platform & Application Development		Development Team / SuperMap
4.1	Configure SuperMap components (iServer, iEdge, iPortal)	Functional platform environment	SuperMap Technical Advisor
4.2	Develop API Center	Functional interfaces & SDKs	Back-End Developer
4.3	Implement 3D visualization & bilingual UI	3D interactive bilingual interface	UI/3D Designer
5.0	API Gateway & IoT Integration		Integration & IoT Team
5.1	Design RESTful APIs	API documentation & endpoints	Integration Specialist
5.2	Integrate IoT sensors (temperature, gas, PPE, etc.)	Active IoT data feeds	IoT Engineer
5.3	Synchronize data with 3D digital twin	Real-time data synchronization	Integration Specialist
5.4	Dock AI/ML algorithms (fire detection, route optimization)	AI integration report	AI Developer
5.5	Validate communication protocols (MQTT, Modbus, HTTP)	Connectivity testing report	Integration Engineer
6.0	Testing & Validation		QA / Security Team
6.1	Conduct functional & integration testing	Functional test report	QA Engineer
6.2	Perform performance & load testing	Performance benchmark report	QA Engineer
6.3	Execute security audit & penetration testing	Security compliance report	Security Specialist
6.4	Conduct User Acceptance Testing (UAT)	UAT approval report	PM / be’ah PMO

6.5	Final system optimization	Optimization & issue resolution log	QA / Dev Team
7.0	Training, Documentation & Handover		Training & Support Team
7.1	Develop training materials & user guides	Training manuals & quick-reference guides	Trainer / Technical Writer
7.2	Conduct bilingual (Arabic/English) training	Training attendance reports	Trainer / PM
7.3	Deliver technical & API documentation	Final technical documentation set	Technical Writer
7.4	Execute final system handover	Handover certificate & closure report	PM / Client Representative
7.5	Initiate warranty & post-go-live support	Maintenance service plan	Support Engineer

Key Milestones

Milestone	Timeline	Output / Acceptance Criteria
M1: Project Kick-off	Week 1	Signed kickoff minutes, team mobilized
M2: Requirements & Design Approved	End of Month 1	Approved design and architecture document
M3: Data Integration Completed	End of Month 4	Validated geodatabase and unified schema
M4: Platform Modules Deployed	End of Month 7	Core modules operational in staging environment
M5: API and IoT Integration Completed	End of Month 9	Real-time data exchange demonstrated
M6: UAT & Security Testing Passed	End of Month 10	UAT sign-off by be’ah project committee
M7: Training & System Handover	End of Month 12	Formal handover, user training completion, warranty start

Risk Management and Mitigation

Risk	Impact	Mitigation
Data inconsistency or missing datasets	Medium	Early data audit and validation procedures in Phase 2
Integration delays with IoT systems	Medium	Parallel testing environment and API mockups during development
User adaptation challenges	Low	Extended bilingual training and on-site support post-deployment

Hardware or network issues	Medium	Cloud-based fallback deployment and redundancy design
Change in scope or priorities	Medium	Controlled change management and formal approval workflow

Platform Functional Capabilities

- The Digital Twin Platform for be’ah is designed to deliver powerful spatial visualization, analytics, and real-time operational control for waste infrastructure management.
- It integrates geospatial, operational, environmental, and sensor data into a unified environment to support intelligent decision-making and predictive maintenance.
- Built on SuperMap’s digital twin framework, the platform establishes three-dimensional models for key assets such as landfills, transfer stations, treatment facilities, waste transport vehicles, and smart waste bins — enabling real-time monitoring, spatial analytics, and scenario-based simulation.
- Building upon global best practices in landfill digitalization and environmental compliance, Jeel proposes the integration of smart landfill monitoring subsystems within the be’ah Digital Twin Platform.
- This component will extend beyond visualization to establish a data-driven environmental intelligence framework, enabling be’ah to continuously monitor air, water, soil, and operational conditions across its waste-management facilities.
- The design references proven implementations similar to those illustrated below, adapted to Oman’s regulatory, climatic, and operational context.

Spatial Analytics and Simulation Tools

Jeel Engineering, in partnership with SuperMap, can deploy advanced 3D spatial analytics such as gas-leakage traceability, diffusion modeling, and explosion-damage simulations within the be'ah Digital Twin Platform. These capabilities allow for safety-risk prediction, emergency-response planning, and rapid scenario visualization, enabling operational teams to assess potential hazards and take preventive action in real time.

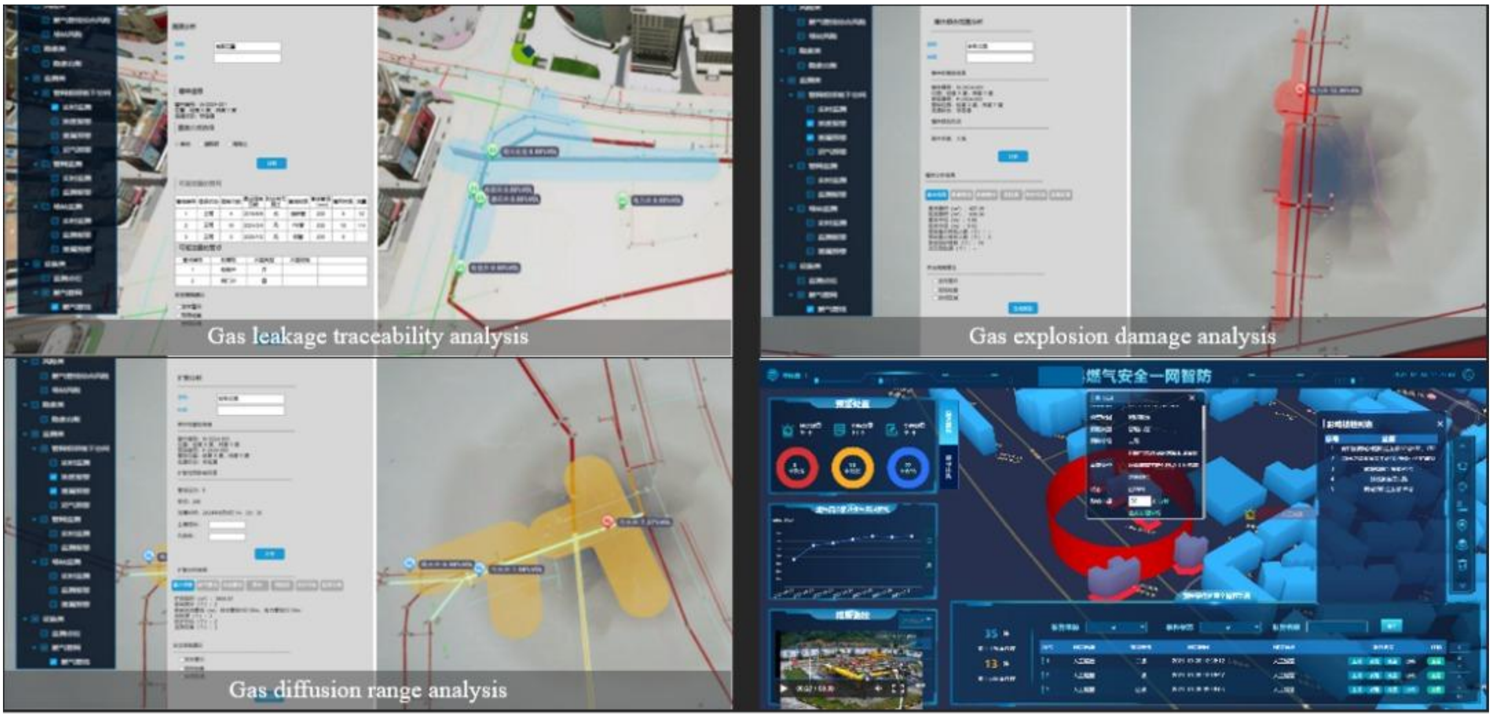


Figure 9: Real-time Gas Risk Simulation and Safety Analysis

Urban Traffic Digital Twin and Live Mobility Dashboard

This example demonstrates the platform's ability to visualize real-time traffic flow, congestion analytics, and sensor-based vehicle monitoring through a unified digital-twin interface. Jeel Engineering will adapt this architecture for be'ah's operations to monitor waste-collection vehicle fleets, route optimization, and service KPIs across governorates.

AI-Enabled Anomaly Detection and Visual Surveillance

- Jeel Engineering, in partnership with SuperMap, proposes the deployment of an AI-assisted anomaly-detection subsystem integrated with CCTV and UAV video feeds.
- This system applies real-time image recognition and machine-learning algorithms to automatically detect operational, environmental, and safety-related anomalies across all be’ah facilities.
- By leveraging the existing network of cameras and edge devices, the platform performs intelligent analytics including object detection, behavior recognition, and pattern deviation alerts.
- Detected events are instantly visualized within the Operations Command Center, generating automated alerts and maintenance tickets for immediate action.

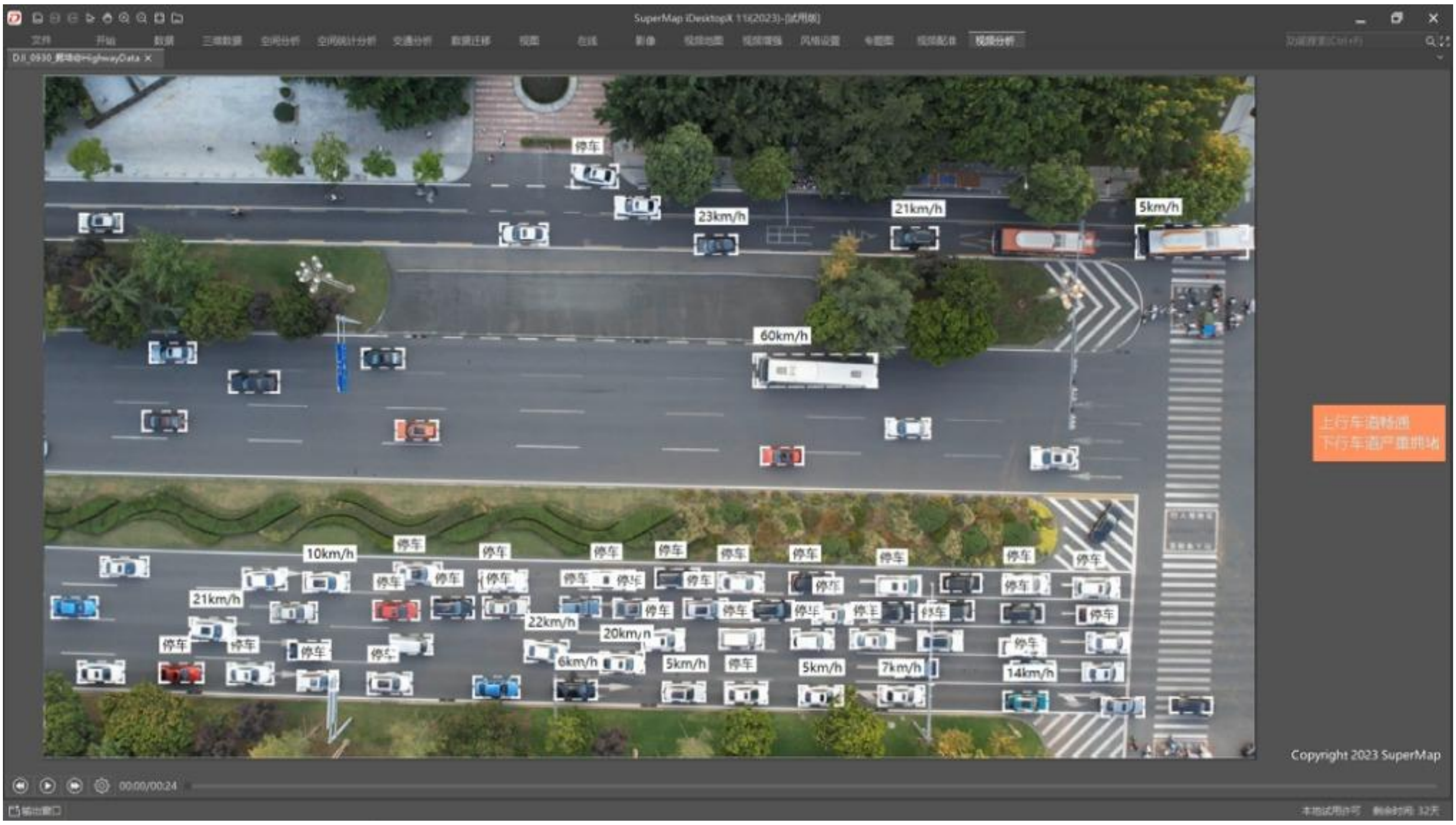


Figure 10: Vehicle-Speed and Movement Detection from CCTV Feeds

The AI engine analyzes high-resolution video streams to identify individual vehicles, estimate speeds, and detect congestion or stationary anomalies in real time.

For be’ah, this capability will be adapted to monitor waste-collection vehicle flow, unauthorized vehicle entry, and queue build-up at landfill gates, ensuring efficient operations and safety compliance.

Surface Defect and Infrastructure Monitoring

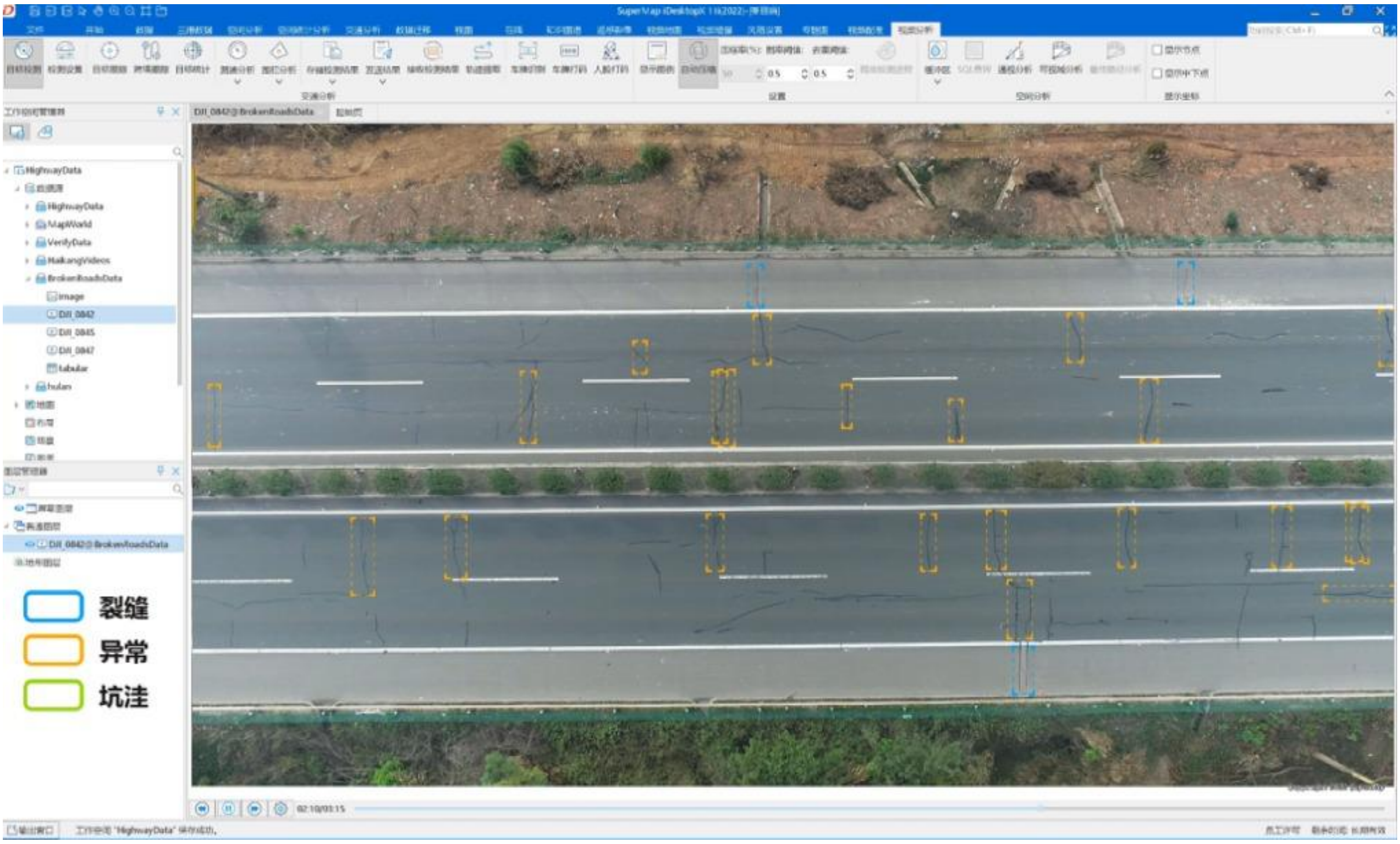


Figure 11: Automated Detection of Road Surface Defects

Using UAV or fixed-camera imagery, the system automatically recognizes cracks, potholes, and surface deterioration, classifying each by severity and type (highlighted in blue, orange, and green).

These results feed into the asset-maintenance dashboard, enabling preventive repair scheduling for access roads, leachate channels, and waste-transfer driveways.

Fire and Smoke Detection

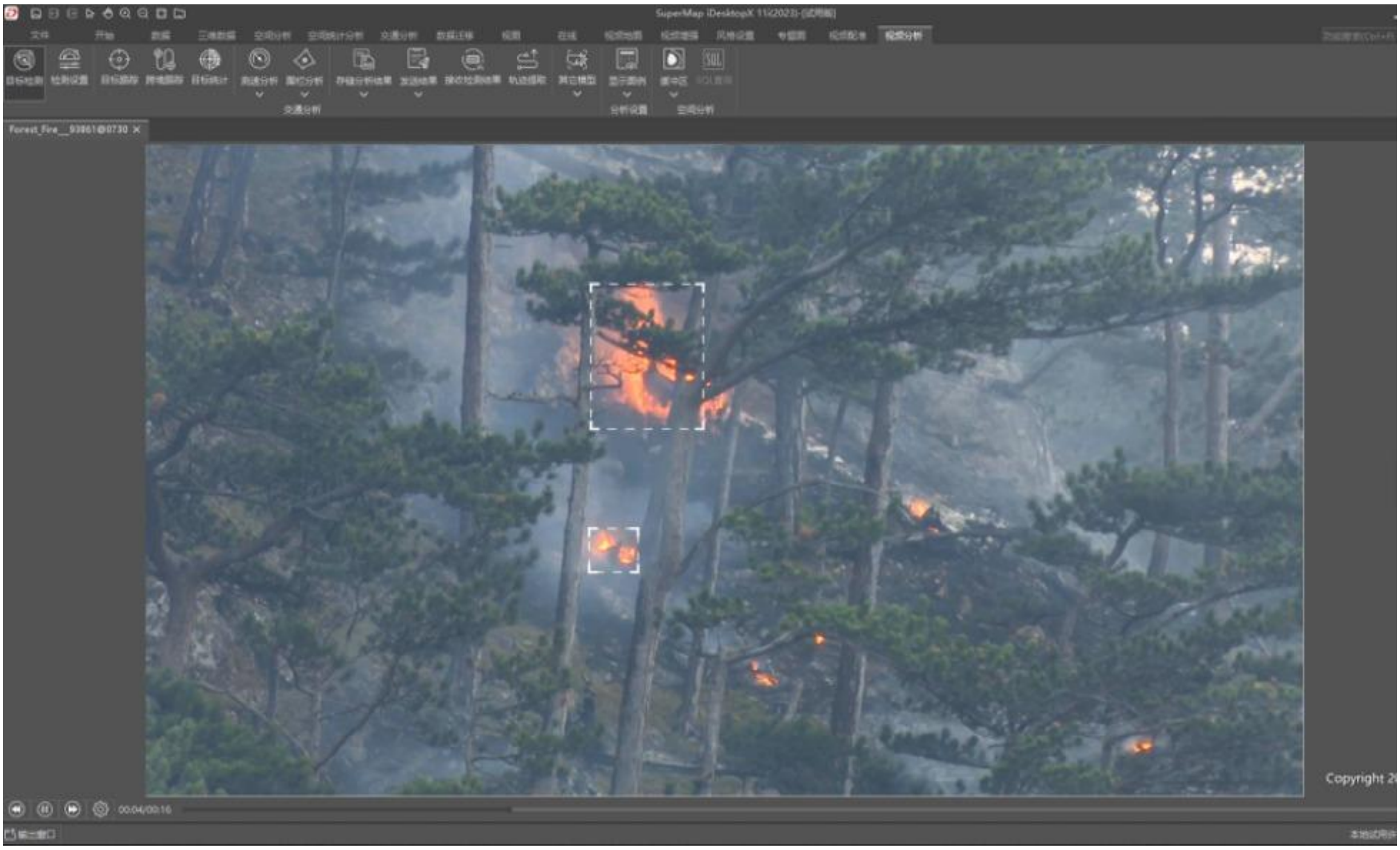


Figure 12: AI-Based Fire and Smoke Detection from Video Streams

Deep-learning models trained on environmental imagery detect early-stage fire and smoke plumes, automatically issuing alerts to the OCC.

This provides be'ah with a critical early-warning mechanism for landfill fires or spontaneous combustion events, allowing immediate mobilization of response teams.

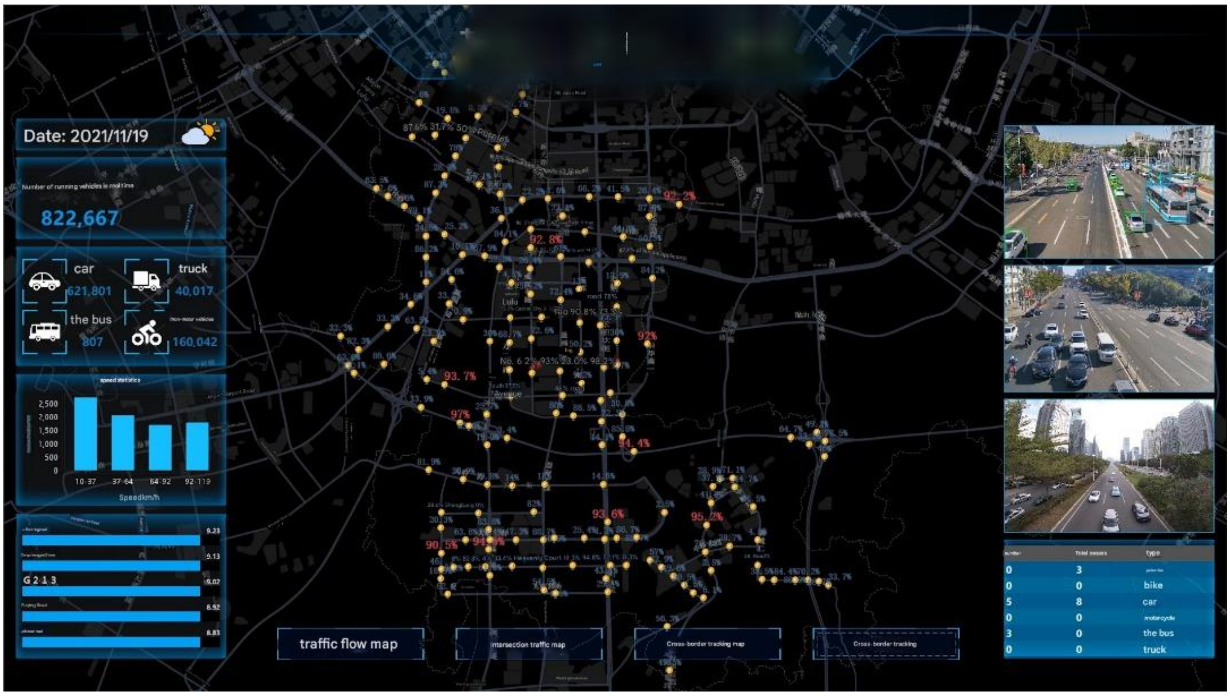
Site Activity and Worker-Safety Monitoring

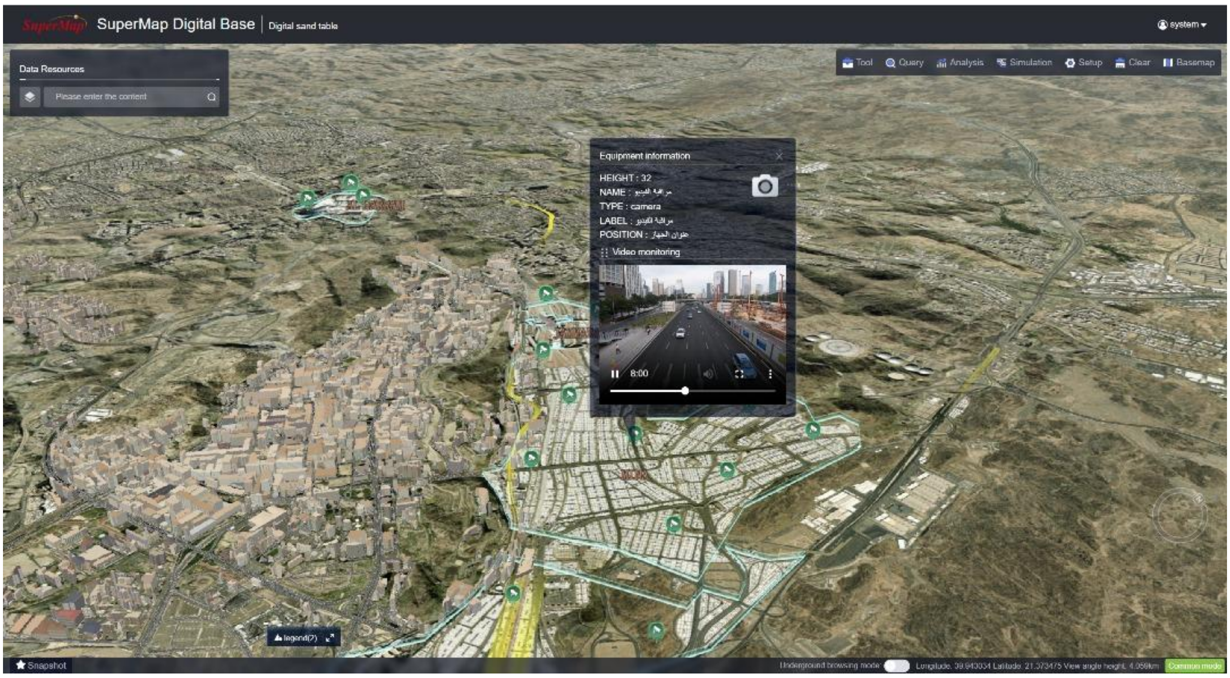
Figure 13: AI-Driven Worker-Safety and Activity Detection

The surveillance system identifies human presence, protective-gear compliance (helmet, vest), fall-risk activities, and restricted-area intrusion using computer-vision algorithms.

These detections are logged as safety events within the OCC and linked to HSE reports, ensuring continuous behavioral safety monitoring across be’ah’s operational facilities.

3D City Visualization and CCTV Integration

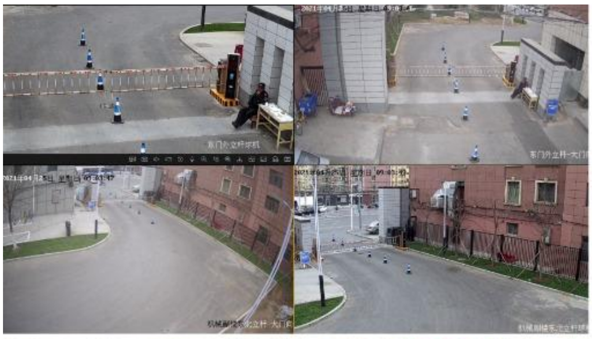




Demonstrating SuperMap's real-time video integration, this 3D digital environment enables operators to visualize camera locations, playback live feeds, and monitor field conditions directly from the 3D twin. Jeel will apply this same architecture at be'ah's landfill and transfer facilities to monitor site activities, vehicle movements, and safety compliance in real time.

Occupational Safety and Site Surveillance

The be’ah Digital Twin will include AI-powered video analytics capable of detecting safety-helmet compliance, restricted-area entry, and incident tracking through connected CCTV networks. Jeel Engineering will integrate these capabilities to enhance on-site occupational safety monitoring and ensure compliance with be’ah’s operational HSE standards.

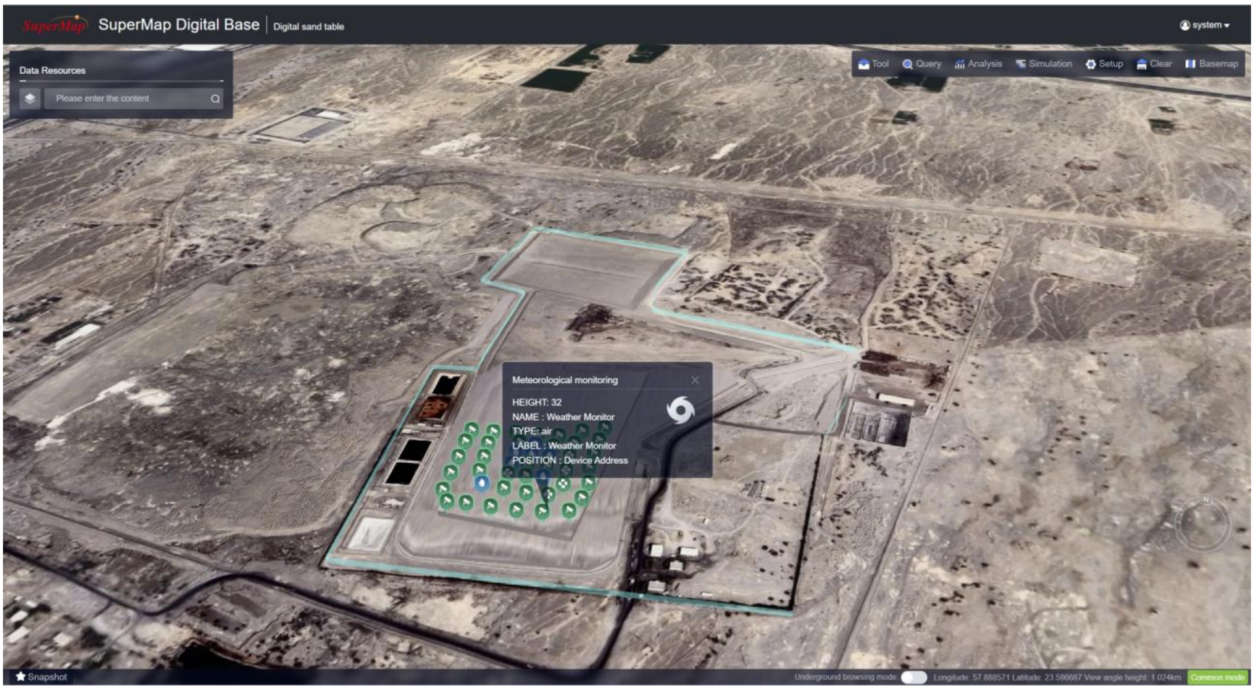


3D Construction and Facility Digital Twin (CPECC Example)

A representative digital twin of an industrial facility showing real-time integration of construction progress, environmental sensors (PM2.5, humidity, temperature), and asset health metrics. Jeel Engineering will replicate similar dashboards for be’ah’s treatment plants and waste-processing centers, enabling proactive maintenance and environmental compliance tracking.

Environmental Intelligence and Smart Landfill Monitoring

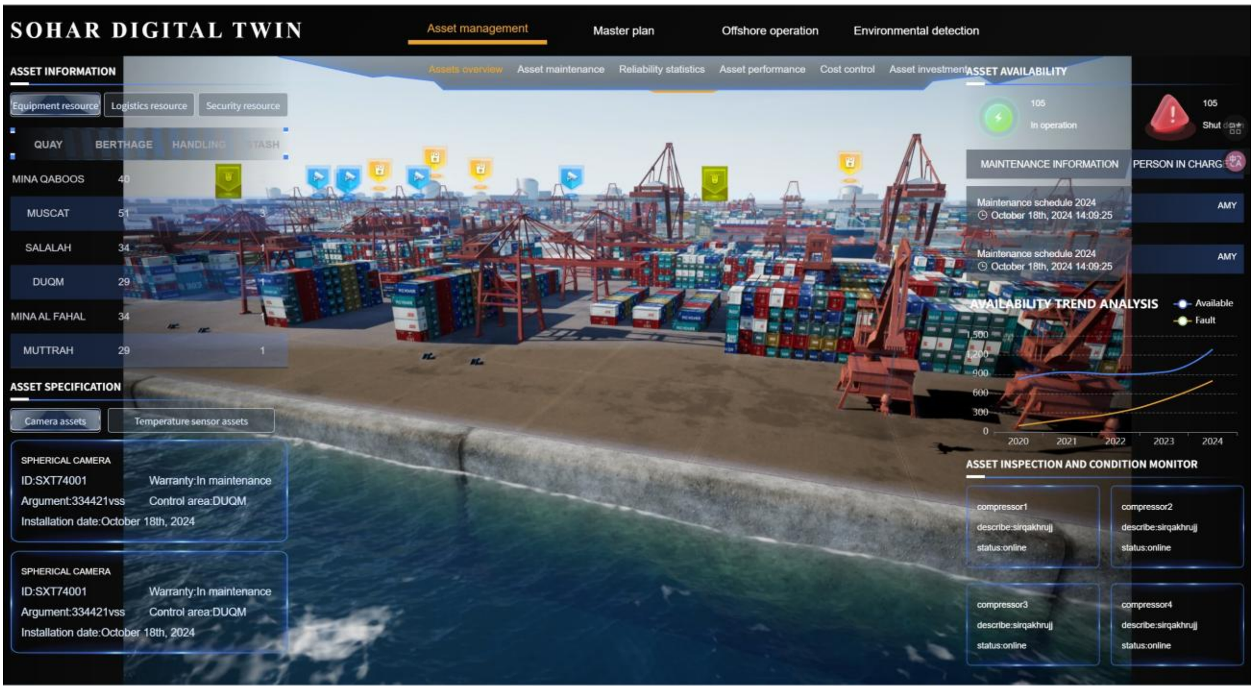
Integrated weather and air-quality sensors feed real-time data to the digital twin to monitor parameters such as temperature, wind speed, humidity, and particulate matter (PM2.5, PM10). Jeel will configure similar sensor nodes across landfill perimeters to generate dynamic odor dispersion and pollution heatmaps within the be'ah platform.

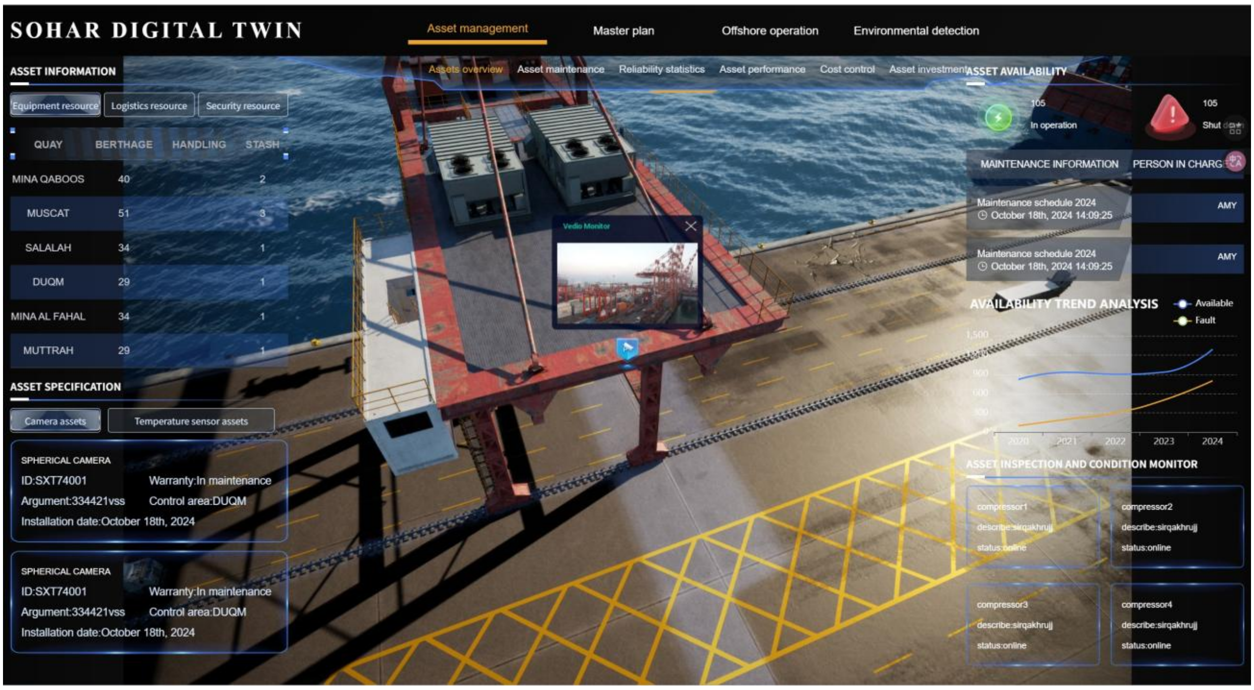


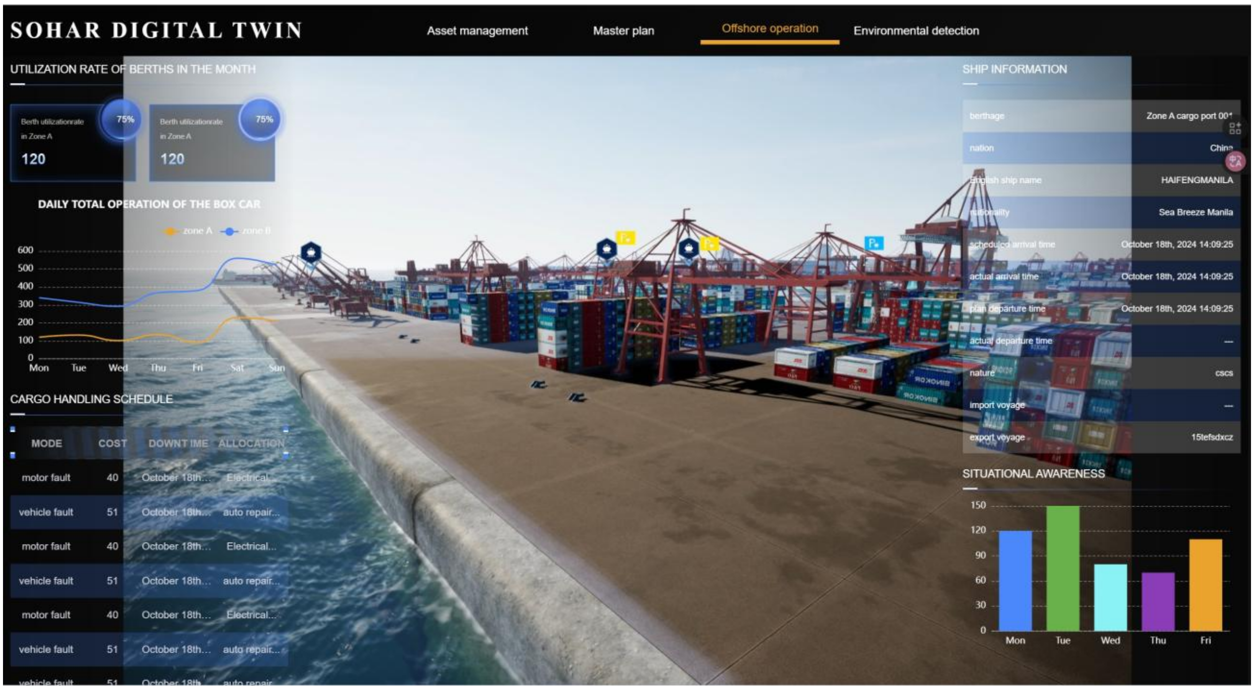
LOCAL PROJECT REFERENCES IN OMAN

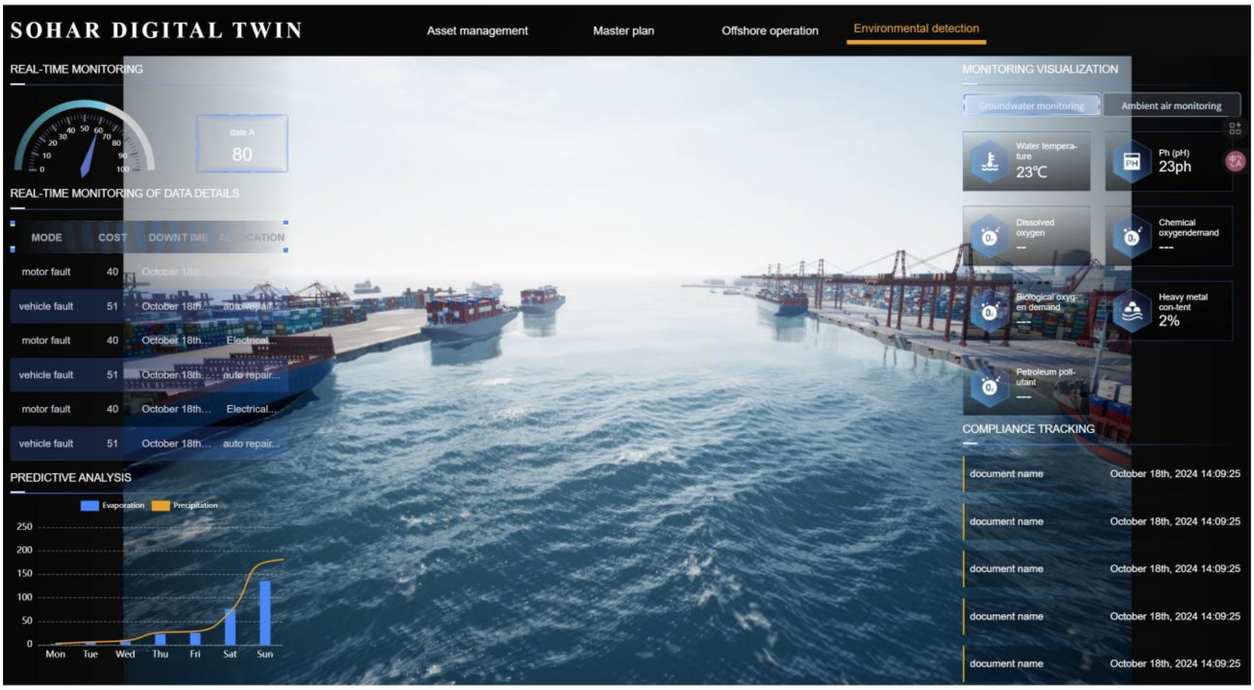
Digital Twin: Asset Maintenance and Performance Dashboard

A real-world Oman-based implementation powered by SuperMap, this example illustrates Jeel's capability to manage asset performance, maintenance scheduling, and reliability analytics. The same architecture will be extended for be'ah to monitor equipment uptime, fault trends, and predictive maintenance across waste-handling and recycling facilities.






SOHAR DIGITAL TWIN
Asset management
Master plan
Offshore operation
Environmental detection
UTILIZATION RATE OF BERTHS IN THE MONTH
Berth utilizationrate in Zone A
75%
120
Berth utilizationrate in Zone A
75%
120
DAILY TOTAL OPERATION OF THE BOX CAR
zone A
zone B
600
500
400
300
200
100
0
Mon Tue Wed Thu Fri Sat Sun
CARGO HANDLING SCHEDULE
MODE COST DOWNT IME ALLOCATION
motor fault 40 October 18th… Electrical…
vehicle fault 51 October 18th… auto repair…
motor fault 40 October 18th… Electrical…
vehicle fault 51 October 18th… auto repair…
motor fault 40 October 18th… Electrical…
vehicle fault 51 October 18th… auto repair…
SHIP INFORMATION
berthage Zone A cargo port 001
nation China
English ship name HAIFENGMANILA
nationality Sea Breeze Manila
scheduled arrival time October 18th, 2024 14:09:25
actual arrival time October 18th, 2024 14:09:25
plan departure time October 18th, 2024 14:09:25
actual departure time —
nature cscs
import voyage —
export voyage 15tefsdxcz
SITUATIONAL AWARENESS
150
120
90
60
30
0
Mon Tue Wed Thu Fri


SOHAR DIGITAL TWIN
Asset management
Master plan
Offshore operation
Environmental detection
REAL-TIME MONITORING
0 10 20 30 40 50 60 70 80 90 100
Gate A
80
REAL-TIME MONITORING OF DATA DETAILS
MODE COST DOWNT IME ALLOCATION
motor fault 40
vehicle fault 51 October 18th… auto repair…
motor fault 40 October 18th… Electrical
vehicle fault 51 October 18th… auto repair…
motor fault 40 October 18th… Electrical…
vehicle fault 51 October 18th… auto repair…
PREDICTIVE ANALYSIS
Evaporation
Precipitation
250
200
150
100
50
0
Mon Tue Wed Thu Fri Sat Sun
MONITORING VISUALIZATION
Groundwater monitoring
Ambient air monitoring
Water temperature
23℃
Ph (pH)
23ph
Dissolved oxygen
--
Chemical oxygendemand

Biological oxygen demand

Heavy metal content
2%
Petroleum pollutant

COMPLIANCE TRACKING
document name October 18th, 2024 14:09:25
document name October 18th, 2024 14:09:25
document name October 18th, 2024 14:09:25
document name October 18th, 2024 14:09:25
document name October 18th, 2024 14:09:25


2025-11-4 20:01:47
Digital Twin Command Dashboard
Project overview
Duration (days) 1,712.0
investment (million) 1,712.0
Building (m²) 1,712.0
pipeline corridor (m) 1,712.0
Construction site attendance
total people 1,712.0
attendance 1,712.0
speed enforcement
environmental monitoring
28 °C temperature
16 humidity
PM2.5 34 air quality
PM10 37 air quality
Quality monitoring
to be rectified 15
pending review 25
done 35
security management
to be rectified 50
pending review 40
done 100
Surveillance
Total number of reminders 12
Early warning 25
Raise the alarm 22
malfunctions 16
Project schedule management (300 days of work, 200 days constructed)
Normal progress
Actual progress: 60%
Planned Progress: 60%
Extension of mandate: 0
Construction preparation 2024-10-14 12:00 fulfil
Groundwork construction 2024-11-14 12:00 fulfil
Underground Construction 2024-12-14 12:00 toward
clean-up and acceptance phase 2025-01-14 12:00 not yet started

Site Context and Buffer Management

- High-resolution satellite imagery and UAV data will be used to define environmental-sensitivity zones surrounding each waste site — such as schools, residential areas, river corridors, and agricultural land.
  These zones will be integrated into the Digital Twin as geofenced constraint layers to automatically trigger alerts when activities or emissions exceed safe boundaries.
- 500 m buffer around educational or residential areas.
- Dynamic odor/noise modeling based on prevailing wind direction.
- Proximity-based vehicle routing optimization to minimize disturbance.
-

This approach mirrors global landfill-risk zoning methods (similar to Figure 9) but will be adapted using local Omani spatial datasets and live meteorological feeds.

Figure 14: Site context map showing MSW boundary, adjacent school, Pandu River corridor, and nearby residential locality—priority constraints for risk buffers, odor/noise management, and emergency planning.

Landfill Digital-Twin Model Construction

Each landfill will be modeled as a 3D multi-layer digital twin, capturing the full vertical structure — base liner, waste lifts, intermediate soil layers, and surface cover.

The model will store geotechnical attributes such as compaction, porosity, permeability, and shear strength, allowing predictive simulations for settlement and seepage.

Key model inputs include:

- Geometry of waste cells, berms, and drainage channels.
- Soil and liner characteristics from be'ah's design drawings.
- Borehole and monitoring-well data (where available).
- Leachate and gas network schematics.

This corresponds to the structural concept shown in Figure 10 below and will be built in SuperMap 3D using the S3M standard, integrated with IoT sensors and AI models.

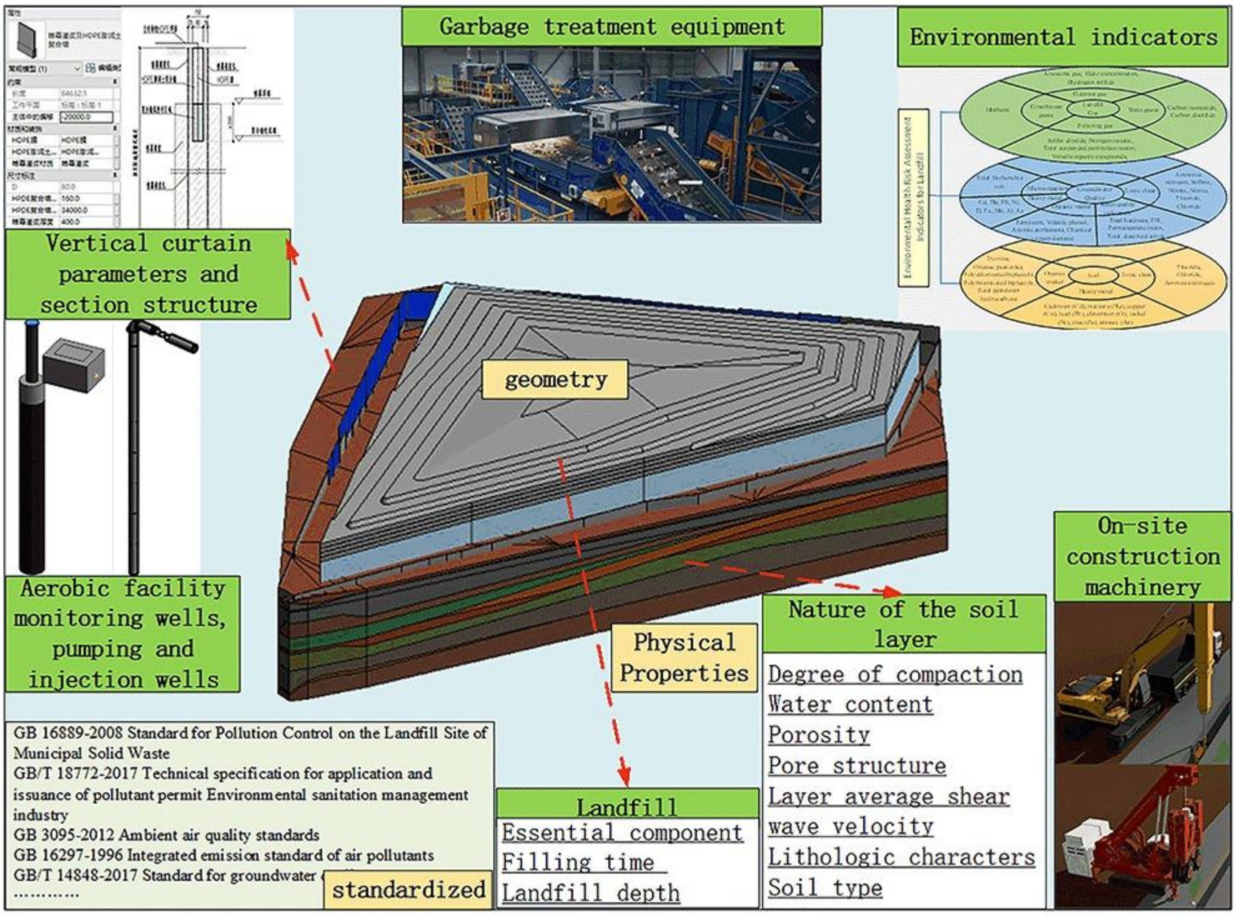


Figure 15: Landfill digital-twin concept: geometry, soil layers, monitoring wells, machinery zones, and compliance parameters aligned to air/groundwater standards—inputs to model/AI registry and OCC KPIs.

Leak Detection and Liner Integrity

Jeel proposes implementing digital geomembrane-integrity monitoring within the QA module. Sensors or portable probes will feed voltage-gradient readings to the platform, allowing the detection of liner punctures or leachate leaks.

The OCC dashboard will:

- Display the geomembrane grid in 2D/3D view.
- Mark detected anomalies as spatial events.
- Auto-generate maintenance tickets with timestamp, coordinates, and severity ranking.

This concept (Image 11) will be localized using RESTful API feeds from in-situ monitoring contractors, ensuring early detection and compliance with be'ah's environmental-safety requirements.

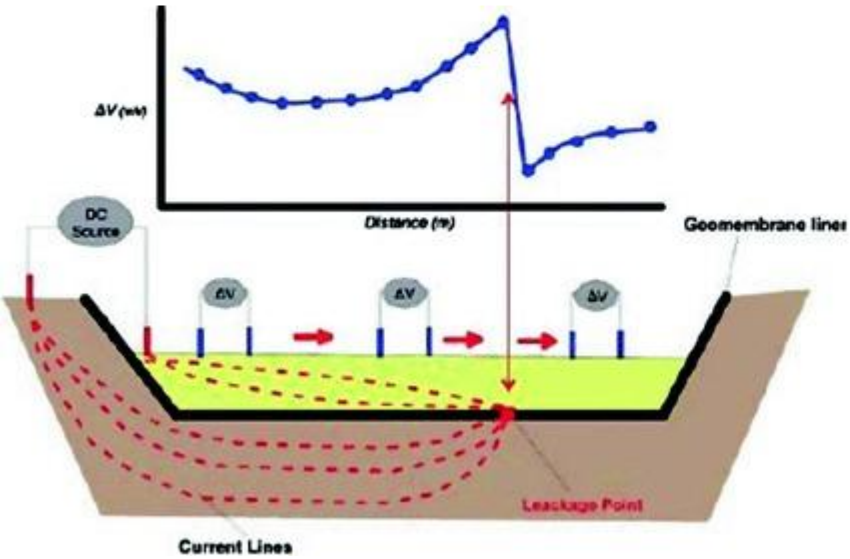


Figure 16: Geomembrane integrity monitoring concept (voltage/gradient method): current lines concentrate at defects; anomaly curve drives OCC leak-alert workflows.

Leachate and Gas-Collection Network Monitoring

The Digital Twin will visualize and monitor leachate pipelines, gas vents, and aerobic-decomposition zones in real time.

Sensors will capture key parameters — temperature, flow, pH, methane, CO_2, and pressure — feeding analytics to predict overflow or methane-emission risks.

Core features:

- 3D depiction of leachate flow direction and collection sumps.
- Pump-status tracking and inflow/outflow dashboards.
- Predictive modeling for aeration efficiency and fermentation temperature (50–70 °C).
- Automated alerts for abnormal trends in gas concentration or leachate levels.
-

This capability (Image 12) positions be'ah at the forefront of waste-site process intelligence.

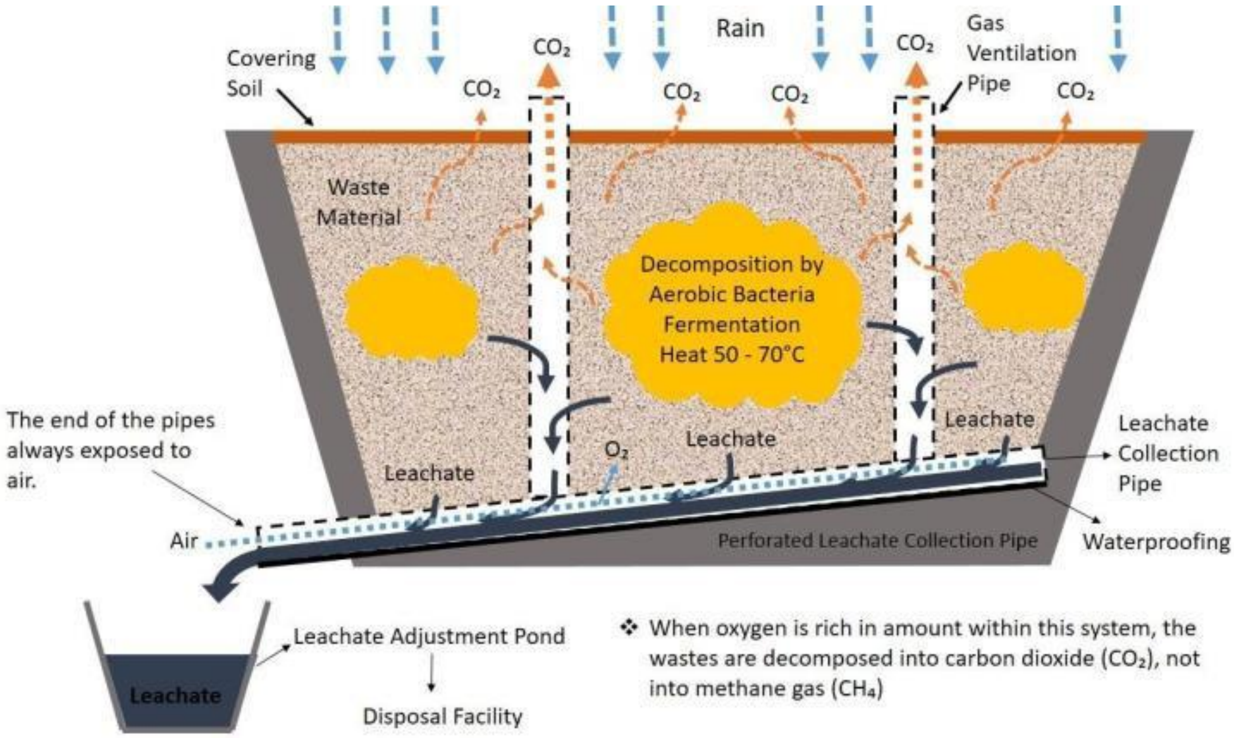


Figure 17: Leachate and gas management process: perforated pipe network, adjustment pond linkage, aerobic fermentation heat band (50–70 °C), and ventilation—mapped to sensors, alarms, and maintenance tickets.

Remote-Sensing Change Detection and Vegetation Health

Satellite and drone imagery will be periodically analyzed using NDVI (Normalized Difference Vegetation Index) and thermal indices to track site-surface changes, vegetation stress, and unauthorized waste accumulation.

Automated change-detection scripts will produce monthly thematic layers within the Digital Twin.

Deliverables:

- NDVI heatmaps showing vegetation recovery or stress on landfill caps.
- Thermal hotspot maps identifying potential smoldering zones or gas leaks.
- Temporal comparison dashboards (e.g., 2020 vs 2021 trend maps as in Image 5).

This remote-sensing integration supports be'ah's ESG reporting and early-warning system for environmental degradation.

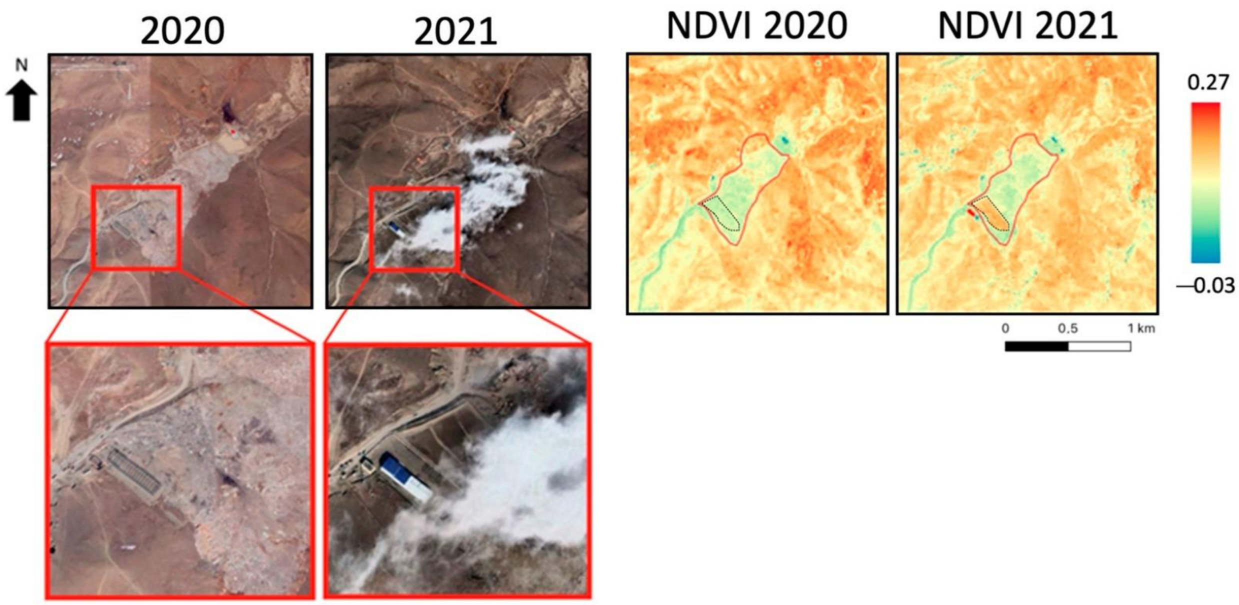


Figure 18: Remote-sensing change analysis: high-res imagery and NDVI 2020 vs 2021 for vegetation stress and smoke/heat anomalies—baseline for monthly compliance monitoring.

Operations Command Center (OCC) for Integrated Monitoring

At the center of this ecosystem is the Operations Command Center, an interactive 3D control room interface visualizing live field conditions.
All asset classes — heavy machinery, sensor nodes, weather stations, CCTVs, and network telemetry — will appear as real-time icons on the Digital Twin map.

Key OCC capabilities include:

- Gas, meteorological, and equipment data streaming in real time.
- Live dashboards for CO_2, CH_4, and leachate parameters.
- Predictive maintenance alerts for pumps and blowers.
- CCTV and drone video overlays for operational supervision.
- Unified alarm panel with multi-level thresholds and SLA-based response tracking.

This aligns with the integrated OCC visualization shown in Image 14 and forms the operational heart of the be’ah Digital Twin.

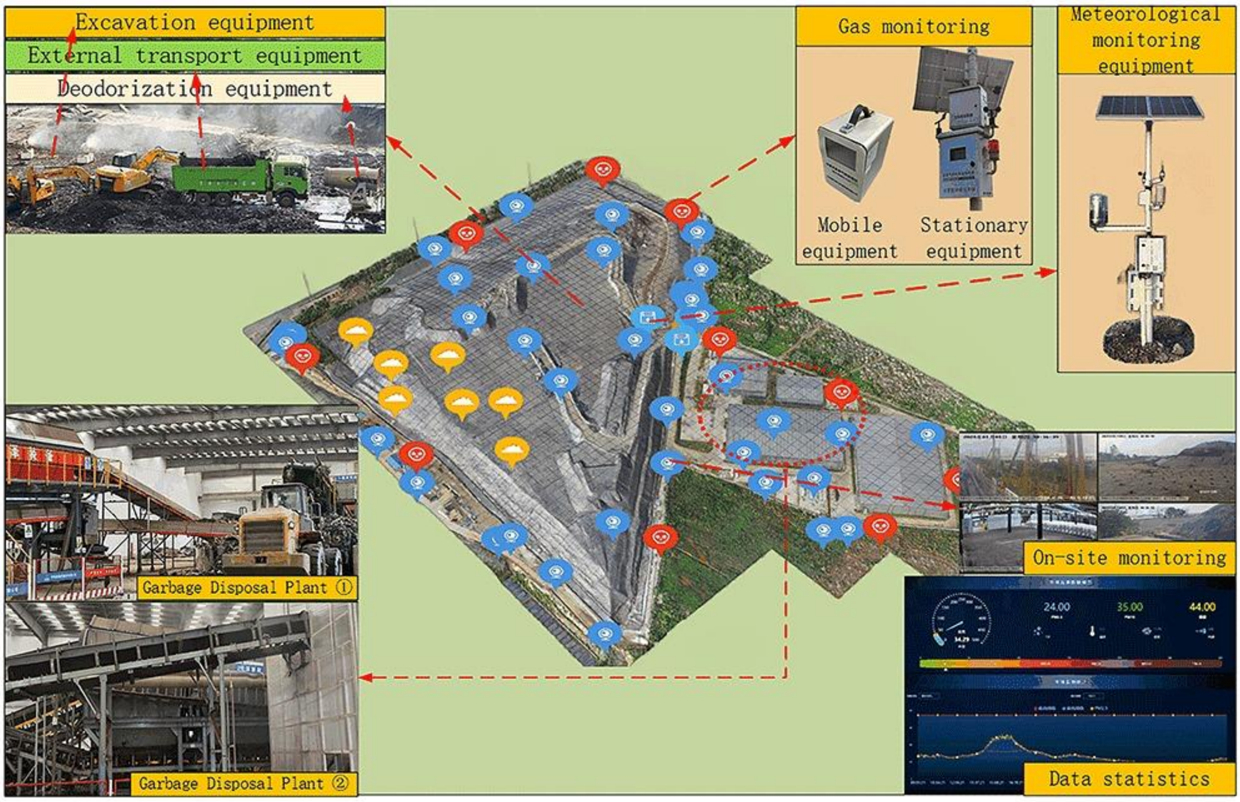


Figure 19: OCC situational layer: tagged equipment (excavation, transport, deodorization), gas & met stations, CCTV, and dashboards—unified icons, live states, and KPI panels.

Resource Directory

A centralized resource directory provides users with a structured and searchable repository of all available datasets, services, and assets.

- Resource Management: Organize published resources according to user-defined categories and view data quantities by type.
- Search & Discovery: Supports precise and fuzzy queries with intelligent recommendations based on metadata and usage history.
- Permission Control: Allows users to request access for restricted datasets directly through the interface.
- Metadata & Statistics: View detailed resource metadata, perform attribute-based statistical queries, and visualize resource distribution over time and space.
- Spatial Location: Instantly locate selected resources within the 2D/3D environment.

2D Map Operations

The 2D visualization environment enhances situational awareness and data interpretation through intuitive map navigation and query tools.

- Penetration Queries: Execute point, rectangle, or polygon-based queries with tabular and graphical outputs.
- Place Name Search: Search by geographic name or address.
- Roaming & Navigation: Smooth map panning and zooming with hawk-eye (overview) window.
- Legend Management: Display, reorder, or toggle thematic layers for clarity.
- 2D Tools and Utilities
- A suite of 2D analytical and utility tools supports deeper exploration and cartographic output.
- Advanced Search: Perform multi-dimensional attribute searches, grouping, and statistical plotting.
- Map Printing: Print or export the current map view, with custom legends, scale bars, compass, and authorship metadata.

3D Scene Operations

The 3D environment extends visualization into immersive, multi-level spaces — including surface and underground infrastructure.

- Thematic Queries: Click on any 3D feature to retrieve related asset information.
- Underground Mode: Explore buried networks and underground facilities.
- Address Search: Locate assets by name or address in the 3D scene.

3D Spatial Analysis

- Advanced 3D analytical functions support operational planning, engineering evaluation, and environmental simulation.
- Visibility & Intervisibility Analysis: Determine line-of-sight between observation points or along routes.
- Shadow & Solar Analysis: Simulate illumination, shadow duration, and daylight coverage for given time periods.
- Skyline Analysis: Generate skylines and height-limit visualizations for urban zones.
- Mass Haul & Cut/Fill Analysis: Compute excavation and fill volumes across project areas.
- Submergence Simulation: Model flood or water-level rise scenarios dynamically.
- Slope & Contour Analysis: Visualize gradient, aspect, and contour variations.

- Buffer & Overlay Analysis: Perform spatial proximity and set operations (intersection, merge, erase).

3D Tools and Interactions

- Interactive tools enhance data interpretation and scene exploration in both analytical and presentation contexts.
- Measurement Tools: Measure distance, area, height, or ground elevation.
- Split-Screen & Roller Shutter View: Compare data layers side-by-side interactively.
- Look-Around & Flight Modes: Orbit around assets or simulate drone-like fly-throughs of facilities.
- Scene Recording: Record and replay virtual inspection paths.
- Environmental Effects: Simulate weather (rain, snow), lighting, night scenes, and skybox conditions.
- Visualization Enhancement: Adjust transparency, contrast, hue, brightness, and light intensity.

Data Upload

- The platform supports direct import and display of multiple geospatial formats, including:
- TXT, SHP, CAD, and UDB files.
  Uploaded data is automatically rendered on the map and integrated into the database for analysis and visualization.

Annotations and Markups

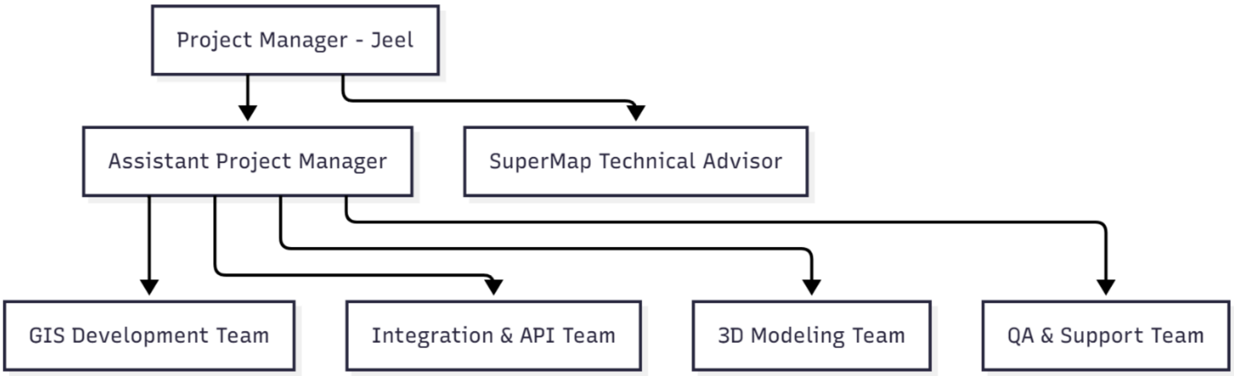
Users can add 2D and 3D annotations to enhance map communication and reporting.

- 2D Annotations: Points, lines, polygons, circles, and symbols with editable styles.
- 3D Annotations: Cylinders, cuboids, spheres, cones, and s3m models (e.g., waste bins, poles, vehicles).
- Annotation Layers: Organize and manage multiple annotation groups by theme or project.

Map Collections

- A convenient collections module allows users to bookmark, organize, and quickly access frequently used datasets or views.
- Catalog Management: Create, rename, and delete favorites directories.
- Quick Access: Automatically locate saved maps or scenes for recurring operational analysis.

Project Organization and Roles



- Project Manager: Overall delivery and coordination.
- GIS Developer: Data processing and platform customization.
- Integration Specialist: API gateway and IoT linkage.
- 3D Modeler: Asset reconstruction and visualization.
- QA Engineer: Testing, validation, and documentation.
- SuperMap Advisor: Platform configuration and advanced analytics.

Drone Operations

Jeel Engineering LLC is a leading provider of geospatial and engineering solutions in the Sultanate of Oman, offering end-to-end aerial survey services powered by cutting-edge drone technology and advanced data analytics. Leveraging a combination of high-precision UAV platforms, RTK/PPK georeferencing, and photogrammetric and LiDAR-based workflows, Jeel delivers accurate, reliable, and scalable aerial mapping solutions tailored to diverse sectors including infrastructure, utilities, construction, oil & gas, urban planning, and environmental monitoring.

Our aerial survey operations are built on a foundation of technical accuracy, regulatory compliance, and operational safety. Whether the objective is topographic base mapping, 3D modeling, volumetric analysis, or progress monitoring, we deliver georeferenced outputs that are compatible with leading CAD, GIS, and BIM platforms.

With a skilled team of certified UAV pilots, licensed survey engineers, and geospatial analysts, Jeel ensures full lifecycle project support — from initial flight planning to ground control deployment, data capture, processing, and final deliverables. We adhere to globally recognized standards such as ASPRS and RICS and operate in alignment with Oman’s Civil Aviation Authority (CAA) regulations.

Jeel’s drone-based survey services empower clients to make informed decisions, reduce field time and costs, and accelerate project execution timelines — all while achieving centimeter-level accuracy.

Core Aerial Survey Services Offered

- High-resolution Orthophotography (1–5 cm GSD)
- Digital Elevation Models (DEM), Digital Terrain Models (DTM), and Digital Surface Models (DSM)
- 3D Point Clouds and mesh models (LAS/LAZ/OBJ formats)
- Contour mapping and terrain visualization
- Topographic base maps for design and engineering

- As-built documentation and progress monitoring
- Volumetric calculations (cut/fill, stockpile analysis)
- Feature extraction (roads, utilities, land parcels)
- Thermal and multispectral imaging (on request)
- Integration-ready outputs for AutoCAD, ArcGIS, Civil 3D, and BIM platforms
- Regulatory-compliant reports including accuracy assessments and flight logs
- Optional: AI-based object detection, dashboards, and change detection analytics

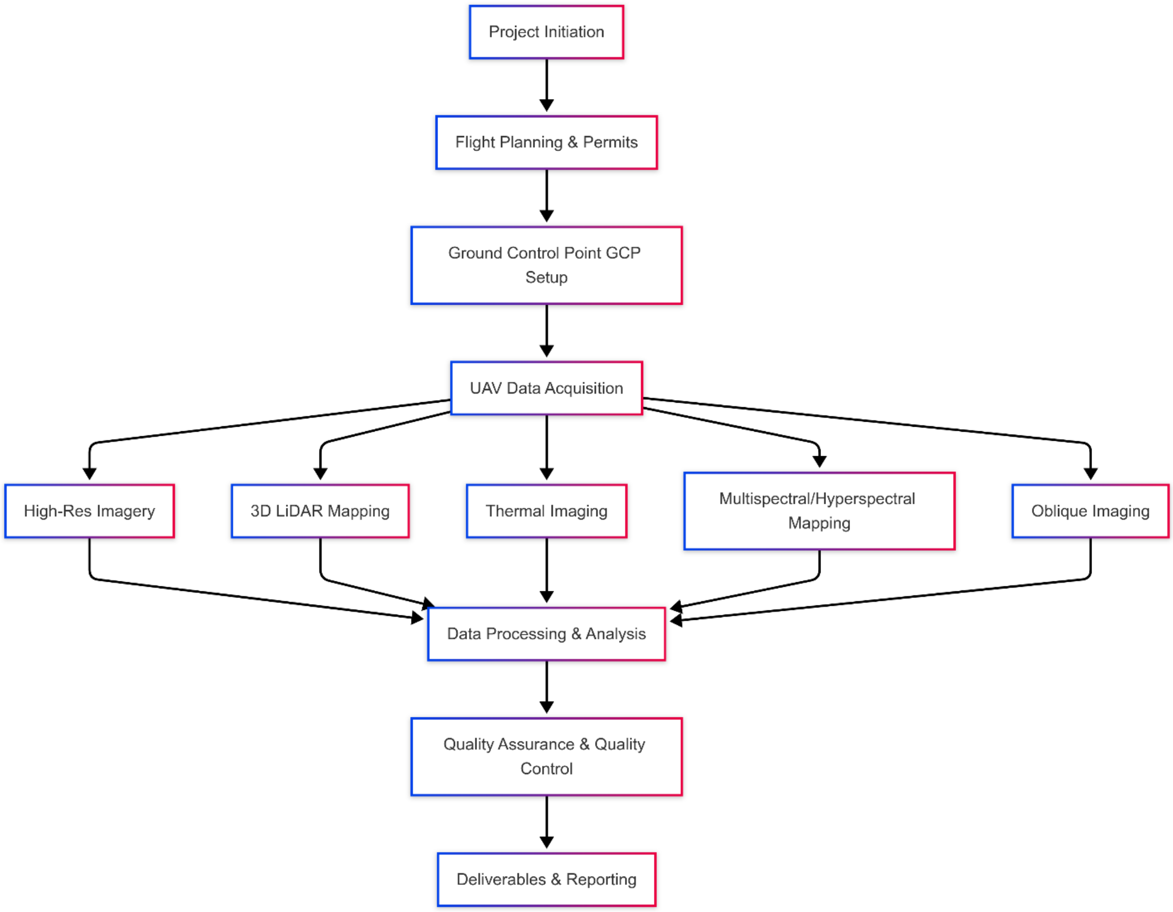


Figure 20: Aerial Survey Workflow

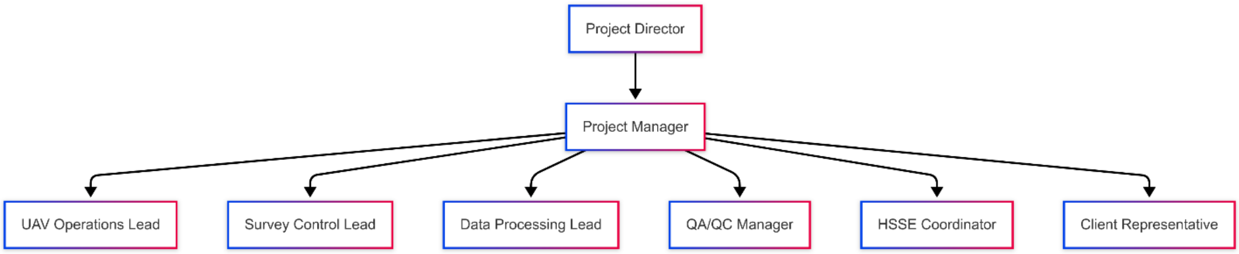
Project Management

Our experienced project management team will ensure that the project is executed on time, within budget, and to the client's satisfaction. Our team will oversee all aspects of the project, including flight planning, image acquisition, data processing, and quality control. We will provide regular progress reports and will maintain open communication with the client throughout the project.

Our project management team will take the lead in ensuring that all aspects of the project are carried out in a timely, efficient, and effective manner. The team will consist of a project manager, flight planning expert, image acquisition specialist, data processing expert, and quality control personnel.

Project Governance Structure

The project governance structure ensures clear roles, reporting lines, and escalation mechanisms.



- Project Director: Executive oversight and resource commitment.
- Project Manager: Daily coordination, stakeholder communication, schedule adherence.
- UAV Lead: Manages all drone flights and UAV personnel.
- Survey Lead: Responsible for GCP planning, layout, and quality checks.
- Data Lead: Oversees photogrammetry workflows and output creation.
- QA/QC Manager: Ensures deliverables meet client and industry standards.
- HSSE Coordinator: Implements safety, environmental, and regulatory plans.

Project Manager

The project manager will be responsible for overall project coordination, including ensuring that all team members are working together cohesively, monitoring project progress, and communicating with the client regularly to provide updates on project status. The project manager will also work closely with the flight planning expert to develop a detailed flight plan that meets the client's requirements and ensures that all areas of interest are captured.

Image Acquisition Specialist

The image acquisition specialist will oversee the drone flights, ensuring that all required images are captured in the correct resolution and quality. They will also monitor weather conditions and adjust the flight plan as needed to ensure that images are captured under optimal conditions.

Data Processing Expert

Our data processing expert will work with the acquired imagery to generate orthophoto and DEM/DTM files. They will ensure that all data is processed to meet the client's specifications and requirements, and that the final data products are delivered on time.

Quality control personnel

Finally, our quality control personnel will perform rigorous checks on all data products to ensure that they meet the required quality standards. They will also verify that the images and data are accurately geo-referenced and have the required resolution and accuracy.

Throughout the project, our project management team will maintain open communication with the client to ensure that their needs and expectations are being met. We will provide regular progress reports, including updates on flight planning, image acquisition, and data processing, to keep the client informed about the project's status. We believe that clear and open communication is essential to a successful project outcome, and we will work closely with the client to ensure their satisfaction.

Methodology

Survey Planning and Design

Jeel Engineering LLC follows a structured aerial survey methodology aligned with international geospatial and photogrammetric standards. The planning phase ensures that the aerial survey is optimized for spatial accuracy, operational safety, and efficient data acquisition.

We will capture high-resolution aerial imagery over the defined Area of Interest (AOI) using fixed-wing and rotary UAV platforms equipped with calibrated RGB sensors. The survey aims to achieve a Ground Sampling Distance (GSD) of ≤2 cm, with a relative positional accuracy better than ±5 cm and absolute accuracy better than ±10 cm, when tied to well-distributed Ground Control Points (GCPs). Flight parameters — including UAV type, flight height, sensor orientation, and weather windows — will be optimized to meet these accuracy goals.

Proposed UAV Platforms

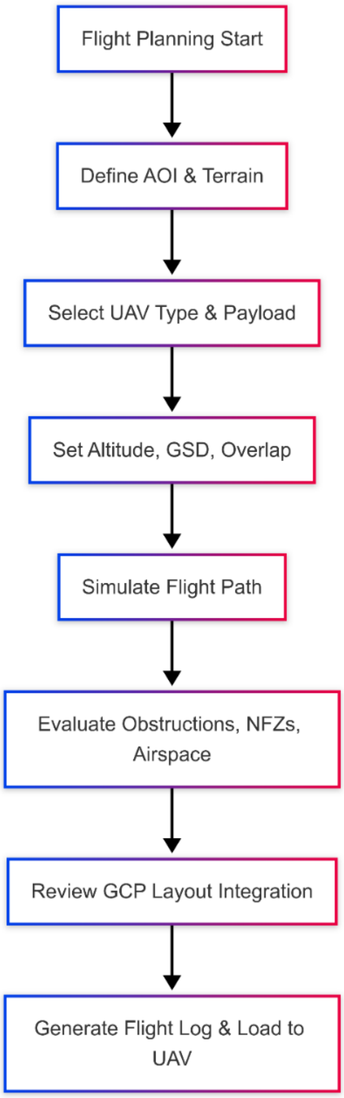
Based on the scale and terrain of the project area, we propose a hybrid deployment of fixed-wing and multi-rotor UAVs to maximize endurance and flexibility:

UAV Model	Type	Endurance	Use Case	
SenseFly eBee X	Fixed Wing	60 mins	Wide-area mapping with high GSD	
CW-15 - VTOL	Fixed Wing	180 mins	Long corridor or multi-km² coverage	
FD-400 - VTOL	Fixed Wing	240 mins	Large-scale surveys in rural terrain	
DJI M300 RTK	Quadcopter	40 mins	Urban, small-scale, or obstacle-rich sites	

Each UAV is equipped with real-time telemetry systems, onboard GNSS/IMU logging, and fail-safe mechanisms. Sensor payloads can include RGB, LiDAR, thermal, or multispectral cameras depending on the project's technical requirements.

Flight Planning and Overlap Strategy

- Proper planning ensures complete coverage and high photogrammetric fidelity. Planning is performed using software such as UGCS, DJI Pilot, or eMotion.
- Key Parameters:
- Altitude: Set to match required GSD and terrain relief
- Overlap: 80% forward / 70% side minimum
- Flight Path: Grid-based for area surveys; corridor-based for linear assets
- Line Junctions: Overlap to ensure stereoscopic consistency
- GCPs/Checkpoints: Integrated within the flight grid



Preliminary Planning Activities

This phase ensures legal, environmental, and logistical readiness:

- AOI Finalization: Boundaries, exclusions, and access verification
- Permit Processing: CAA flight approvals, stakeholder notifications
- Weather Modeling: Use of Windy, UAVForecast for solar angle, wind, and cloud data
- Terrain Analysis: Identification of zones with elevation anomalies or vegetation
- Team Assignment: Flight crew, survey team, safety officer confirmed
- Pre-Flight Preparations
- Before flight operations begin:
- UAVs are inspected (airframe, motors, GPS, telemetry)
- Sensor payloads are calibrated and focus-tested
- Battery levels and firmware versions are verified
- Flight paths and contingencies are uploaded to UAV controllers

- ➢ RTK GNSS receivers are deployed for GCP surveying
- ➢ Emergency protocol review is conducted with the field team

All pre-flight tasks are logged through Jeel's UAV Ops Checklist System (UOCS).

Flight Execution

All flights are conducted under VLOS (Visual Line of Sight) with constant telemetry monitoring.

UAVs follow preloaded missions with real-time telemetry feedback

Adjustments are made in the field for wind, terrain obstruction, or lighting issues

GCP coordinates are collected using RTK GNSS receivers with sub-centimeter precision

Images are tagged with GNSS metadata and quality-assured post-mission

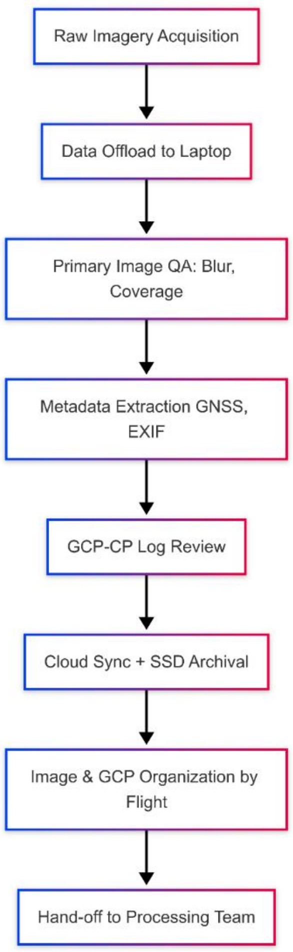
In urban or restricted zones, multi-rotor UAVs (e.g., DJI M300 RTK) are deployed with reduced altitude and grid spacing to avoid obstructions.

Post-Flight Data Handling

Collected data undergoes immediate field-level review and secure offloading:

- ➢ Blurred or underexposed images are flagged for re-flight
- ➢ Flight logs (e.g., .DAT, .TXT, .KML) are organized and archived
- ➢ Each flight folder includes:
- ➢ Geotagged imagery
- ➢ Flight plan
- ➢ GCP coordinates
- ➢ Telemetry logs
- ➢ Image quality review sheet

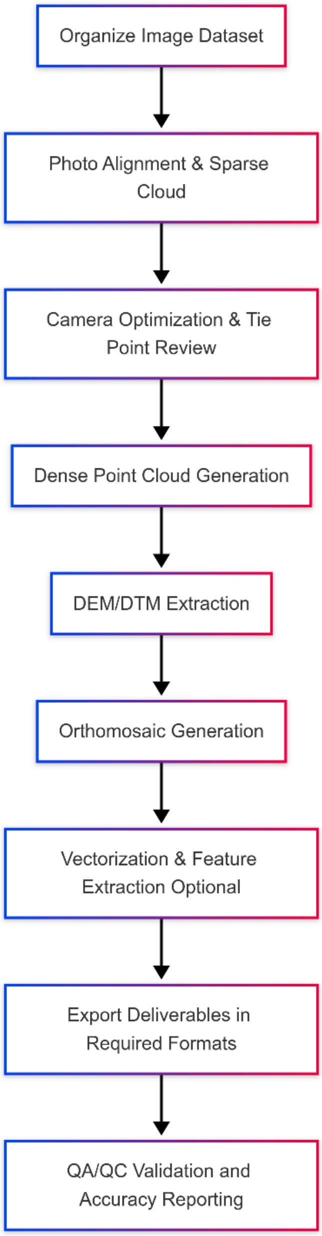
Only after successful completion of this pipeline is the data passed to the photogrammetry team for further processing.



Data Processing & 3D Modeling

Post-flight, Jeel's geospatial processing team transforms raw UAV-acquired imagery into deliverables such as orthomosaics, Digital Elevation Models (DEMs), Digital Terrain Models (DTMs), 3D point clouds, and vector layers. The processing adheres to ASPRS accuracy standards, with robust QA/QC protocols at each step.

All processing is performed using industry-standard photogrammetry suites, including Agisoft Metashape, Pix4D Mapper, RealityCapture, iTwin Capture and is supported by ArcGIS Pro, Global Mapper, and CloudCompare for QA, visualization, and GIS integration.



Dataset Preparation

- Organize flight outputs by mission ID
- Exclude blurred or low-quality images
- Verify embedded geotags from RTK/PPK systems
- Import GCPs and Check Points into the processing environment
- Photo Alignment & Sparse Cloud
- Generate a sparse point cloud
- Perform camera alignment, bundle adjustment, and internal calibration
- Review camera location residuals and remove outlier points
- Dense Point Cloud Generation
- Use Multi-View Stereo (MVS) algorithms to reconstruct a dense 3D point cloud
- Apply noise filtering to remove vegetation bloom, sky reflections, or parallax distortions
- Classify ground vs. non-ground points for DTM extraction
- DEM / DTM Generation
- Interpolate surface (DSM) from the dense cloud including all features

- ➢ Filter non-ground features to extract Digital Terrain Model (DTM)
- ➢ Apply smoothing or gap-filling algorithms in areas with vegetation or low-texture surfaces
- ➢ Orthomosaic Generation
- ➢ Rectify images using DTM and camera calibration parameters
- ➢ Perform color balancing and seamline optimization
- ➢ Generate final orthophoto tiles in GeoTIFF format, ready for GIS use
- ➢ Feature Vectorization (Optional)
- ➢ Extract line/polygon features such as:
- ➢ Roads, fences, utilities
- ➢ Parcel boundaries
- ➢ Pavements and drainage lines
- ➢ Export as .SHP, .DXF, or GeoPackage layers
- ➢ Layer styling and attribution performed as per client specifications.

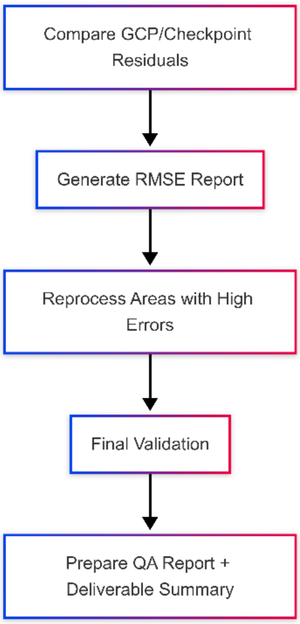
Quality Control and Accuracy Assessment

RMSE Calculation: Verified using independent checkpoints not involved in modeling.

Control Report: Includes accuracy residuals (XY, Z), flight logs, camera stats.

Visual QA: Includes seamline artifacts, elevation spikes, misclassifications.

Metadata Delivery: Includes coordinate reference system, GSD, image overlap %, processing date.



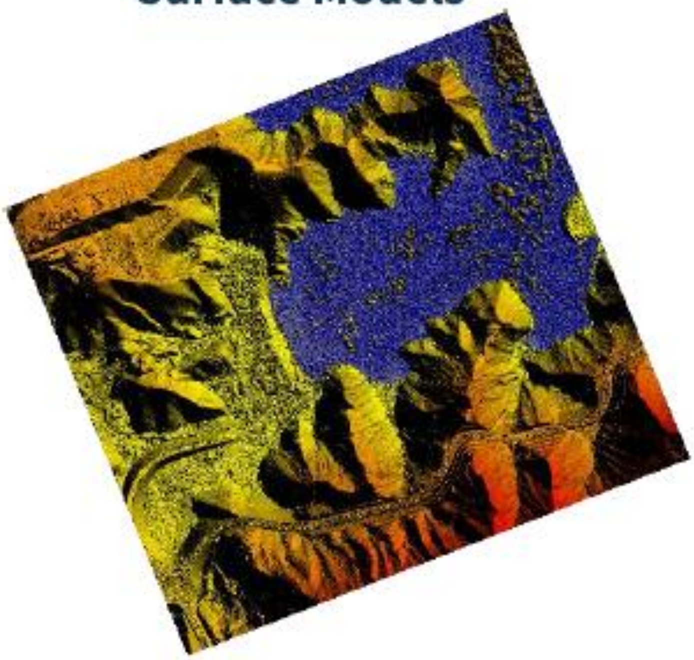
Final Deliverables

Deliverable	Format
Orthomosaic	GeoTIFF, ECW
DSM/DTM	GeoTIFF
3D Point Cloud	.LAS, .LAZ, .XYZ
Vector Layers (optional)	SHP, DXF
Elevation Contours (optional)	SHP, DWG
Accuracy/QA Report	PDF + Excel Summary
GCP/CP Logs	CSV + Map Preview

Deliverable	Format
Flight Logs	.DAT, .KML, .JPG (optional)

Orthomosaic

Surface Models



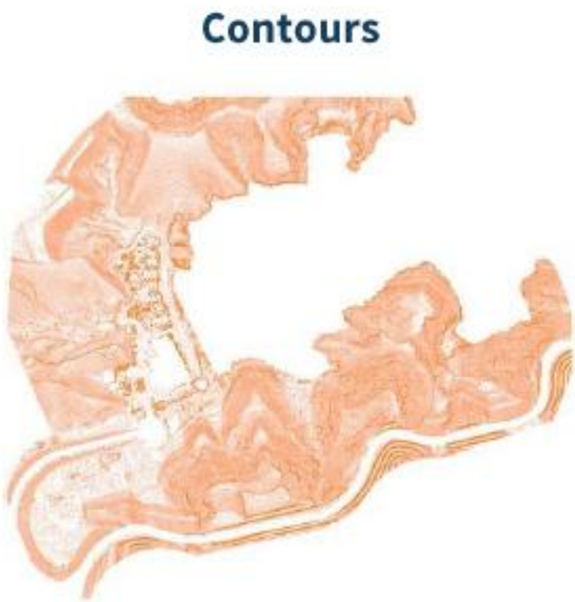


Figure 21: Aerial Survey Deliverables

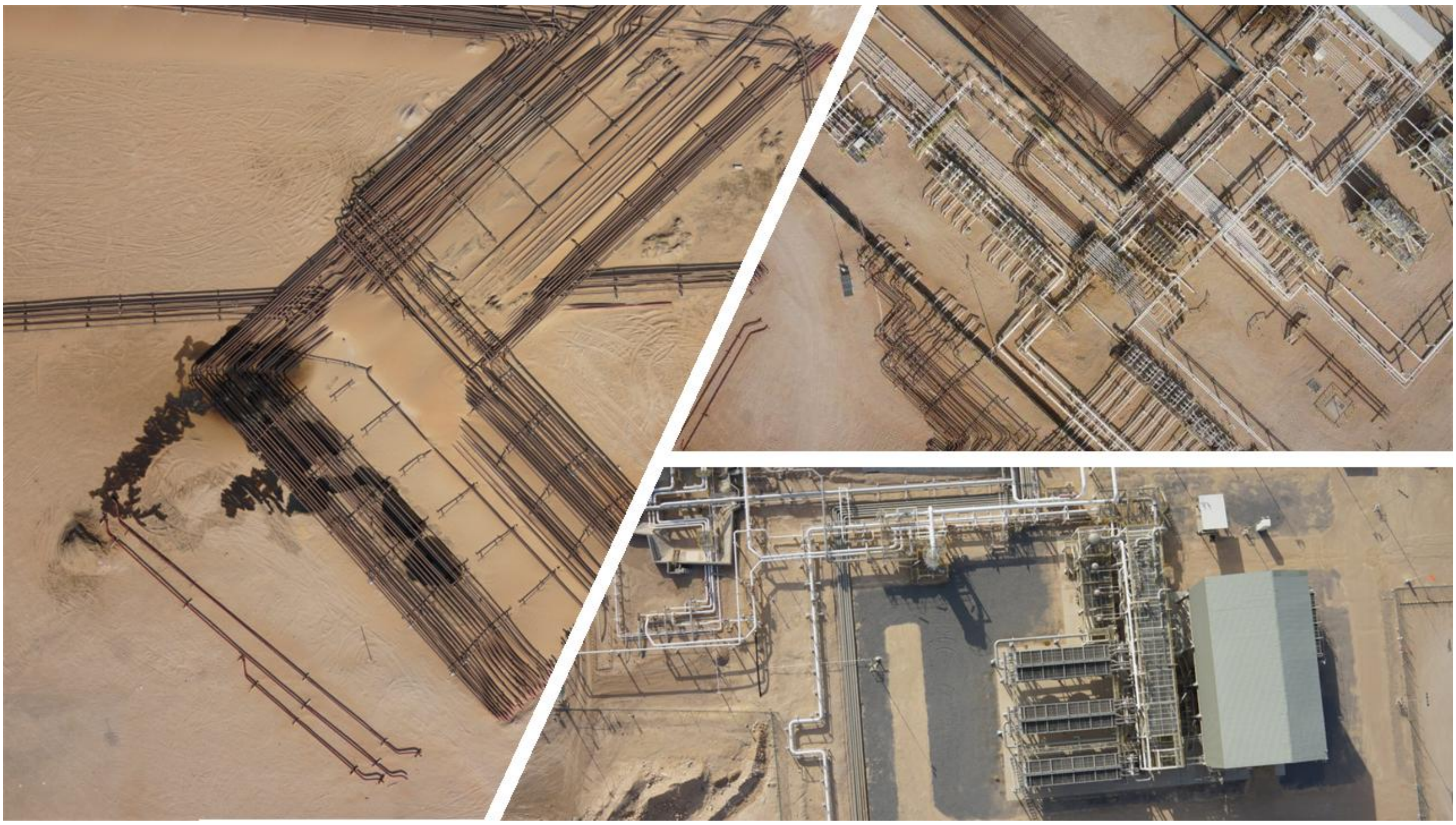


Figure 22: Facility Monitoring and Inspection Aerial Survey

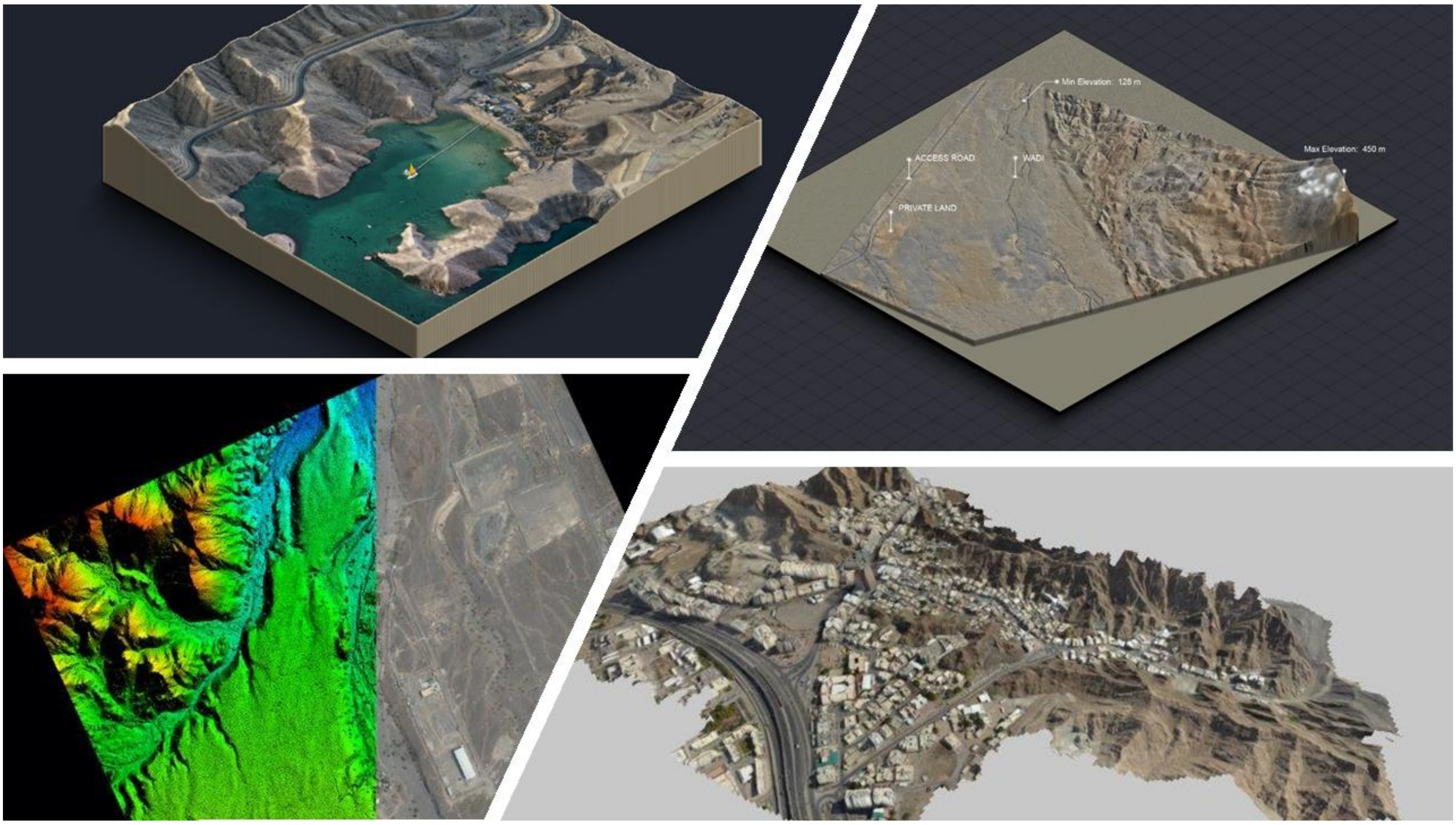


Figure 23: Elevation Models Generated from Aerial Images

Figure 24: 3D Models for Oil & Gas Facilities

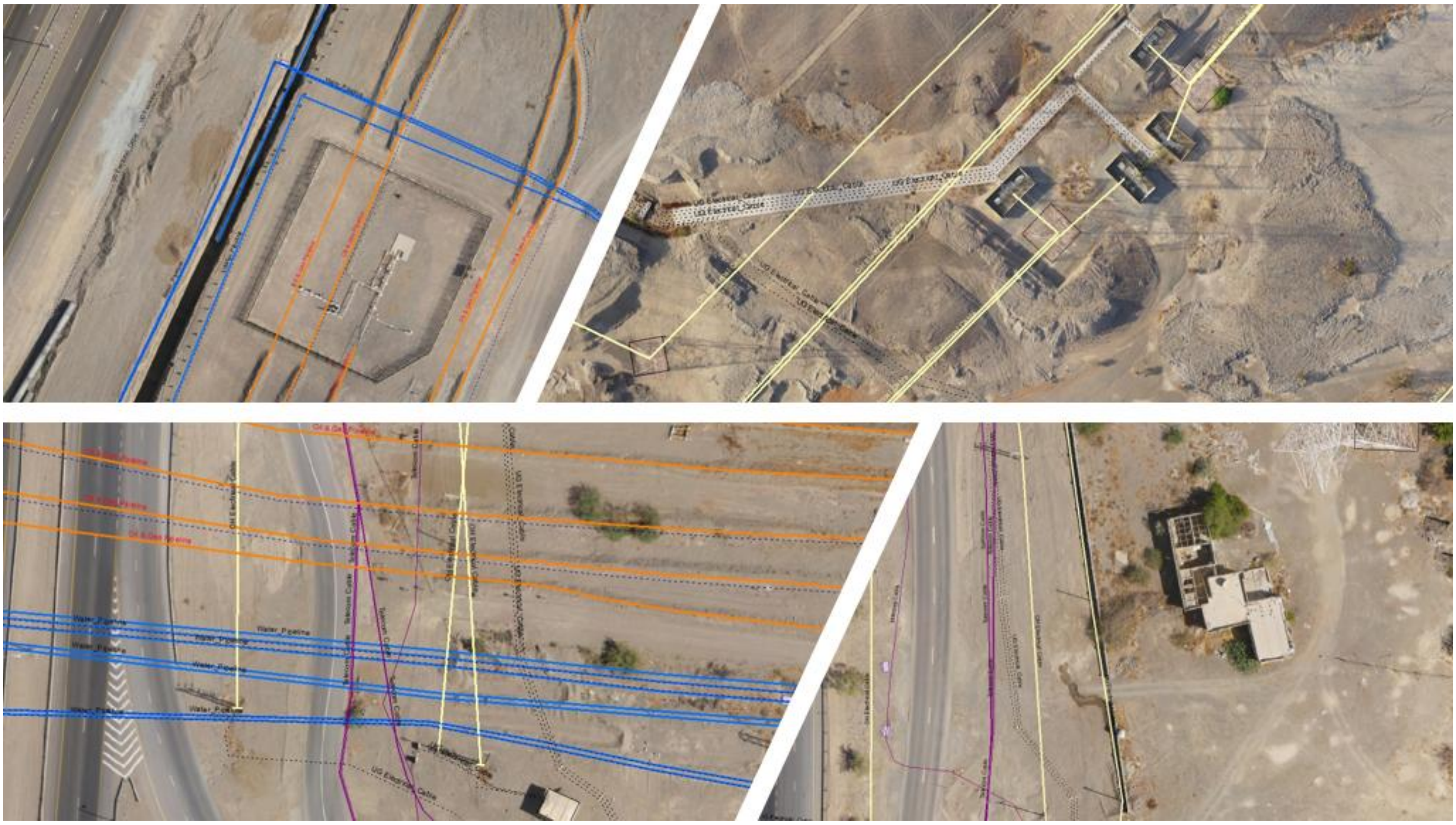


Figure 25: As-built Mapping & Feature Extraction

Quality Assurance / Quality Control (QA/QC)

Jeel implements a multi-tier QA/QC system conforming international Standards. Each phase of the survey undergoes checks for positional, visual, and logical accuracy.

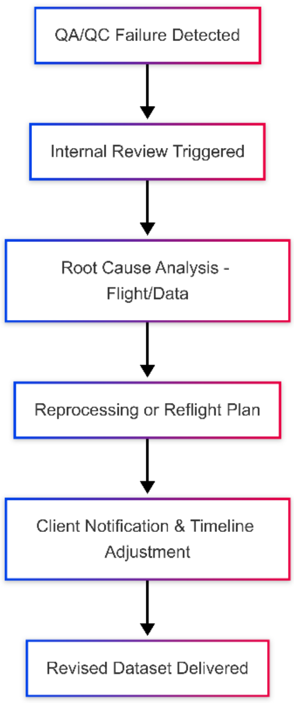
- Control Point Accuracy Checks
- GCPs: Used to anchor the dataset and improve model accuracy
- Check Points (CPs): Withheld from processing and used solely for validation
- RMSE (Root Mean Square Error) is computed for both planimetric (XY) and vertical (Z) dimensions
- Target RMSE Thresholds:

Accuracy Class	Horizontal RMSE (XY)	Vertical RMSE (Z)	Use Case
Class I	≤ 3 cm	≤ 5 cm	Engineering-grade base mapping
Class II	≤ 10 cm	≤ 15 cm	Utility corridor mapping
Class III	≤ 20 cm	≤ 30 cm	General reconnaissance surveys

A residual report is included with each dataset, displaying deviations at each CP location and spatial distribution heat maps.

- Visual and Logical QA
- Orthomosaic Checks:
- Seamline smoothness
- Cloud/shadow artefacts
- Color balance
- Point Cloud Checks:
- Noise filtering
- Classification (ground/non-ground)
- Uniform density
- Vector Layers:
- Topological correctness (no overlaps/gaps)
- Attribute consistency
- Metadata Validation:
- CRS alignment
- GSD confirmation
- Overlap %, camera calibration logs
- Rework & Escalation Protocol

If any deliverable fails to meet accuracy or completeness thresholds, the following is triggered:



Work Breakdown Structure (WBS)

WBS Code	Task Description	Responsible Party
1.0	Project Initiation & Mobilization	Project Manager
2.0	Flight Planning & Permits	UAV Operations Lead
3.0	Ground Control Point Survey	Survey Control Lead
4.0	UAV Data Acquisition	UAV Team
5.0	Data Ingestion & Processing	Data Processing Lead
6.0	QA/QC & Accuracy Assessment	QA/QC Manager
7.0	Report Generation & Deliverables	Project Manager
8.0	Client Review & Final Submission	Project Manager

Communication & Reporting Plan

Audience	Report Type	Frequency	Medium
Client	Progress Report	Weekly	Email + Call
Internal Team	Daily Briefing	Daily	WhatsApp + Sheet
Project Stakeholders	Milestone Review	At Each Stage	Presentation
QA/QC Lead	Accuracy Summary	Post Processing	PDF + Log

Schedule and Milestone Management

Phase	Deliverable
Mobilization & Planning	Kickoff, flight plan
GCP Setup & Validation	GCPs surveyed and validated
UAV Data Collection	Raw image datasets
Data Processing & Modeling	DEM, DTM, Orthomosaic
QA/QC & Final Adjustments	Accuracy log, corrections
Report & Client Submission	Final report, datasets

Safety And Compliance Plan

Personnel and Equipment Safety:

- All personnel involved in the operation of the UAVs shall be trained in safe UAV operation and maintenance.
- All UAVs shall be inspected prior to each flight to ensure that they are in proper working condition.
- All UAVs shall be operated in accordance with the manufacturer's guidelines and limitations.
- Personnel involved in the operation of the UAVs shall be provided with the appropriate personal protective equipment, including safety glasses, hard hats, and high-visibility clothing.
- All UAVs shall be equipped with fail-safe systems that automatically return the UAV to a pre-determined location in the event of a loss of signal or malfunction.
- Compliance with Applicable Laws and Regulations:
- All UAV operations shall be conducted in compliance with applicable laws and regulations, including local, state, and federal regulations.
- The operation of the UAVs shall comply with all applicable air traffic control regulations.
- All necessary permits and approvals shall be obtained prior to the commencement of UAV operations.

Risk Assessment and Mitigation:

- A risk assessment shall be conducted prior to the commencement of UAV operations to identify potential hazards and to develop mitigation strategies.
- All personnel involved in the operation of the UAVs shall be briefed on the risks associated with the operation and the mitigation strategies that have been developed.
- A safety officer shall be appointed to oversee the UAV operations and to ensure that all safety protocols are followed.

Risk Description	Likelihood	Impact	Mitigation Strategy
Adverse Weather Conditions	Medium	High	Schedule buffer days; monitor forecasts
UAV System Failure	Low	Medium	Backup drones; pre-flight system checks
Regulatory/Permit Delays	Low	High	Early permit applications; contingency sites
Inaccessible Terrain	Medium	Medium	Use RTK fallback or alternate drone types
GCP Survey Errors	Low	High	Cross-checks and dual-team validations

Emergency Response Plan:

- An emergency response plan shall be developed and implemented prior to the commencement of UAV operations.
- The emergency response plan shall include procedures for responding to UAV malfunctions, lost signals, and other emergency situations.
- All personnel involved in the operation of the UAVs shall be trained on the emergency response plan and shall be prepared to respond in the event of an emergency.
- Environmental Considerations:
- All UAV operations shall be conducted in a manner that minimizes environmental impact.
- The UAVs shall be operated in accordance with all applicable environmental regulations.
- The area to be surveyed shall be assessed for environmental hazards, including potential impact on wildlife and vegetation, and appropriate mitigation measures shall be taken.

Record Keeping:

- All records related to UAV operations shall be maintained and stored in accordance with applicable regulations.
- Records shall include flight plans, flight logs, maintenance records, and incident reports.
- All records shall be made available to the client upon request.
- The safety and compliance plan is designed to ensure that all UAV operations are conducted in a safe and compliant manner, while also minimizing environmental impact and maintaining high-quality data collection. By following these guidelines, we can ensure the success of the project while protecting the safety of personnel and the environment.
- HSSE (Health, Safety, Security, and Environment) Plan

HSSE Policy and Objectives:

Our company is committed to achieving the highest standards of HSSE performance in all our activities. Our HSSE policy is based on the principles of prevention, protection, and continuous improvement. Our objectives are to ensure the health and safety of all personnel involved in the inspection activity, protect the environment, and comply with all applicable HSSE-related legal and regulatory requirements.

Risk Assessment:

We shall conduct a comprehensive risk assessment of the inspection activity to identify all HSSE-related risks, including those relevant to health, safety, security, and the environment. We shall develop a risk register to document the results of the HSSE risk assessment(s) and the risk management measures planned or in place for the identified risks. We shall periodically review and amend the HSSE risk assessment(s) and risk register(s) as necessary to enable us to meet the HSSE requirements.

Emergency Response Plan:

We shall have a documented emergency response plan to respond promptly to incidents. The plan shall include procedures for reporting incidents, mobilizing resources, and coordinating with the client and relevant authorities. We shall have and maintain the capability, including available resources and trained personnel, to respond to any incident in accordance with the applicable emergency response plan.

Incident Reporting and Investigation:

We shall report and investigate all incidents related to the inspection activity, including near-misses. The purpose of incident reporting and investigation is to identify the causes of incidents, prevent their recurrence, and continuously improve our HSSE performance.

Personnel Qualifications and Competencies:

Prior to making changes to personnel critical to safe operations (as listed in the HSSE plan), we shall provide the client representative with justification for the change(s) and the qualifications of proposed replacement personnel, with evidence the new post holder satisfies the minimum required competencies for the role. We shall obtain approval, which shall not be unreasonably delayed or withheld.

Prohibited Substances:

We shall prohibit the use, possession, sale, purchase, transfer, concealment, transportation, or possession of prohibited substances by any personnel when performing work or otherwise, while on the client worksite, in any client vehicle, or on client time. We shall ensure personnel comply with this prohibition and are free from the effects of prohibited substances at these times and locations.

Personal Protective Equipment:

Appropriate PPE shall be worn by personnel at the worksite. The selection, use, and maintenance of PPE shall be in accordance with applicable regulations, standards, and company procedures.

Lessons Learnt:

We shall incorporate lessons learnt from previous surveys into our inspection procedure to continuously improve our HSSE performance.

Our company is committed to ensuring the safety and health of all personnel involved in the inspection activity, protecting the environment, and complying with all applicable HSSE-related legal and regulatory requirements. We shall conduct a comprehensive risk assessment, have an emergency response plan, report and investigate incidents, ensure personnel qualifications and competencies, prohibit the use of prohibited substances, use appropriate PPE, and incorporate lessons learnt from previous surveys into our inspection procedure.

Project Specific HSSE Plan

Hazard Identification

The first step in the HSSE plan for Aerial Survey using drones is to identify the hazards associated with the operation. Hazards can be identified by conducting a risk assessment of the operation. The risk assessment will cover the following areas:

- Flight operations
- Battery handling and charging
- Transportation of equipment and personnel
- Environmental hazards
- Personnel hazards
- Safety Measures

Based on the risk assessment, safety measures will be put in place to mitigate the identified hazards. Some of the safety measures that can be put in place include:

- Training: All personnel involved in the operation will undergo training on drone operations, emergency response, and HSSE procedures.
- Personal Protective Equipment (PPE): All personnel involved in the operation will wear appropriate PPE, including helmets, gloves, high visibility vests, and safety glasses.
- Emergency Response: An emergency response plan will be developed, and all personnel will be familiar with the plan. The emergency response plan will include procedures for responding to incidents such as crashes, battery fires, and injuries.
- Environmental Protection: Measures will be put in place to protect the environment, such as avoiding sensitive areas and managing waste.
- Equipment Maintenance: Regular maintenance will be carried out on the drones, batteries, and other equipment to ensure they are in good working condition.
- Security: Measures will be put in place to protect the drones and other equipment from theft or damage.

Safety Checklist

A safety checklist will be developed to ensure that all safety measures are in place before and during the operation. The safety checklist will cover the following areas:

- Pre-flight checks
- Flight checks
- Post-flight checks
- Battery handling and charging
- Transportation of equipment and personnel

Communication Plan

A communication plan will be developed to ensure that all personnel involved in the operation can communicate effectively. The communication plan will cover the following areas:

- Use of radio communication
- Use of hand signals
- Emergency communication procedures

Incident Reporting

An incident reporting system will be put in place to ensure that all incidents are reported and investigated. The incident reporting system will cover the following areas:

- Procedure for reporting incidents
- Investigation of incidents
- Follow-up actions

Continuous Improvement

Continuous improvement will be an integral part of the HSSE plan for Aerial Survey using drones. The following areas will be considered for continuous improvement:

- Regular review of the HSSE plan
- Regular review of the risk assessment
- Regular training of personnel on HSSE procedures
- Regular review of incidents and near misses
- Regular maintenance of equipment

By following the above HSSE plan, you can ensure the safe operation of drones for aerial surveying while mitigating any risks to personnel, equipment, and the environment.

Closure & Handover

Project closure includes:

- Final submission of all deliverables
- Technical handover session with client team
- Archival of data and flight logs
- Post-project review (lessons learned)
- Issuance of completion certificate and satisfaction note.