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From Vision to System in the Gulf: T-NEVs, Pilot Operations, Unified MaaS, and the Smart Urban Mobility Authority (SUMA)

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ABSTRACT

Gulf cities face a persistent implementation gap: ambitious multimodal visions codified in Oman's Greater Muscat Structure Plan (GMSP), and the Oman National Transport Model (ONTM) and echoed in Saudi Vision 2030 programs, continue to struggle in converting policy intent into lived, climate-responsive mobility. Building on five prior studies that conceptualized, ecologized, engineered, evaluated, and institutionally framed Integrated Humanization (IH), this paper advances a systems blueprint that bridges the vision–delivery divide through four coordinated innovations. First, a legislative innovation defines the Thermal-Protected Neighborhood Electric Vehicle (T-NEV) as a new vehicle class - fully enclosed and air-conditioned - with explicit right-of-way, safety, and licensing parameters tailored to hot-arid neighborhoods. Second, an operational innovation deploys a neighborhood-scale pilot connecting homes to BRT/LRT stations, combining shaded access corridors with geofenced speed control to validate first–last-mile performance before major capital commitments. Third, a technical innovation specifies a unified, account-based mobility platform ("One-App") that integrates ticketing, routing, and fleet dispatch across BRT, buses, T-NEVs, micromobility, and taxis - eliminating digital fragmentation for residents and visitors alike. Fourth, an institutional innovation establishes a Smart Urban Mobility Authority/Unit (SUMA) to consolidate mandates, data governance, procurement, and performance enforcement. IH's climate realism is operationalized by embedding two performance tools ASTI (Access-Shed Thermal Index) and IH-IMI (Institutional Humanization–Institutional Maturity Index) into codes, contracts, and dashboards. The resulting framework provides a practicable pathway to implement GMSP Section 6 (Efficient Transport System) and to align execution with Oman Vision 2040 and Saudi Vision 2030 trajectories. Ultimately, the study demonstrates how IH evolves from a research series into an enforceable, measurable, and scalable urban-mobility framework-offering a replicable Gulf standard for human-centered, climate-resilient mobility across Muscat, Riyadh, and peer cities.

INTRODUCTION

The evolution of Gulf urbanism has entered a decisive stage where transport planning, climate adaptation, and institutional coordination must finally converge. In Oman, national frameworks such as the Greater Muscat Structure Plan (GMSP, 2023), Action Area Plans (AAPs, 2023), and the Oman National Transport Model (ONTM, 2020) articulate a clear multimodal ambition integrating BRT, LRT, water taxis, and micromobility into a coherent metropolitan network. Meanwhile, Saudi Vision 2030 has accelerated similar transformations in Riyadh, Dammam, and Jeddah, where public transport, electric mobility, and smart governance are now strategic levers for livability and decarbonization. Yet across the Gulf, a common implementation challenge persists: strong strategic visions but fragmented execution. The gap is no longer conceptual it is operational, legislative, and digital.

The Integrated Humanization (IH) framework, developed through five preceding studies, provides a Gulf-centric paradigm that unites infrastructure, institutions, and behavior within a climate-realist mobility grammar. Its five pillars urban planning, humanization, public transport, road engineering, and micromobility collectively define the spatial and governance logic for thermal comfort and human-scale accessibility. Each prior study built one layer of this foundation: from conceptualization (defining IH as a Gulf paradigm), to ecological integration (blue–green corridors), engineering reinterpretation (right-of-way and shading standards), governance and evaluation (ASTI), and institutionalization (IH-IMI). Together, they established the intellectual scaffolding upon which implementation can now occur.

The Emergence of a Gulf Urban School of Integrated Humanization

Conceived by Saad and further developed in this co-authored study, the Integrated Humanization (IH) framework has now matured into what can be recognized as a Gulf Urban School of Thought the first in the Arab world to originate from within its own climatic, social, and institutional realities. Unlike the Copenhagen School (Gehl, 2010; Montgomery, 2013), which centered on

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livability and pedestrianism in temperate climates, or the Chicago School (Park *et al.,* 1925), which interpreted the city as a sociological organism, the Gulf School of Integrated Humanization redefines the human not merely as a social actor but as an engineering and legislative variable a measurable determinant embedded directly within the codes, contracts, and design geometry of the city itself.

This distinction is what gives IH its intellectual originality. It does not limit humanization to behavioral observation or the pursuit of "livable streets." Instead, it quantifies comfort, shade, and accessibility through measurable engineering parameters and enforceable policy instruments. Its five pillars Urban Planning, Humanization, Public Transport, Road Engineering, and Micromobility form a unique epistemological framework that fuses philosophy, engineering, and law into a single operational grammar. No previous school of urbanism whether Western or otherwise has embedded road engineering and mobility systems so centrally within its philosophical structure.

In doing so, the IH school transcends both the moral humanism of Copenhagen and the sociological urbanism of Chicago by introducing a measurable humanism: one that translates ethics into geometry, and empathy into code. While Western and imported Arab planning traditions have long relied on borrowed standards and climate-neutral manuals, IH generates indigenous, climate-realistic urban knowledge suited to the Gulf's arid context. Through its proprietary indices ASTI (Access-Shed Thermal Index) and IH-IMI (Institutional Humanization–Institutional Maturity Index) it transforms heat, shade, and institutional performance into auditable engineering and governance metrics.

This intellectual and operational synthesis positions IH not as an isolated theory, but as the nucleus of a new Gulf Urban School, one that produces knowledge rather than imports it. It anchors human comfort, sustainability, and climate resilience as engineering and legislative obligations, not aspirational slogans. Within this sixth paper, the school's philosophy materializes through four integrated innovations that convert theory into measurable systems:

1. Legislative innovation defining the Thermal-Protected Neighborhood Electric Vehicle (T-NEV) as a Gulf-specific vehicle class designed for hot-arid neighborhoods;
2. Operational innovation implementing pilot neighborhoods that connect homes to BRT/LRT stations under real thermal and behavioral conditions;
3. Technical innovation developing a unified account-based "One-App" Mobility-as-a-Service (MaaS) platform integrating all transport modes; and
4. Institutional innovation establishing the Smart Urban Mobility Authority (SUMA) to consolidate mandates and embed IH's performance tools (ASTI and IH-IMI) into codes, contracts, and dashboards.

Collectively, these four pillars demonstrate how the Gulf Urban School of Integrated Humanization translates philosophy into enforceable system, bridging research and regulation, and redefining not only how Gulf cities are designed, but how humanity itself is engineered into their laws.

Transition to the Four-Innovation Framework

This sixth paper thus represents the executional and governance phase of the IH research arc. It advances a four-innovation framework that translates visionary intent into measurable and enforceable systems. Methodologically, the paper follows a Vision → Code → Contract → Operation → Dashboard continuum, transforming IH from a conceptual model into an operational governance tool.

It challenges the outdated notion that congestion should be artificially manufactured to force modal shift, arguing instead for a complete door-to-network ecosystem that achieves the "15-minute neighborhood" ideal through thermally protected feeders, shaded access, and unified mobility management.

Across Gulf cities, however, a persistent policy paradox undermines mobility reform: while planners advocate congestion as a behavioral lever to promote public transport, municipal agencies simultaneously pursue road widening and intersection upgrades to eliminate delays. The result is a self-cancelling loop visions for mode shift coexist with infrastructure that perpetuates car dependence. Integrated Humanization (IH) resolves this contradiction by reframing the objective: not to punish car users through congestion, nor to endlessly expand road capacity, but to design a thermally comfortable, multimodal ecosystem where human-scale access replaces coercive deterrence. By embedding IH within the institutional frameworks of Oman Vision 2040 and Saudi Vision 2030, this study proposes a replicable Gulf governance model—one that integrates legislation, technology, and human-centered design into a coherent, climate-resilient mobility system for Muscat, Riyadh, and peer Gulf cities.

LITERATURE REVIEW

Positioning this Paper within the IH Research Arc

The Integrated Humanization (IH) framework emerged as a Gulf-born response to the mismatch between imported urban standards and the region's climatic and behavioral realities. Over five preceding studies (2024–2025 Series), IH evolved from a conceptual hypothesis into an institutional methodology-each paper addressing a different stage of system maturity. The Integrated Humanization (IH) series was not an accidental progression but a deliberately structured research program conceptualized by Saad between June 2023 and January 2025, following a clear roadmap of six interlinked studies. Each paper was intentionally designed to address a specific stage in the system's maturation-from paradigm formation to ecological integration, engineering reinterpretation, governance evaluation, institutionalization, and, finally, system implementation. This deliberate sequencing ensured that IH evolved coherently from theoretical vision to operational governance, providing cumulative depth rather than fragmented insight. Collectively, these studies established IH as both a theoretical foundation and a policy instrument for climate-resilient mobility in the Gulf.

Article 1 Conceptualizing IH (Paradigm Formation): introduced IH as a Gulf-specific planning philosophy linking Oman Vision 2040 to human-centered mobility goals. It defined five interdependent pillars-urban planning, humanization, public transport, road engineering, and micromobility-and framed humanization as a measurable planning principle rather than an abstract value.

Article 2 Ecologizing IH (Blue–Green Corridors): reinterpreted wadis and ecological spines as dual-function infrastructures for stormwater, shade, and non-motorized access, merging ecological cooling and mobility equity.

Article 3 Engineering IH (Road Standards Revisited): translated IH principles into cross-section design, lane hierarchy, and shaded pedestrian zones, emphasizing thermal comfort as design geometry and positioning road engineering as an active agent of urban livability.

Article 4 Governing and Evaluating IH: operationalized IH through performance indicators and governance indices - ASTI (Access-Shed Thermal Index) and IH-IMI (Institutional Humanization–Institutional Maturity Index) -providing quantitative tools to evaluate comfort, safety, accessibility, and institutional readiness.

Article 5 Institutionalizing IH: diagnosed fragmentation across ministries and municipalities as the principal barrier to execution. It proposed institutional coupling and codification mechanisms to embed IH into national transport and planning frameworks, while introducing IH-IMI as a decision-support system for policy enforcement. These five layers established a coherent methodological trajectory - from concept to code, from governance to institution - laying the intellectual foundation for a human-centered Gulf urbanism.

This sixth paper, titled "From Vision to System in the Gulf: T-NEVs, Pilot Operations, Unified MaaS, and the Smart Urban Mobility Authority (SUMA)", represents the implementation and systems phase of the IH research arc. It consolidates the conceptual, ecological, engineering, and institutional foundations developed in earlier studies into four executable innovations: the Thermal-Protected Neighborhood Electric Vehicle (T-NEV), the neighborhood pilot, the unified Mobility-as-a-Service (MaaS) platform, and the Smart Urban Mobility Authority (SUMA). Together, these elements transform IH from a theoretical framework into a governance-ready operational system, completing the evolution from vision to measurable, enforceable, and replicable urban mobility for the Gulf.

National Mobility and Planning Frameworks in Oman and the Gulf

Oman's Integrated Planning Framework

Oman's planning architecture for sustainable transport rests on three flagship instruments: the Greater Muscat Structure Plan (GMSP, 2023), the Action Area Plans (AAPs, 2023), and the Oman National Transport Model (ONTM, 2020)-each addressing a different layer of scale, governance, and enforcement. GMSP (2023): the metropolitan backbone of the capital region, whose Efficient Transport System section defines a multimodal vision linking BRT, LRT, and water taxis through shaded, humanized corridors. It explicitly calls for first–last-mile integration and micromobility feeders, positioning neighborhood connectivity as a precondition for mass-transit success.

This study extends that intent by proposing a thermally adapted feeder - the Thermal-Protected Neighborhood Electric Vehicle (T-NEV) - as the operational instrument that converts GMSP policy intent into measurable field performance. The T-NEV thus emerges as the physical embodiment of GMSP's "humanization" goal, connecting residential fabrics to high-capacity modes through climate-adapted means. AAPs (2023): represent the spatial and regulatory translation of GMSP's metropolitan strategy into district-scale projects. They incorporate corridor retrofits, station-area redevelopment, and land-use intensification but stop short of codifying vehicle typologies or defining the digital governance layer. The present study provides this missing execution dimension by defining legal classes (T-NEVs), operational pilots, and digital orchestration (One-App MaaS) that AAPs can explicitly reference in their design briefs, concession agreements, and development control regulations.

ONTM (2020): the analytical substrate for national transport forecasting - demand, travel times, and accessibility. While technically robust, it remains thermally neutral: it treats distance as a geometric metric independent of microclimate. Embedding ASTI into ONTM's impedance formulations introduces thermal realism, aligning modeled accessibility with real Gulf walking and waiting conditions. The result is a data-driven approach where thermal comfort becomes a quantifiable determinant of access equity. Legacy studies (MATS and Municipal Traffic Studies 2011–2012): earlier frameworks such as the Muscat Area Transportation Study (MATS) already anticipated multimodal integration-phased public transport, shaded access, and parking reform-but lacked institutional coupling and enforcement mechanisms. The IH framework, through ASTI, IH-IMI, and SUMA, now provides the missing instruments to operationalize these long-standing aspirations.

Saudi Arabia's Complementary Frameworks under Vision 2030: In parallel, Saudi Vision 2030 and the National Transport and Logistics Strategy (NTLS) pursue comparable objectives of integration, electrification, and governance modernization. The Royal Commission for Riyadh City (RCRC) oversees the Riyadh Public Transport Program, integrating metro and bus systems under a unified digital platform (Darb), supported by the Transport General Authority (TGA) for data governance and operator licensing. Complementary initiatives-such as NEOM's shared electric shuttles, Diriyah's micromobility corridors, and Riyadh's thermal-comfort retrofits- demonstrate a regional shift toward humanized smart mobility that mirrors IH's principles: comfort, integration, and institutional clarity. Saudi Vision 2030's emphasis on urban livability, digital transformation, and environmental stewardship aligns with Oman Vision 2040's focus on smart, connected, and resilient cities, forming a shared policy terrain for regional mobility reform.

Convergence and Gulf Replication: The comparison between Oman's GMSP–AAP–ONTM triad and Saudi Arabia's Vision 2030–RCRC–NTLS ecosystem reveals complementary strengths. Oman contributes a spatially grounded and climatically calibrated methodology through ASTI and IH-IMI, while Saudi Arabia contributes a mature institutional and financial architecture for implementation. Together, they form a Gulf-wide template for human-centered, thermally resilient mobility. By treating neighborhood feeders, unified digital management, and institutional integration as a single governance continuum, the IH-based T-NEV + SUMA framework offers a replicable model for Muscat, Riyadh, and other Gulf cities seeking to translate visionary planning into enforceable, measurable, and climate-responsive systems. This convergence effectively situates the Gulf as a living laboratory for applied mobility governance under arid conditions.

What the Literature Gets Right-and What It Still Misses

Existing scholarships and planning frameworks across the Gulf have made significant progress in acknowledging the interdependence of infrastructure, governance, and human-scale design. Most correctly identify three insights. First, multimodal backbones - BRT, LRT, and water taxis-require reliable first–last-mile feeders to achieve full operational value. Second, thermal exposure, particularly mean radiant temperature and shade continuity, is a decisive determinant of humanized accessibility in hot-arid climates; without mitigating exposure, "walkability" remains a theoretical construct. Third, cross-agency governance is indispensable for ensuring performance in complex metropolitan networks. Yet, despite these advancements, three structural deficiencies persist. They lack a legal identity for climate-fit neighborhood vehicles-without codification, such feeders remain pilots without permanence. They also fail to provide a unified digital orchestration layer, leaving users to navigate fragmented applications that fracture experience and oversight. Finally, they neglect code–contract integration, where key performance indicators seldom appear in enforceable clauses. Embedding tools such as ASTI and IH-IMI into planning permits, service-level agreements, and acceptance gates remains the missing link between policy aspiration and regulatory practice. Without these mechanisms, the Gulf's multimodal ambitions risk remaining visions rather than verifiable systems.

Conceptual Anchors and Analytical Framework

Translating visionary urban plans into enforceable mobility systems requires more than infrastructure-it demands a shared analytical language that bridges climate, human behavior, and institutional capability. Within the Integrated Humanization framework, this role is fulfilled by two interlinked tools - the Access-Shed Thermal Index (ASTI) and the Institutional Humanization - Institutional Maturity Index (IH-IMI) - as well as by a KPI–Code–Contract mapping logic. Together, these instruments anchor the methodological continuum from vision → code → contract → operation → dashboard, ensuring that both physical and institutional integration evolve in measurable tandem.

ASTI - Measuring Thermal-Realist Accessibility: The Access-Shed Thermal Index (ASTI) reframes accessibility through the lens of thermal effort rather than geometric distance. In Gulf cities, exposure to mean radiant temperature (Tmrt) and solar load can reduce effective walking distance by 40-60%, making shade continuity, material reflectance, and microclimatic comfort central to equitable access. ASTI converts these variables - Tmrt, humidity, surface albedo, and shaded-path ratio - into a weighted thermal impedance, redefining access radii to transit nodes. By embedding ASTI into transport modeling (within ONTM) and design codes (GMSP and AAPs), planners can classify corridors from Class A (Thermally Optimal) to Class E (Critical Exposure). This approach links environmental performance directly to legal and operational thresholds. Practically, ASTI functions as both a design tool and a regulatory gate: no feeder corridor or T-NEV route qualifies for operation unless it achieves at least Class B thermal comfort. This quantification transforms humanization from an ethical aspiration into a codified technical requirement, ensuring that urban comfort is measurable, enforceable, and transparent.

IH-IMI - Auditing Institutional Readiness: While ASTI evaluates the physical readiness of access corridors, the Institutional Humanization - Institutional Maturity Index (IH-IMI) evaluates the institutional readiness to sustain and govern them. Developed in Articles 4 and 5 of the IH series, IH-IMI measures governance capacity across four pillars:

1. Mandate clarity: existence of explicit legal authority for humanized transport.
2. Budget alignment: earmarked funding tied to measurable performance.
3. Data governance: interoperability, privacy safeguards, and real-time reporting capability.
4. Enforcement capacity: KPI-linked service agreements, penalties, and accountability structures.

Each pillar is scored from 0 to 3, producing maturity levels that correspond to phases of reform: Level 1 (pilot readiness), Level 2 (delegated powers and data-driven enforcement), and Level 3 (autonomous regulation and regional replication). In this study, IH-IMI acts as both diagnostic and gatekeeper: the proposed Smart Urban Mobility Authority (SUMA) cannot expand pilot operations or authorize new operators until Level 2 maturity is verified. This coupling of physical and institutional thresholds ensures that expansion is evidence-based rather than aspirational, preventing premature scaling and maintaining system coherence.

Coupled Governance Logic: ASTI and IH-IMI operate as a dual feedback loop within the IH system:

• ASTI governs where human-scale mobility is physically feasible;

• IH-IMI governs when institutions are mature enough to deliver and regulate it.

When combined on a shared dashboard, these indices create the data spine of the Gulf's new mobility governance. They translate comfort and capability into two synchronized dimensions of accountability: the human body and the institution. Their integration transforms IH from an analytical concept into a living regulatory ecosystem, where every shaded corridor and every licensed operator is auditable under a unified, measurable logic.

Finally, to operationalize this integration, a KPI–Code–Contract mapping framework ensures that each performance indicator - door-to-station time, geofenced compliance, dispatch reliability, or corridor ASTI class - is linked to an enforceable legal clause or SLA condition. This mapping closes the loop between policy intent and daily operations, embedding humanization in law, design, and contract alike.

Research Positioning and Contribution

Building directly on GMSP, AAPs, and ONTM, as well as the preceding IH research series, this paper advances a four-innovation model that closes the execution gap between strategic vision and operational reality:

1. Legislative innovation: establishing a standardized Thermal-Protected Neighborhood Electric Vehicle (T-NEV) class with codified right-of-way, safety, licensing, and geofencing regulations.
2. Operational innovation: implementing a neighborhood pilot that empirically validates thermal-realist first–last-mile performance before large-scale BRT or LRT investments.
3. Technical innovation: deploying a unified, account-based One-App MaaS platform integrating ticketing, routing, and fleet dispatch across all modes-including T-NEVs-eliminating application fragmentation for residents and visitors;
4. Institutional innovation: creating a Smart Urban Mobility Authority/Unit (SUMA) that consolidates mandates, data governance, and performance enforcement while embedding ASTI and IH-IMI into codes, contracts, and dashboards.

The outcome is a literature-grounded yet execution-ready framework that operationalizes the GMSP vision into a measurable, enforceable, and scalable system suited to Muscat and replicable across Gulf cities. Comparable precedents in Dubai, Singapore, and Doha confirm that the success of multimodal systems in hot climates depends on three preconditions: legal clarity, unified digital governance, and adaptive micro-vehicles such as the T-NEV. Together, these four innovations enable Gulf cities to move from fragmented experimentation to integrated, climate-adaptive mobility systems, anchored in measurable humanization and institutional accountability.

MATERIALS & METHODS

Research Design and Approach

This study adopts a qualitative synthesis and policy-design methodology that combines documentary analysis, institutional mapping, and systems prototyping. The objective is not to generate new empirical data but to translate existing Gulf planning and policy frameworks into an enforceable operational model. Methodologically, the paper builds upon the first five Integrated Humanization (IH) studies and extends them through a design-oriented inquiry focused on four coordinated innovation layers: legislative, operational, technical, and institutional. The analytical logic follows a "vision → code → contract → operation" continuum, in which planning intent (vision) is systematically tested against regulatory texts (code), implementation instruments (contracts), and expected field behavior (operation). This continuum ensures that IH evolves from conceptual theory to measurable, regulatory practice-linking national visions such as Oman Vision 2040 and Saudi Vision 2030 to operational delivery mechanisms.

Data Sources and Materials

All materials were drawn from publicly accessible institutional documents (available via government portals or upon formal request), ensuring transparency, reproducibility, and policy relevance.

Primary Sources Include

• Greater Muscat Structure Plan (GMSP, 2023) - Volumes 2 and 3, particularly Section 6 (Efficient Transport System) defining multimodal integration principles.

• Action Area Plans (AAPs, 2023) – official district-scale spatial frameworks derived from the GMSP. While publicly referenced by MoHUP, full datasets and detailed plan volumes are available upon formal institutional request rather than public download.

• Oman National Transport Model (ONTM, 2020) - offering demand, accessibility, and travel-time modeling foundations.

• The five preceding IH papers (2024–2025 Series) - forming the theoretical, environmental, engineering, governance, and institutional backbone for this operational synthesis.

• National Transport and Logistics Strategy (NTLS, 2021) - Kingdom of Saudi Arabia – providing national-scale transport/ logistics targets and frameworks for integration.

Each document was coded thematically under three analytical lenses:

1. Integration intent: the degree of multimodal and inter-agency coherence;

2. Thermal or climatic realism: acknowledgment of microclimate and comfort variables;
3. Institutional delivery structure: allocation of authority, budget, and enforcement responsibility.

This tri-lens coding allowed direct comparison between Omani, Saudi, and international precedents in multimodal governance.

Policy-Design Prototyping

Building upon these matrices, the study developed a policy-design prototype to test how new instruments-legislation, pilot operations, unified app, and institutional unit-could be embedded within Oman's and the wider Gulf's regulatory ecosystems. Input included national planning objectives (Vision 2040/2030), the IH pillars, and ASTI/IH-IMI indicators. Processes comprised the drafting of T-NEV classification clauses, pilot operational parameters, digital-governance protocols, and the SUMA organizational blueprint. Outputs took the form of a cohesive governance framework integrating codes, contracts, and dashboards. The design process followed a Plan–Do–Check–Act (PDCA) cycle common to Gulf performance-governance systems. Each loop captures feedback from field pilots - for example, T-NEV ridership, corridor ASTI scores, or app reliability - and channels it into iterative refinement of legal and institutional instruments. This cyclic prototyping ensures that the IH framework is not static but adaptive, learning from operational realities and continuously calibrating regulations, contracts, and data architecture.

Analytical Framework

The analytical phase was structured around two primary matrices and two cross-cutting indices, providing a layered audit of integration, enforcement, and maturity. Matrix A - Integration Audit: Matrix A cross-maps Oman's national frameworks (GMSP, AAPs, ONTM) against the five IH pillars: urban planning, humanization, public transport, road engineering, and micromobility. The matrix identifies gaps where physical, institutional, or behavioral integration remains weak-for instance, uncoordinated responsibilities between ministries or thermal exposure neglected in station-area design. Matrix B -KPI–Code-Contract Mapping: Matrix B links each performance indicator - travel time, comfort, safety, accessibility - to its corresponding enforcement instrument: regulatory clause, licensing term, or service-level agreement (SLA). This mapping converts otherwise aspirational KPIs into binding contractual or regulatory obligations.

ASTI - Access-Shed Thermal Index: ASTI quantifies the effective thermal accessibility of transport catchments by integrating microclimatic data (solar exposure, shade continuity, mean radiant temperature) into travel impedance. Instead of measuring linear distance, ASTI measures thermal effort - a critical metric for hot-arid Gulf mobility. The index grades each corridor from Class A (Thermally Optimal) to Class E (Critical Exposure). Corridors below Class B comfort are excluded from T-NEV or pedestrian service until mitigated through shading or material retrofits.

IH-IMI - Institutional Humanization–Institutional Maturity Index: IH-IMI assesses the readiness of institutions to operationalize IH principles across four parameters: mandate clarity, budget alignment, data governance, and enforcement capacity. Each dimension is scored 0–3, producing composite maturity levels: Level 1 – Pilot readiness; Level 2 – Delegated powers & data-driven enforcement; Level 3 – Autonomous regulation & regional replication. IH-IMI defines the maturity thresholds required to launch or scale T-NEV pilots, manage One-App MaaS governance, and graduate SUMA from a unit to an independent authority. Together, Matrix A/B + ASTI + IH-IMI form the analytical scaffold converting the IH paradigm into a quantifiable, enforceable system.

Validation and Triangulation

Validation relied on logical triangulation rather than statistical sampling, emphasizing conceptual consistency and institutional feasibility. Each proposal or indicator was cross verified through three perspectives:

1. Regulatory consistency – verifying alignment with GMSP/AAP/ONTM provisions and, where relevant, Saudi NTLS and RCRC standards.
2. Institutional feasibility – assessing compliance with mandates of MoHUP, MoTCIT, and Muscat Municipality, as well as potential coordination with Saudi counterparts under Vision 2030.
3. Thermal-realism check – confirming compatibility with ASTI thresholds ($\leq$ 160 W/m² mean radiant exposure for acceptable access).

This triangulation method ensures that the framework is legally sound, institutionally executable, and climatically valid. By substituting numerical replication with cross-domain verification, it secures robustness appropriate for policy design in emerging-governance contexts.

Methodological Output

The outcome of this methodological process is a four-part innovation model supported by enforceable performance indices. The model functions simultaneously as a research instrument and a policy prototype, bridging academic insight and regulatory design.

1. It transforms ASTI into a measurable gate for thermal accessibility and design compliance.
2. It operationalizes IH-IMI as a maturity compass guiding institutional scaling.
3. It aligns Matrix A/B with Vision 2040/2030 targets for integration, efficiency, and livability.
4. It embeds the four innovation layers - legislative (T-NEV), operational (pilot), technical (MaaS One-App), and institutional (SUMA) - within a unified PDCA cycle.

Collectively, these outputs convert the Integrated Humanization framework from an analytical paradigm into a governance-ready system capable of implementation, evaluation, and replication across Gulf cities. The methodology thus bridges the gap between visionary planning and enforceable urban-mobility governance - turning the IH series from research into regulatory architecture.

RESULTS & DISCUSSION

This section translates the Integrated Humanization (IH) framework from a conceptual and planning paradigm into an enforceable operational system tailored for the Gulf's hot-arid context. Building on the methodological continuum -Vision → Code → Contract → Operation → Dashboard- the results are structured into four interdependent innovations that collectively operationalize IH within the Greater Muscat Structure Plan (GMSP) framework.

1. Legislative Innovation: establishing a new vehicle class, the Thermal-Protected Neighborhood Electric Vehicle (T-NEV), defined by geometry, safety, and geofenced rights-of-way, transforming micromobility from informal practice into a codified legal category.
2. Operational Innovation: implementing a pilot neighborhood feeder that empirically validates thermal, behavioral, and operational feasibility before capital-intensive BRT or metro investments.
3. Technical Innovation: developing a unified mobility platform ("One-App") that integrates routing, ticketing, and dispatch for all modes-BRT, buses, taxis, micromobility, and T-NEVs-eliminating fragmentation and enabling data-driven oversight.
4. Institutional Innovation: establishing a Smart Urban Mobility Authority/Unit (SUMA) to consolidate mandates, regulate operators, manage the unified app, and embed IH's performance tools-ASTI (Access-Shed Thermal Index) and IH-IMI (Institutional Humanization–Institutional Maturity Index)-into enforceable governance.

Together, these four innovations close the implementation gap identified across Oman's mobility frameworks (GMSP, AAPs, ONTM) by coupling legislation, technology, and institutional maturity under a measurable, thermally resilient, and human-centered mobility system.

Legislative Innovation – Defining and Regulating the T-NEV Class

Context and Problem

Across Gulf cities, first–last-mile mobility remains trapped in regulatory ambiguity. Existing traffic laws recognize only conventional motor vehicles and open light-mobility devices (bicycles, scooters), leaving no legal room for small, enclosed, air-conditioned electric vehicles that can safely operate within residential streets. Consequently, pilot programs lack licensing procedures, insurance frameworks, and rights-of-way, preventing scalability or integration with public-transport networks such as BRT or LRT corridors.

Legislative Mechanism

This paper proposes the creation of a Thermal-Protected Neighborhood Electric Vehicle (T-NEV) class-an explicitly defined vehicle category adapted to the Gulf's climatic realities and neighborhood morphology.

Embedding the T-NEV in Oman's Traffic Law and Municipal Street Code transforms micromobility from an informal convenience into a lawful, thermally resilient feeder system.

Proposed operative definition: "A Thermal-Protected Neighborhood Electric Vehicle (T-NEV) is a small, fully enclosed, air-conditioned electric vehicle intended for short-range travel within residential neighborhoods and for first–last-mile connection to public-transport stations. Its operation is limited by certified geofenced speed zones and authorized right-of-way corridors designated by the competent authority."

Table 1: Baseline Specification and Performance Parameters

Category	Specification	Rationale / Code Hook
Dimensions	Width ≤ 1.50 m; length ≤ 3.70 m; turning radius ≤ 4.5 m	Ensures lane compatibility and curb efficiency on local streets; determines eligibility for neighborhood corridors.
Speed limits	25 km/h (residential cores); 35 km/h (collector spines)	Safety and noise control; consistent with international LSV regimes; enforced through digital geofencing recorded in the operator license.
Range	50–80 km per charge	One full day of local operation without battery swap; defines minimum fleet capability.
Safety equipment	3-point seatbelts; interlocked doors; daytime running lights; audible low-speed alert; battery retention system (UNECE R100-equivalent)	Links safety compliance to annual inspection; cites REESS standard in the technical annex.
Data & telemetry	GNSS tracking; over-the-air geofence updates; hashed trip logs (anonymized)	Enables KPI auditing while preserving privacy; mandatory clause in data-governance policy.

(Referenced in operator licenses and technical appendices; cross-linked to 1.12.4 Licensing and Obligations.)

Rights-of-Way and Priority Rules

(Referenced in Table 2 and embedded in Municipal Street Code clauses.)

• Dedicated or shared T-NEV lanes on local collectors (3.0–3.2 m target width) with priority markings at minor intersections.

• Protected crossings synchronized with pedestrian signals to guarantee safe low-speed coexistence.

• Access control via geofencing: exclusion zones around schools during peak hours and high-conflict commercial frontages.

• Parking and dwell: curbside stops restricted to signed bays; maximum dwell ≤ 90 s unless at a designated micro-hub.

Digital geofencing for speed and zone control follows international micromobility safety guidance (OECD/ITF 2022; NACTO 2023). SUMA certifies all geofence maps and treats tampering as a major violation under Article XX of the Traffic Law.

Licensing, Insurance, and Operator Obligations

• Operator license: annual, renewable permit issued by the Smart Urban Mobility Authority (SUMA) upon proof of fleet compliance and data submission.

• Insurance: comprehensive fleet liability coverage meeting or exceeding national minimums.

• Vehicle inspection: lightweight technical audit every 12 months or 10,000 km covering REESS battery, brakes, and lighting.

• Data compliance: mandatory transmission of encrypted daily trip summaries to SUMA's data lake within 24 hours of operation, per privacy-by-design principles.

Table 2: KPI-to-Law Hooks (Illustrative Mapping) - (Demonstrates how each performance indicator is anchored in a legal or contractual clause; cited in operator SLA and license terms.)

Target KPI	Enabling Legal / Code Clause	Enforcement Mechanism	Audit Data Source
Door-to-station ≤ 10 min (p95)	Priority at residential junctions; geofenced speed regulation	Monthly travel-time audit; route correction	One-App telemetry
Zero serious injuries (KSI = 0)	Mandatory safety equipment + 25/35 km/h cap	Incident reporting + on-board data recorder	Crash logs / EDR
ASTI uplift ≥ 2 classes (feeder corridors)	Shade and ROW standards in Municipal Code	Quarterly thermal-comfort field audit	Field audit + remote sensing
On-time arrival ≥ 85 %	SLA clause in operator license	Bonus/Malus adjustment	Operator dashboard
Speed compliance ≥ 98 %	Certified geofence map; tampering offence	Fines + partial suspension	Telematics violations feed
Data completeness ≥ 99 % (D-1)	Data policy requirement (privacy + retention)	Warning → fine → license suspension	Data-ingestion reports
Customer satisfaction ≥ 85 % (VG/Excellent)	Quality-of-Service clause in SLA	Monthly survey review + route adjustment	In-app surveys

Box 1 - Sample Legislative Clauses

1. Classification: "The Thermal-Protected Neighborhood Electric Vehicle (T-NEV) is recognized as a distinct category for neighborhood transport under Article XX of the Traffic Law."

2. Speed control: "T-NEV operation shall conform to certified digital geofence maps approved by the Authority; any tampering constitutes a major traffic violation."

3. Safety compliance: "All T-NEVs shall maintain functional seatbelts, daytime-running lights, and audible low-speed alerts; persistent non-compliance results in immediate license suspension."

4. Battery safety: "Rechargeable energy storage systems (REESS) shall comply with UNECE R100 (Rev. 3) or an equivalent national standard."

5. Data submission: "Operators shall upload encrypted trip summaries to the Authority's data platform within 24 hours of service completion."

6. Insurance: "Fleet operators must submit proof of comprehensive liability coverage prior to annual license renewal."

7. Public-realm protection: "Stopping or parking outside authorized T-NEV bays is prohibited and subject to fines not exceeding OMR XXX per offence."

8. Thermal compliance: "No T-NEV route shall operate along corridors rated below ASTI Class C until mitigation measures are implemented and verified."

Data collected under this license shall be restricted to mobility-service purposes, minimized to operational necessity, anonymized for analytics, retained no longer than 30 days for raw logs, and subject to a 72-hour breach notification. Cross-referencing: Box 1 clauses are cited within the amended Traffic Law, the Municipal Street Code, and the standard Operator License Template. They correspond directly to Table 1: Baseline Specification and Performance Parameters and Table 2: KPI-to-Law Hooks (Illustrative Mapping), forming the legal backbone of the T-NEV regulatory framework.

Global Alignment and Precedents

The proposed T-NEV legislation draws explicitly on established international frameworks to ensure technical

Table 3: Global Alignment and Precedents (Benchmarks supporting the legislative draft; used in policy memos and TOR documents.)

Theme	Global Reference	Borrowed Principle	Referenced in
Low-Speed Vehicle (LSV) limits	FMVSS No. 500 (US)	25–35 km/h caps and urban operational scope	Table 1 (Speed limits) / Box 1 (2)
Battery / REESS safety	UNECE R100 (Rev. 3)	Structural and thermal battery-safety testing for EVs	Table 1 (Safety equipment) / Box 1 (4)
Micromobility governance	OECD/ITF Guidelines; NACTO Permitting Guide	Licensing, curb management, operator data duties, and geofencing standards	§ 1.12.3–1.12.4 / Table 2
Unified ticketing (MaaS)	LTA SimplyGo (SG); RTA S'hail (Dubai)	Account-based ticketing, open APIs, and fare-capping models	Forward link § 1.13 & § 1.14
Thermal comfort metrics	Microclimate literature (MRT/Tmrt studies)	Mean radiant temperature as primary ASTI input	Table 2 (ASTI KPI) / Box 1 (8)

equivalence, interoperability, and safety comparability. Table 3 summarizes the principal global benchmarks that underpin the legislative text and its accompanying code clauses.

Together, these precedents confirm that the T-NEV framework conforms to internationally recognized safety, data, and operational norms. They provide the regulatory benchmarking backbone for the Gulf's first thermally protected neighborhood-mobility class. Subsequent sections (§ 1.13 and § 1.14) extend these global lessons into operational pilots and digital governance, demonstrating the applied feasibility of a regionally codified yet globally aligned system.

Discussion and Implications

The establishment of a T-NEV legal class fills a long-standing institutional vacuum. Once codified, it enables procurement, contracting, and enforcement agencies to align safety, data, and operational responsibilities under measurable KPIs (Table 2). It also converts thermal adaptation from architectural aspiration into statutory requirement by referencing ASTI-based corridor standards (Box 1, Clause 8). The principal implementation risks and their mitigation pathways are summarized in Table 4, which also serves as a governance "gate" for SUMA's enforcement strategy.

By grounding legislative text in measurable KPIs and ASTI thresholds, the T-NEV becomes the legislative cornerstone of thermally protected first–last-mile mobility-a foundation for both the Neighborhood Pilot (1.13) and the Unified Mobility Platform (1.14). In short, codification transforms Integrated Humanization's climate realism into enforceable law, bridging the gap between visionary planning and operational delivery.

Table 4: Key Risks and Mitigation Mechanisms

Risk	Likelihood	Impact	Mitigation / Gate Mechanism
Upsizing toward mini-cars	Medium	High	Enforce dimensional caps (Table 1) and chassis-weight limits in licensing terms.
Curb saturation in mixed zones	Medium	Medium	Controlled curb permits, digital dwell-time management, and penalty scaling.
Privacy concerns over data sharing	Medium	Medium	Enforce privacy-by-design policy; require opt-in aggregated transparency reports verified by SUMA's Data Governance Unit.

Global Alignment and Precedents

The proposed T-NEV classification aligns with global low-speed-vehicle and micromobility regulations, ensuring regulatory interoperability and safety equivalence.

Low-speed-vehicle class and speed caps. The T-NEV envelope and its 25–35 km/h geofenced limits are consistent with international Low-Speed-Vehicle (LSV) regimes. In the United States, FMVSS No. 500 defines LSVs as four-wheeled vehicles with attainable speeds above 20 mph and not exceeding 25 mph, confirming the upper bound and operational intent referenced in this paper.

Battery / REESS safety. Reference to UNECE R100 (Rev. 3) for Rechargeable Energy Storage Systems (REESS) aligns the T-NEV's safety requirements with global EV practice. This standard can be cited directly in the safety-equipment clause, specifying enclosure integrity and thermal-test compliance.

Micromobility regulation and geofencing. The governance model-encompassing operator licensing, curb-space management, data responsibilities, and geofenced speed / no-go zones-follows OECD/ITF micromobility-safety recommendations and NACTO permitting guidelines for shared systems. These precedents validate the use of data-driven SLAs, curb discipline, and digital speed control.

Unified ticketing / One-App MaaS. The "account-based, single-app" architecture is globally proven. Singapore's LTA SimplyGo and Dubai RTA's S'hail applications demonstrate feasibility and user acceptance, directly underpinning the § 1.14 specification of an account-based, open-API MaaS system. UITP's MaaS policy guidance supports the architectural choices of account-based back-ends, interoperability, and fare capping.

Thermal realism (ASTI basis). Framing user comfort via mean radiant temperature (MRT/Tmrt) and shade continuity is strongly supported in microclimate research. MRT is a primary driver of outdoor thermal load and, therefore, of first–last-mile viability in hot-arid contexts. These findings justify embedding ASTI thresholds into both design codes and service-level agreements. Together, these precedents position the T-NEV legislative framework as globally benchmarked, technically defendable, and regionally adaptable. With this alignment complete, the paper proceeds to the next pillar-1.13 Operational Innovation: Neighborhood Pilot Preceding BRT/Metro-to translate the legislative foundation into an applied field prototype.

Operational Innovation - Neighborhood Pilot Preceding BRT/Metro

Context and Global Precedents

The operational pilot represents the translation of legislative readiness into field evidence. Global experiences show that first–last-mile innovation succeeds only when small-scale trials precede large capital commitments.

The MARTA Reach Pilot (Atlanta, 2022) integrated demand-responsive shuttles with fixed-route transit to bridge short gaps between homes and rail stations, achieving high user satisfaction and measurable increases in rail ridership. The Microtransit Peer Case Studies Report (Baltimore Metropolitan Council, 2021) documents similar systems with average wait times under ten minutes and productivity levels of 5–15 boardings per vehicle-hour-benchmarks that inform this study's performance targets. Ferguson (2023) and the Bay Area Station Interface Study highlight that the success of micromobility-to-transit linkage depends on shaded, secure station interfaces - features directly mirrored in the ASTI-based corridor design adopted here. Within the Gulf, the early Oman Micromobility Sandbox (Zawya 2024) and the Mwasalat–UTAS integration trials demonstrate national momentum toward mixed-mode access, while Saudi Vision 2030's Riyadh Public Transport Program and Diriyah micromobility corridors provide a parallel policy environment for regional benchmarking. Together, these precedents confirm that a carefully instrumented pilot-with defined Key Performance Indicators (KPIs), boundary conditions, and feedback cycles-can de-risk full-scale adoption and generate credible Gulf-specific evidence.

Design of the Pilot

The pilot transforms the T-NEV legislative framework into a controlled, measurable operation that links homes to planned BRT/LRT stations within Muscat's metropolitan growth area.

Service Footprint and Catchment

- Target neighborhoods lie within 1–2 km of future BRT/LRT stops.
- The design objective is a 10-minute door-to-station isochrone under geofenced operation and shaded pedestrian access.
- Corridors are upgraded with retrofitted shading, vegetation, and reflective pavements to raise the ASTI class by ≥ 1–2 levels.

Fleet and Operation

- Fleet size: 12–20 T-NEVs (+ 15–20 % spares).
- Operating model:
    - Peak hours - fixed-route headways 6–8 min.
    - Off-peak - on-demand routing with ≤ 7 min promise time.
- Daily operation 06:00–22:00 (with possible late-night extension).
- Charging infrastructure: 8–10 AC chargers (7–11 kW) at two hubs + one light depot for overnight charging.

Integration and Ticketing

- Fully account-based ticketing shared with BRT/LRT using the same QR/NFC token.
- Fare policy: first/last-mile trips included within base fare - no surcharge.
- All booking and tracking occur through the One-App MaaS platform (§ 1.14).

Speed and Access Control

- Geofencing v1.0 enforces speed caps (25 km/h residential, 35 km/h collectors) and exclusion zones around schools and narrow lanes.
- Curbside stops restricted to signed T-NEV bays with maximum dwell ≤ 90 s unless at designated micro-hubs.

Data and Monitoring

- Real-time telemetry collected on trip origins/destinations, wait times, detours, and idle ratios.
- A live dashboard feeds data to the Smart Urban Mobility Authority (SUMA) for compliance auditing.
- Monthly performance reports compare operator KPIs against Service Level Agreement (SLA) thresholds.

KPIs, Benchmarks and Code Hooks

Performance metrics convert qualitative intent into measurable obligations. Table 5 consolidates the key KPIs adopted for the pilot, together with benchmarks drawn from international case studies and their corresponding enforcement mechanisms in SUMA's regulatory framework.

Table 5: Operational Pilot KPIs, Benchmarks and Code Hooks

KPI	Target / Benchmark	Source / Justification	Legal or Contractual Hook
Door-to-station travel time (p95)	≤ 10 min	Global first–last-mile threshold; MARTA Reach pilot	Clause 3 of Operator SLA + Geofenced Priority Rule (Table 2)
Boardings per vehicle-hour	5–15 (peak)	Microtransit peer studies (Baltometro 2021)	Performance audit via SUMA dashboard
Wait-time promise adherence	≥ 85 % on-time	Standard SLA benchmark	Monthly report + bonus/malus adjustment
Mode substitution (shift from private cars)	≥ 30 % of short car trips	Climate-relief target (Gulf adaptation)	Included in MoTCIT Sustainability Report
Chained trips with transit	≥ 70 %	Indicator of true feeder role (MARTA Reach)	Integrated ticket data from One-App
Safety (KSI = 0)	Zero serious injuries	Vision Zero policy alignment	Clause 8 in T-NEV Regulation + Insurance Mandate
ASTI uplift on corridors	+1 to +2 classes	Design requirement for shaded access	Linked to Design Approval Permit § ASTI Code
User satisfaction	≥ 85 % "Very Good"	Based on pilot surveys (Reach 2022; Doha BRT 2024)	Public report trigger for expansion decision

Each indicator in Table 5 is embedded in SUMA's SLA framework and linked to an enforcement clause or dashboard metric. Failure to achieve thresholds activates penalty clauses, while over-performance unlocks bonus payments and eligibility for fleet expansion. This code-contract coupling ensures KPIs are not merely evaluative but regulatory.

Risks, Mitigations and Scale-Gate Logic

Operational risk is inevitable in early deployments; governance must transform it into structured learning. Table 6 summarizes principal risks, likelihoods, impacts, and mitigation mechanisms, including the scale-gate logic that links operational growth to institutional maturity (IH-IMI levels).

Table 6: Operational Risks and Mitigation Mechanisms for T-NEV Pilot

Risk	Likelihood	Impact	Mitigation / Gate Mechanism
Under-utilization in early months	Medium	High	Targeted promotion, free introductory rides, dynamic routing to stimulate ridership.
Charging downtime or grid stress	Low–Medium	High	Redundant chargers, staggered charging schedule, backup battery system.
Heat-wave service stress	High (seasonal)	Medium	Temporary route adjustments, reduced fleet size per route, cooling stops with misting or shade tents.
Neighborhood pushback (noise/visual)	Medium	Medium	Strict speed and geofence enforcement, community engagement sessions, clear route signage.
Data privacy concerns	Medium	Medium	Privacy-by-Design architecture, opt-in data aggregation, independent transparency audit by SUMA.

Scale-Gate Mechanism. Expansion of service coverage or fleet size is permitted only when the institution achieves IH-IMI Level 2, verifying adequate mandate, budget, and data governance. Failure to meet KPI thresholds in Table 5 pauses scaling and triggers corrective cycles under SUMA's Plan–Do–Check–Act (PDCA) protocol. This dual-gate model ensures expansion occurs only under verified physical and institutional readiness.

Interpretation and Implications

The Neighborhood Pilot is more than a trial; it functions as a controlled learning laboratory for climate-realist mobility. Continuous PDCA cycles (Plan → Do → Check → Act) allow SUMA and operators to adjust routes, dispatch logic, charging windows, and shading strategies in near real time. Success in meeting the KPI targets and crossing IH-IMI Level 2 thresholds activates scale-up gates, allowing replication in adjacent districts and eventually across Muscat's metropolitan corridors. By juxtaposing Oman's climatic and urban conditions with international benchmarks (MARTA Reach, SimplyGo, Baltometro peer cases), the pilot achieves global comparability while remaining regionally authentic. Its integration with ASTI measurements ensures that thermal comfort becomes a quantitative determinant of mobility performance, not an aesthetic afterthought. In doing so, the pilot bridges the gap between law and lived experience, converting Integrated Humanization from policy rhetoric into operational reality under the governance umbrella of SUMA.

Technical Innovation - A Unified, Account-Based "One-App" Mobility Platform

Rationale and Global Alignment

Digital fragmentation remains one of the most persistent barriers to multimodal integration. In most Gulf cities, each transport operator maintains a separate application-one for metro, another for bus, yet another for taxis or micromobility-forcing users to juggle multiple logins, fare systems, and route maps. This disjointed experience weakens mode-shift potential and deprives regulators of unified data for oversight.

The Unified One-App Platform proposed in this paper remedies that gap through an account-based ticketing (ABT) architecture, where a single backend account processes payments and trip history across all modes-BRT/LRT, buses, T-NEVs, micromobility, and taxis. This architecture is already proven at scale. Singapore's SimplyGo, launched by the Land Transport Authority (LTA), eliminated the need for separate cards, enabling contactless bank and mobile payments with automatic fare capping. Dubai's S'hail platform integrates Metro, Tram, Bus, Taxi, and e-scooters under one front-end application with unified routing and payment logic. Regionally, Saudi Arabia's Vision 2030 initiatives-especially Riyadh's public-transport platform Darb-pursue identical goals of real-time multimodal integration. These precedents confirm the technical maturity and user acceptance of ABT-driven MaaS (Mobility-as-a-Service) ecosystems. At the policy level, the International Association of Public Transport (UITP) recommends open interfaces, data-sharing APIs, and fare capping within MaaS procurement, providing the regulatory backbone for the system envisioned here. Embedding these guidelines into Oman's framework transforms digital convenience into enforceable public-sector accountability.

Target User Experience (Residents & Visitors)

From a user's perspective, the platform must unify every stage of the trip chain-from door to station, station to city. The design philosophy follows three core principles: simplicity, climate-adaptiveness, and inclusivity.

- One app, one account: plan + book + pay across all modes without "download per mode."
- Thermal-aware routing: algorithms minimize not just travel time or fare but ASTI-weighted thermal exposure, integrating microclimate data into route choice.
- Assisted transfers: dynamic, in-app guidance from home to T-NEV bay, to BRT gate, to final destination.
- Contactless everything: ABT supports bank cards, mobile wallets, or prepaid transit accounts-no top-ups, no physical cards.
- Accessibility and language: bilingual (Arabic/English), full WCAG accessibility compliance, and offline ticket validation for limited-connectivity zones.

Together, these design elements turn fragmented travel into a continuous Gulf-relevant experience-a vital shift for residents and visiting users navigating Muscat, Riyadh, or Doha.

System Architecture (Regulator-Grade Design)

The One-App ecosystem is conceived as a three-layered architecture combining public accessibility with regulator-grade monitoring. Table 7 summarizes the architecture components, their functions, and enforcement interfaces.

Table 7: System Architecture of the Unified One-App Platform

Layer	Core Components	Function	Regulatory Interface / Enforcement
Client Layer	iOS / Android app, web mini-app, voice interface	User-facing trip planning, ticketing, and support; multilingual accessibility	SUMA UI compliance; certified front-end vendor (annual audit)
Orchestration Layer	Journey engine + dispatch engine	Multi-objective routing (time, cost, ASTI exposure) + dynamic fleet allocation (T-NEV)	KPIs logged to SUMA dashboard; SLA latency < 3 s
Ticketing & Payments Layer	Account-Based Ticketing (ABT) engine, fare capping, QR/NFC tokens	Backend transaction management; through-fare across modes	Fare policy clauses under Oman Urban Mobility Code (OUMC)
Data Lake & Analytics	GTFS/GBFS schemas + T-NEV telemetry	Real-time data ingestion, anonymized analytics, open-data publication	SUMA Data Governance Unit (privacy-by-design audit)

Open APIs	Operator onboarding, live position feeds, disruption alerts	Vendor-neutral interoperability; prevents lock-in	Mandatory API conformance in operator license (§ 1.14.5)
Security & Privacy	End-to-end encryption, differential privacy	Protect user data; enable "privacy-max" settings	Privacy Charter enforcement (72 h breach rule)

This architecture ensures full interoperability between public and private operators while giving SUMA real-time oversight of performance, safety, and equity metrics.

KPIs and Dashboards (Operational Governance)
Digital integration without measurable governance risks opacity. The One-App embeds Key Performance Indicators directly into system analytics. Table 8 details these KPIs, their target thresholds, and enforcement routes.

Table 8: Digital Governance KPIs for the Unified One-App Platform

Category	KPI / Metric	Target	Data Source	Enforcement Mechanism
Reliability	Wait-time promise adherence	≥ 85 %	Live dispatch logs	SLA + bonus/malus payment
	On-time arrivals (BRT + T-NEV)	≥ 90 %	GPS telemetry	Automated penalty trigger
Safety	Speed/geofence violations	≤ 2 % of trips	T-NEV telemetry	License points; automatic alerts to SUMA
	Harsh-braking events	≤ 5 per 1 000 km	On-board sensors	Preventive audit requirement
Equity	Service coverage by zone / gender / income	≥ 95 % target zone coverage	App usage analytics	SUMA quarterly inclusion audit
Thermal Resilience	ASTI corridor compliance	≥ Class B maintenance	ASTI sensor network	Linked to corridor maintenance contract
Transparency	Monthly public dashboard	100 % on-time release	SUMA data lake	OUMC reporting clause

Public transparency is mandatory: SUMA must publish aggregated monthly dashboards showing reliability, equity, and ASTI compliance scores. This digital visibility builds trust while anchoring regulatory credibility.

Code and Contract Hooks (Making It Enforceable)
Digital systems become governance instruments only when procurement and contract clauses enforce interoperability. The One-App framework embeds the following legal anchors:

- Procurement split: tender the app, orchestration layer, and payment gateway separately to prevent vendor lock-in and ensure iterative improvement (as practiced in Singapore's ABT contracts).
- Operator SLA: stipulates data completeness, latency < 3 s, promise adherence, and geofence compliance, with bonus/malus scaling (cross-linked with Table 8 KPIs).
- Fare policy: account-based with daily/weekly capping and integrated through-fares across all modes, cited from UITP MaaS Policy Guidelines (2022).
- Privacy charter: explicit "mobility-only" purpose limitation, anonymization thresholds, and mandatory breach disclosure within 72 hours, aligned with UITP Privacy-by-Design Brief (2023).

Collectively, these clauses translate digital architecture into contractual enforceability, transforming software governance into statutory compliance.

Regional Benchmarking with Vision 2030 and Vision 2040
Muscat's One-App concept is not isolated-it sits within a regional wave of digital mobility reform.

- Riyadh (RCRC): the Darb platform under the Royal Commission for Riyadh City integrates metro, bus, and parking systems through a single digital backend, supporting Vision 2030 goals of accessibility and sustainability.
- Dubai (RTA): S'hail offers unified trip planning and fare capping across multiple operators, demonstrating scalability within Gulf institutional structures.
- Singapore (LTA): SimplyGo validated ABT's technical feasibility and user adoption worldwide.

Oman's implementation aligns these best practices with Vision 2040's Smart & Sustainable Cities pillar, embedding data governance, climate realism (ASTI), and institutional maturity (IH-IMI) into one adaptive ecosystem.
Cross-vision interoperability-shared APIs, regional payment tokens, and data exchange standards-enables Gulf-wide mobility continuity for visitors and residents alike.

Risks and Mitigation Framework

No digital ecosystem is risk-free. The One-App architecture anticipates the principal governance and technical risks summarized in Table 9.

Table 9: Digital Governance Risks and Mitigation Mechanisms

Risk	Likelihood	Impact	Mitigation / Response Strategy
Vendor lock-in	Medium	High	Modular procurement + open-standards mandate + data escrow clauses in all contracts.
Privacy backlash / data misuse	Medium	High	Pre-published Privacy Charter; independent annual audits; "privacy-max" user settings.
Operational fragmentation among operators	Medium	Medium	Mandate API conformance as licensing condition; staged compliance deadlines enforced by SUMA.
Cybersecurity breach	Low	High	End-to-end encryption; real-time threat monitoring; incident response protocol < 72 h.
Low user adoption in early months	Medium	Medium	Public awareness campaigns; fare incentives; user-experience feedback loops.

Every mitigation is codified within SUMA's regulatory plan. System resilience is measured through continuous PDCA cycles (Plan–Do–Check–Act) where performance audits inform iterative software and policy updates.

Interpretation and Strategic Implications

A One-App, ABT-based ecosystem is not a luxury-it is the operating system of Integrated Humanization. By linking user experience with regulatory oversight, it transforms the fragmented transport network of Gulf cities into a single auditable system. The ASTI-weighted routing engine introduces climate realism into digital mobility for the first time, quantifying heat exposure as a travel cost. Simultaneously, open APIs and ABT integration create a shared digital fabric across Muscat, Riyadh, and Dubai-each node reinforcing regional interoperability under Vision 2040/2030 convergence.

In governance terms, the One-App allows SUMA to evolve from a coordinating body into a real-time regulator, where every trip, corridor, and operator is evaluated by data rather than anecdote. This digital transparency elevates public trust and provides the empirical foundation for scaling Integrated Humanization across the Gulf.

Institutional Innovation - Establishing the Smart Urban Mobility Authority (SUMA)

Context and Rationale: The Institutional Gap

Across the five preceding studies in the Integrated Humanization (IH) series, one structural truth persisted: the Gulf's transport systems are technically sophisticated yet institutionally fragmented.

- Article 2 (Ecologizing IH) showed that no single agency was responsible for shaded corridors or blue-green infrastructure, leaving "thermal connectivity" unmanaged.
- Article 3 (Engineering IH) revealed a disconnect between design manuals and policy objectives: standards evolved, but agency coordination lagged.
- Article 4 (Governing & Evaluating IH), through the IH-IMI Index, quantified how mandates, budgets, and enforcement powers were dispersed across ministries, municipalities, and consultants.
- Article 5 (Institutionalizing IH) concluded that this fragmentation was the central barrier preventing frameworks such as GMSP, AAPs, and ONTM from translating vision into delivery.

Together, these findings identified a missing institutional nexus - a body able to link planning (vision), design (standards), operation (services), and evaluation (metrics) under one governance continuum. The Smart Urban Mobility Authority (SUMA) is conceived precisely to fill this void.

Mission and Functional Mandate

The Authority's mission captures the synthesis of all IH pillars into a single operational charter.

Table 10 summarizes the official mission statement, key functions, and measurable deliverables that define SUMA's role.

Organizational Structure and Governance Phasing

SUMA evolves through three institutional phases, corresponding to maturity levels within the IH-IMI framework.

Table 11 details this staged evolution and introduces the RACI (Responsible, Accountable, Consulted, Informed) matrix governing cross-agency collaboration.

This phased model ensures that SUMA's empowerment follows proven capacity-maturity before mandate.

Table 10: SUMA Mission, Functions, and Deliverables

Domain	Mandate / Function	Operational Deliverable	Performance Metric (Link to ASTI / IH-IMI)
Planning Integration	Align urban planning, transport, and micromobility systems.	Oman Urban Mobility Code (OUMC) integration with GMSP and AAPs.	% of projects with Class B+ ASTI compliance.
Regulation & Licensing	Issue and enforce T-NEV and operator licenses.	Annual licensing registry and compliance report.	IH-IMI Enforcement Sub-score ≥ 2.0.
Digital Governance	Manage One-App platform, APIs, and data lake.	Functional integration of ≥ 5 operator APIs.	Data Governance pillar (Level 2 IH-IMI).
Performance Management	Operate ASTI & IH-IMI dashboards; enforce SLA penalties.	Public dashboard published quarterly.	KPI compliance ≥ 85 %.
Contractual Oversight	Integrate KPI clauses into service contracts.	Template SLA and contract manual.	% contracts ASTI/IH-IMI-linked.
Knowledge & Innovation	Maintain mobility database and training programs.	Annual Mobility Innovation Report.	Staff training hours per year.

Table 11: Organizational Phasing and Governance Model

Phase	Description / Trigger Criteria	Institutional Status	Primary RACI Assignments
Phase 1: Launch (0–9 months)	Ministerial resolution creates SUMA Unit under MoHUP; pilot supervision begins.	Special unit with delegated authority from MoTCIT and Muscat Municipality.	R: SUMA Unit • A: MoHUP • C: MoTCIT • I: Municipalities.
Phase 2: Scale (9–18 months)	IH-IMI Level 2 achieved (mandate + budget + data); Royal Decree grants semi-autonomy.	Semi-autonomous authority with board and budget line.	R: SUMA Board • A: Inter-ministerial Council • C: Finance / Environment • I: Public.
Phase 3: Replication (18–36 months	IH-IMI Level 3 achieved; national roll-out begins.	Fully autonomous national authority under GCC cooperation framework.	R: SUMA HQ • A: Supreme Council for Planning • C: GCC Mobility Council • I: Cities Network.

Table 12: Regulatory and Policy Instruments for SUMA Operationalization

Instrument	Purpose / Scope	Issuing Entity	Legal Status
Royal Decree Establishing SUMA	Formally creates the Authority and defines jurisdiction.	Royal Court / MoHUP	Primary law (Article XX).
Inter-Ministerial Protocol	Coordinates MoHUP, MoTCIT, Municipality data and projects.	Cabinet Decree	Binding administrative agreement.
Oman Urban Mobility Code (OUMC)	Merges engineering standards with IH design principles.	SUMA + MoHUP	Technical code / mandatory.
IH Implementation Handbook	Operationalizes ASTI and IH-IMI procedures.	SUMA Technical Dept.	Guideline with enforcement reference.
Smart Mobility Operations Manual	Defines digital requirements for One-App and T-NEVs.	SUMA Digital Unit	Regulatory standard.

Regulatory and Policy Instruments

Institutional power requires codified instruments. SUMA's authority is operationalized through a suite of legal and procedural documents listed in Table 12.

By binding codes, manuals, and data governance within SUMA's legal jurisdiction, Oman transforms guidance into enforceable policy.

Funding and Sustainability Mechanisms

Institutional sustainability depends on predictable funding streams linked to performance. Table 13 outlines the Authority's financial model, balancing self-generated revenue with public and climate-finance support.

This blended approach converts mobility performance into budgetary credibility.

Table 13: Funding and Sustainability Mechanisms

Revenue Source	Description / Mechanism	Alignment with Vision 2040/2030	Monitoring Indicator
Operator Licenses & Fines	Annual license fees and penalties for non-compliance.	Encourages regulatory discipline and cost recovery.	% license renewal on time.
Transaction Fees (One-App)	Fractional service fee on digital transactions.	Digital economy growth & smart city ecosystem.	Transaction volume growth rate.
Parking Revenue Share	10–15 % allocation from municipal parking systems.	Integrates TDM (Transport Demand Management).	Monthly reconciliation reports.
Climate Finance Grants	Access to international funds (GCF, GEF) for emission reduction.	Links mobility to environmental sustainability.	Annual carbon abatement report.
Performance-Based Budget (PBB)	MoF allocations tied to ASTI/IH-IMI improvements.	Promotes evidence-based governance.	ΔASTI × ΔIH-IMI ≥ target.

Data Governance and Transparency Architecture

Data is SUMA's bloodstream. Table 14 shows how each data layer contributes to regulatory oversight and public accountability.

This system ensures that every corridor, operator, and institution becomes auditable by both SUMA and the public.

Table 14: Data Governance and Transparency Architecture

Data Layer	Content / Source	Governance Rule	Public Output
Transport Operations	BRT/LRT, T-NEV telemetry, micromobility feeds (GBFS)	Mandatory real-time submission < 60 s latency.	Live mobility map + service alerts.
Thermal & Environmental	ASTI sensor network + remote sensing imagery.	Class B+ threshold for corridor approval.	ASTI heat map on public dashboard.
Institutional Performance	IH-IMI audits per agency.	Annual report with maturity scores.	Open IH-IMI index portal.
Financial & Contractual	SLA metrics and operator payments.	Bonus/malus clauses triggered automatically.	Quarterly financial summary.
Citizen Feedback	App ratings and survey inputs.	Privacy-by-Design anonymization.	Public sentiment score indicator.

Regional Alignment and Interoperability

SUMA's design is regionally convergent. It reflects Oman Vision 2040's "Smart and Sustainable Cities" pillar while aligning with Saudi Vision 2030's digital mobility transformation. Table 15 maps functional interoperability with key Gulf counterparts.

By embedding GCC-level interoperability in APIs and KPIs, SUMA positions Oman as a regional benchmark for data-driven mobility governance.

Interpretation and Strategic Implications

The establishment of SUMA is the institutional translation of the entire Integrated Humanization framework-from vision to verifiable practice.

1. Governance integration. SUMA merges the five IH pillars-urban planning, humanization, public transport, road engineering, and micromobility-within a single enforceable regulatory ecosystem.
2. Performance accountability. ASTI and IH-IMI become SUMA's dual regulatory levers, turning comfort and institutional maturity into budget and license conditions.
3. Institutional learning. Through its PDCA cycle, SUMA functions as a learning organization that continuously refines codes, contracts, and operations.
4. Regional leadership. By bridging Oman Vision 2040 and Saudi Vision 2030, SUMA anchors Gulf mobility governance in measurable humanization.

Without SUMA, the IH framework would remain a research narrative; with SUMA, it becomes a living system-an institutional operating system for climate-adaptive, human-centered urban mobility.

Integration of Tools: Embedding ASTI and IH-IMI into Implementation

The success of Integrated Humanization (IH) depends not only on visionary planning or institutional reform but on the operational embedding of its measurement tools into real governance systems. ASTI and IH-IMI - introduced respectively as the physical and institutional indices of humanization - become the backbone of enforceability when integrated across design codes, contracts, and dashboards. This section bridges the conceptual with the executable: translating

Table 15: Regional Alignment and Interoperability Map

Partner Entity	Comparable Framework / System	Shared Principle or Standard	Collaboration Opportunity
Riyadh (RCRC)	Darb Platform / Vision 2030 NTLS	Unified APIs, ABT, ASTI adaptation	Data exchange / joint pilot cities.
Dubai (RTA)	S'hail / Dubai Urban Plan 2040	Open fare capping & micromobility integration	Cross-border visitor interoperability.
Abu Dhabi (ITC)	Smart Mobility Strategy 2025	MaaS policy alignment / safety telemetry	Regional standards committee.
Doha (ASHGHAL + MOT)	Qatar Integrated Transport Program	Microclimate adaptation in access design	Joint ASTI methodology exchange.
Bahrain (MOW)	Bahrain Urban Mobility Plan 2030	Institutional performance indices	GCC mobility scorecard initiative.

human-centered ideals into quantifiable thresholds that determine when and where mobility systems can expand. Through the Smart Urban Mobility Authority (SUMA), both indices are elevated from analytical instruments to regulatory levers, aligning project approvals, operator performance, and policy decisions with measurable human comfort and institutional maturity. In essence, this integration transforms Integrated Humanization from a framework of intent into a framework of accountability - where every shaded corridor and every institutional decision is tested against thermal realism and governance readiness.

From Metrics to Enforcement

Performance metrics acquire meaning only when institutionalized within legal and contractual frameworks. The Integrated Humanization (IH) framework operates two interlocking tools that convert qualitative aspirations into measurable enforcement:

1. ASTI (Access-Shed Thermal Index) - quantifies how far a person can comfortably access a transit node under Gulf climatic conditions.
2. IH-IMI (Institutional Humanization - Institutional Maturity Index) - assesses whether institutions are structurally ready to deliver and enforce IH principles.

Within Oman's proposed governance architecture, the Smart Urban Mobility Authority (SUMA) becomes custodian of both indices. SUMA embeds them directly into:

- Urban design and planning codes;
- Procurement and contractual clauses;
- Operational and monitoring dashboards.

This embedding process transforms metrics into levers of compliance-ensuring that every shaded corridor and licensed operator performs within measurable thermal and institutional thresholds.

The Access-Shed Thermal Index (ASTI): Measuring Climate-Realist Access

Concept and Methodology

Conventional accessibility metrics treat distance geometrically; ASTI redefines it thermally.

It applies a resistance-weighted function in which mean radiant temperature (Tmrt), humidity (RH), wind speed (v_air), surface reflectance (Material_r), and shade continuity (Shade_c) jointly determine the effective travel effort.

Mathematically simplified: ASTI= f(d, Tmrt, RH, vair, Shadec, Materialr)

Each corridor is classified by thermal comfort class (A–E) based on field and modelled data (Table 16).

Table 16: ASTI Classification and Thermal Parameters

ASTI Class	Mean Radiant Temperature (Tmrt °C)	Effective Walking Distance Ratio	Thermal Condition	Design Implication
A – Thermally Optimal	≤ 45 °C	1.00 (base)	Full comfort	Standard access; no penalty.
B – Comfort Acceptable	46 – 50 °C	0.85	Mild discomfort	Shading ≥ 60 %; vegetated corridors.
C – Moderate Exposure	51 – 55 °C	0.70	Manageable but limited	Mandatory retrofits (pre-launch gate).
D – High Exposure	56 – 60 °C	0.50	Marginally viable	Not operational until improved.
E – Critical Exposure	> 60 °C	0.35	Unsafe	Corridor closure / design redesign.

(ASTI Classes A–B qualify for operation; C requires intervention before license; D–E prohibited under SUMA code.)

Integration into Codes, Permits and Contracts

SUMA institutionalizes ASTI through three implementation pathways summarized in Table 17.

Table 17: ASTI Integration Pathways in Codes, Permits and Contracts

Implementation Channel	ASTI Requirement	Legal or Contractual Instrument	Monitoring Frequency
Design Standards	New access corridors must achieve Class A–B pre-approval.	Oman Urban Mobility Code (OUMC) Clause 6.3.	Pre-construction review.
Permitting Process	Construction permits for stations or feeder links require ASTI assessment report.	MoHUP Building Permit Portal integration.	Annual update with audit.
Service Contracts	Operators receive bonuses for ASTI improvement; penalties for degradation ≥ 1 class.	SUMA Service Level Agreement (SLA) Article 12.	Quarterly field audit.

By embedding ASTI into permits and contracts, thermal comfort becomes a regulated performance criterion rather than a design preference.

Application in the Neighborhood Pilot: The T-NEV Pilot (§ 1.13) uses ASTI as an operational gate: routes scoring below Class C are excluded until retrofits improve conditions. Quarterly audits combine satellite imagery, sensor data, and user perception surveys-validated by methods from Singapore's heat-resilience trials and Doha's pedestrian comfort studies. This loop ensures that thermal reality dictates mobility eligibility.

The Institutional Humanization – Institutional Maturity Index (IH-IMI): Measuring Governance Readiness

Concept and Dimensions: While ASTI measures physical feasibility, IH-IMI evaluates institutional capacity. Developed in Articles 4 and 5, it scores institutions across four pillars-each weighted equally-to produce a composite maturity level (Table 18).

Table 18: IH-IMI Institutional Pillars and Scoring Framework

Pillar	Indicator Examples	Evidence Source	Scoring Scale (0–3)
Mandate	Existence of legal authority; inter-agency protocol.	Royal Decree, MoHUP/MoTCIT documents.	0 = none; 1 = draft; 2 = approved; 3 = operational.
Budget	Dedicated funding and performance-based allocation.	MoF budget records, PBB reports.	0 = none; 1 = ad hoc; 2 = earmarked; 3 = linked to KPIs.
Data Governance	Data lake existence, interoperability, privacy framework.	SUMA digital policy audit.	0 = manual; 1 = partial; 2 = systematic; 3 = real-time.
Enforcement	KPI-linked SLAs, audit cycles, penalties applied.	Operator contracts and reports.	0 = none; 1 = reactive; 2 = routine; 3 = proactive.

Maturity Levels

- Level 1 – Basic Setup / Pilot Readiness.
- Level 2 – Delegated Powers and Routine Data Auditing.
- Level 3 – Autonomous Regulation and Regional Replication.

Embedding within SUMA

- Internal: SUMA's annual report publishes pillar scores; progression unlocks new statutory powers.
- External: Operator SLAs require submission of evidence aligned with IH-IMI criteria.
- Cross-reference: Other agencies benchmark their mobility divisions against SUMA's trajectory to encourage horizontal learning.

This integration turns governance maturity into an auditable performance dimension.

Synergy Between ASTI and IH-IMI

The two indices operate in concert as dual gates for system growth and funding allocation. Table 19 illustrates their interdependency within SUMA's decision hierarchy.

This dual-gate logic prevents the "build-first, manage-later" pattern common in rapid urbanization. Thermal and institutional readiness advance together.

Integration into National and Regional Dashboards

SUMA's data architecture feeds the two indices into both national and GCC platforms for policy alignment. Table 20 summarizes the dashboard ecosystem.

Through these dashboards, metrics become governance instruments accessible to ministries, operators, and citizens alike.

Table 19: Synergy Matrix: ASTI and IH-IMI as Dual Gate Mechanisms

Decision Layer	Trigger Metric	Threshold	Enforcement Actor	Outcome if Not Met
Physical Expansion (new routes / stations)	ASTI Class rating	≥ Class B	SUMA Technical Dept.	Delay approval until retrofits raise ASTI.
Service Scaling (fleet growth / new operators)	IH-IMI Maturity Level	≥ Level 2	SUMA Board of Governors	Suspend license expansion pending audit.
Funding Allocation (PBB trigger)	ΔASTI × ΔIH-IMI Composite Score	> national threshold	Ministry of Finance / Planning Council	Freeze budget release until compliance.
Regional Replication (GCC coordination)	Both indices publicly validated	Annual publication	GCC Mobility Council	Replication only after cross-audit.

Table 20: National and Regional Dashboard Integration Architecture

Dashboard Tier	Platform / Host Entity	Displayed Indicators	Frequency / Access	Policy Use Case
National – Oman Vision 2040 Portal	Supreme Council for Planning	ASTI Class Maps, IH-IMI Scores, Emission Reduction Metrics.	Quarterly update / Public.	Evaluate urban mobility contribution to Vision targets.
SUMA Public Dashboard	SUMA Official Portal	Corridor ASTI maps, operator KPIs, citizen feedback index.	Monthly / Public Open API.	Transparency and citizen engagement.
Institutional Audit Dashboard	MoHUP & MoTCIT Joint System	Departmental IH-IMI scores and budget links.	Annual / Restricted.	Performance-based funding and policy correction.
Regional – GCC Smart Cities Hub	GCC Mobility Council (under Vision 2030 coordination)	Aggregated ASTI/ IH-IMI indices + Mobility KPIs.	Annual summit / Open data exchange.	Regional benchmarking and interoperability.

Table 21: Implementation Philosophy and PDCA Logic

Stage	Core Question	Primary Activity	Expected Output	Validation Instrument
Plan	What do we build, and who governs it?	Define KPIs, ASTI thresholds, IH-IMI targets, budgets.	Annual implementation plan.	Approved by SUMA Board & MoHUP.
Do	How is it executed?	Deploy pilot, enact legal clauses, initiate data collection.	Operational pilot and first dashboards.	Field verification and SLA reports.
Check	Is it working?	Audit KPIs, ASTI, IH-IMI, public satisfaction.	Quarterly audit report.	Independent technical review.
Act	How to improve or scale?	Adjust code, contracts, or scale operations.	Revised standards and expanded service area.	SUMA Policy Revision Protocol.

Interpretation and Strategic Implications

Embedding ASTI and IH-IMI into SUMA's core operations completes the transition of Integrated Humanization from research to regulation.

• ASTI humanizes the corridor: it translates microclimate and thermal comfort into legally enforceable design standards and KPIs.

• IH-IMI humanizes the institution: it quantifies governance capacity, turning institutional evolution into a measurable and fundable process.

• Together they operationalize climate and governance realism: expansion occurs only when the environment and the institution are ready in tandem.

• Cross-vision alignment: their integration serves Oman Vision 2040's targets for "evidence-based policy and sustainability" while echoing Saudi Vision 2030's KPI-driven National Transport and Logistics Strategy.

In essence, ASTI is the metric of the body; IH-IMI is the metric of the institution. Their coupling within SUMA ensures that Muscat's mobility transition is not only climate-realist and human-centered but also institutionally sustainable and regionally replicable.

Roadmap and Implementation Plan

Translating the Integrated Humanization (IH) framework from concept to measurable delivery requires a sequenced roadmap that unites legislation, operations, technology, and governance under one iterative cycle. The roadmap serves as the execution manual for the Smart Urban Mobility Authority (SUMA), defining how each innovation-T-NEV, pilot operations, unified MaaS, and institutional consolidation-progresses from prototype to national policy.

It integrates the IH performance instruments - ASTI and IH-IMI- into a phased Plan - Do–Check–Act (PDCA) structure, ensuring that every expansion decision is evidence-based and climate-realist. Each phase is gated by measurable readiness levels: corridors must achieve minimum thermal performance (ASTI Class B) and institutions must demonstrate governance maturity (IH-IMI ≥ Level 2) before scaling. The roadmap thus converts IH from a research series into a living implementation mechanism, linking Oman Vision 2040 and Saudi Vision 2030 through a common model of adaptive, data-driven urban mobility reform.

Implementation Philosophy

Effective mobility transformation in hot-arid Gulf cities demands sequencing before scaling. Rather than executing legislative, operational, and digital layers simultaneously, the roadmap advances through measurable maturity gates. The process follows a PDCA loop that reinforces accountability and institutional learning.

Table 22: Phase 0–4 Overview (Timeline and Deliverables)

Phase	Duration	Primary Objective	Key Deliverables	Responsible Entity
Phase 0: Regulatory Foundation	0–3 months	Legal scaffolding for SUMA & T-NEV	Ministerial decree; ASTI baseline map	MoHUP + SUMA Interim Unit
Phase 1: Pilot Deployment	3–9 months	Field-test T-NEV and One-App integration	Pilot report; IH-IMI Level 1 audit	SUMA Technical Dept.
Phase 2: Institutional Consolidation	9–18 months	Formalize SUMA as semi-autonomous authority	Royal Decree; OUMC Edition 1; Public Dashboard	SUMA Board + MoF
Phase 3: Metropolitan Scaling	18–36 months	Expand service corridors and regional linkages	BRT integration; IH-IMI Level 3 audit	SUMA HQ + Municipalities
Phase 4: Regional Replication	36–60 months	Extend model nationwide and GCC interoperability	National Statute; GCC MoU; IH Handbook 2.0	SUMA + GCC Mobility Council

Detailed Action Matrix by Phase

Each phase contains legislative, operational, digital, and institutional actions summarized in Table 23.

Table 23: Detailed Action Matrix by Phase

Phase	Legislative / Policy Actions	Operational Actions	Digital Actions	Institutional / Data Actions
0	Draft T-NEV classification; establish inter-ministerial committee.	Map pilot corridors (ASTI baseline).	Prepare API registry & data schemas.	Create SUMA Interim Unit and organogram.
1	Enforce permit clauses (ASTI pre-approval).	Deploy 12–20 T-NEVs; community orientation.	Activate One-App v1 ABT module.	IH-IMI audit (Level 1).
2	Enact Royal Decree establishing SUMA.	Expand to 3 neighborhoods; link to BRT station.	Launch full data lake and dashboard.	Publish IH-IMI Level 2 report.
3	Integrate ASTI/IH-IMI into MoF funding rules.	Extend network city-wide; apply fare capping.	Enable regional API interchange with RCRC / RTA.	Independent performance audit.
4	Issue National Mobility Statute; GCC inter-operability MoU.	Scale to 5 cities; establish Mobility Fund.	Deploy cross-border token payments.	Publish IH Implementation Handbook 2.0.

PDCA Cycle Responsibilities and Frequencies
The cyclical management model institutionalizes learning. Table 24 outlines responsibilities and timing for each PDCA stage.

Table 24: PDCA Cycle Responsibilities and Frequencies

Cycle Stage	Description	Frequency	Responsible Entity	Data Source
Plan	Define targets, budgets, and KPI gates.	Annual	SUMA Board + MoHUP	Vision 2040 plan.
Do	Implement projects per approved plan.	Quarterly	Operators / Municipalities	Service records.
Check	Audit ASTI / IH-IMI / KPIs.	Monthly & Quarterly	SUMA Audit Dept.	Dashboards / Sensors.
Act	Revise policy or scale implementation.	Quarterly & Annual	SUMA Board / MoF	Audit findings.

This regular rhythm ensures that SUMA remains adaptive, transparent, and aligned with evolving evidence.

Expansion Criteria and Equity Safeguards
Scaling is authorized only when measurable equity and performance thresholds are met.
Table 25 defines the quantitative triggers and safeguards. This framework embeds social and climatic fairness directly into the mobility expansion logic.

Table 25: Expansion Criteria and Equity Safeguards

Criterion Category	Trigger Threshold	Measurement Tool	Authority / Gatekeeper	Corrective Action if Unmet
Thermal Readiness	ASTI ≥ Class B for ≥ 90 % of corridors	ASTI audits + field sensors	SUMA Technical Dept.	Delay expansion until retrofit complete.
Institutional Maturity	IH-IMI ≥ Level 2	IH-IMI dashboard	SUMA Board	Suspend fleet growth / staffing.
Equity Coverage	Service access ≥ 95 % of low-income zones	App usage analytics	Social Mobility Division	Re-route services.
Public Satisfaction	≥ 85 % “Very Good” rating	User surveys / App feedback	Public Engagement Dept.	Launch improvement campaign.
Financial Accountability	ΔASTI × ΔIH-IMI > budget threshold	SUMA–MoF link index	MoF Performance Unit	Hold fund disbursement.

Vision 2040 / 2030 Strategic Alignment
The roadmap’s PDCA sequencing supports both Oman Vision 2040 and Saudi Vision 2030 policy matrices. Table 26 illustrates this alignment.

Table 26: Vision 2040 / 2030 Strategic Alignment Map

Domain	Oman Vision 2040 Objective	Saudi Vision 2030 Objective	Roadmap Implementation Response
Governance & Accountability	Evidence-based policy & decentralization.	KPI-driven institutional performance.	PDCA cycle with IH-IMI audits and MoF PBB linkage.
Urban Mobility	Smart, connected, sustainable cities.	Intelligent and integrated transport systems.	One-App platform and T-NEV network integration.
Climate Adaptation	Urban resilience and thermal comfort.	Environmental stewardship and emissions reduction.	ASTI embedded in codes and service contracts.
Innovation & Digital Economy	Smart governance and data ecosystem.	National digital transformation program.	SUMA data lake + open API procurement.
Social Equity & Livability	Inclusive services and community well-being.	Quality of life enhancement programs.	Equity benchmarks in Table 25 expansion gates.

Interpretation and Strategic Implications

The roadmap operationalizes Integrated Humanization as a living system of evidence.

1. Adaptive Governance: PDCA cycles institutionalize responsiveness-policies evolve with data, not rhetoric.
2. Measurable Resilience: ASTI and IH-IMI translate climate adaptation and institutional maturity into funding logic.
3. Equitable Scaling: Service expansion depends on comfort, capability, and inclusion, avoiding "technology-first" inequities.
4. Regional Convergence: The phased design synchronizes Oman's Vision 2040 with Saudi Vision 2030 timelines, promoting shared Gulf standards.

Through this roadmap, Oman shifts from plans on paper to policies in motion: every phase a testbed, every corridor a metric, every institution a learner. It turns the Integrated Humanization framework into a replicable Gulf governance model-one that learns, adapts, and evolves through climate, data, and design.

Transitional Reflection

The Gulf's mobility transformation has reached an inflection point: technical competence now exceeds institutional readiness. The Integrated Humanization (IH) framework and its operational arm-the Smart Urban Mobility Authority (SUMA) - redefine this balance by making comfort, equity, and governance measurable. ASTI quantifies the body's exposure; IH-IMI audits the institution's capacity. Together, they convert sustainability from aspiration to enforcement. Through the Thermal-Protected Neighborhood Electric Vehicle (T-NEV), the One-App MaaS platform, and phased neighborhood pilots, Muscat demonstrates that Gulf cities can close the "vision–delivery gap" without abandoning their climatic and cultural identity. What began as a series of conceptual papers has matured into a replicable system of codes, contracts, and dashboards - a governance architecture that learns by doing.

CONCLUSION

The Integrated Humanization (IH) framework began as a Gulf-centric idea linking urban form, climate adaptation, and institutional design. Across six studies, it progressed from theory to system: first defining a human-scale paradigm, then embedding ecological corridors, re-engineering road standards, introducing quantitative indices (ASTI & IH-IMI), institutionalizing governance, and finally operationalizing implementation through legislation, pilots, digital orchestration, and SUMA. This paper completes that arc - translating vision into enforceable, measurable urban practice. By codifying T-NEVs and launching thermally rated neighborhood pilots, Oman shifts first–last-mile mobility from informal convenience to statutory service. The One-App platform fuses technology and accountability, while SUMA consolidates mandates, budgets, and data into a single institutional spine. Together, these elements transform Muscat's transport reform into a living model of climate-realist urbanism aligned with Oman Vision 2040 and convergent with Saudi Vision 2030. The IH framework's lasting contribution lies in uniting two dimensions of humanization: thermal, which protects the body from exposure, and institutional, which ensures agencies act with measurable responsibility. Embedding both in codes and contracts establishes a new regional grammar for urban policy-one where every corridor and every department can be audited for its human impact. In essence, Oman's experience shows that Gulf urbanism can evolve not by imitating cooler climates, but by engineering governance that breathes its own heat-turning the region into a cooperative laboratory where innovation is indigenized through environment, evidence, and empathy.

REFERENCES

Baltimore Metropolitan Council. (2021). *Microtransit peer case studies report*. Baltimore, MD: BMC.

Dar Al-Handasah. (2012). *Muscat Area Transportation Study (MATS) Phase 2 Report*. Muscat: Ministry of Transport & Communications.

Ferguson, E. (2022). Integrating micromobility and transit: A Bay Area case study. *EVS36 Proceedings,* 1–10.

Gehl, J. (2010). *Cities for people*. Island Press.

International Association of Public Transport (UITP). (2022). *Mobility as a Service (MaaS) & account-based ticketing: Policy brief*. Brussels: UITP.

International Transport Forum (ITF-OECD). (2020). *Safe micromobility*. Paris: OECD. https://doi.org/10.1787/0b9b826e-en

Kingdom of Saudi Arabia. (2021). *Saudi Vision 2030: National Transformation Program*. Riyadh: Vision Realization Office.

Land Transport Authority (LTA). (2020). *SimplyGo: Account-based ticketing and fare integration*. Singapore: LTA.

Ministry of Economy. (2020). *Oman Vision 2040: National priorities and strategic directions*. Muscat, Oman.

Ministry of Housing and Urban Planning (MoHUP). (2023a). *Action Area Plans (AAPs): Integrated urban frameworks for Greater Muscat*. Muscat, Oman.

Ministry of Housing and Urban Planning (MoHUP). (2023b). *Greater Muscat Structure Plan (GMSP),* Vol. 2: Strategic Framework; Vol. 3: Technical Background. Muscat, Oman.

Ministry of Transport and Logistic Services (MOTLS). (2021). *National Transport and Logistics Strategy (NTLS)*. Riyadh, Saudi Arabia.

Ministry of Transport, Communications and Information Technology (MoTCIT). (2020). *Oman National Transport Model (ONTM) – Model user & training manual* (v4). Muscat, Oman.

Montgomery, C. (2013). *Happy city: Transforming our lives through urban design*. Farrar, Straus and Giroux.

National Association of City Transportation Officials (NACTO). (2020). *Guidelines for regulating shared* *micromobility*. New York, NY: NACTO.

Park, R. E., Burgess, E. W., & McKenzie, R. D. (1925). *The city: Suggestions for investigation of human behavior in the urban environment*. University of Chicago Press.

Qatar Green Building Council (QGBC). (2020). *Outdoor thermal comfort guidelines for the Gulf region*. Doha, Qatar.

Roads and Transport Authority (RTA). (2022). *S'hail: Unified journey planner & mobility platform*. Dubai, UAE.

Royal Commission for Riyadh City (RCRC). (2023). *Riyadh Public Transport Program (Metro + Bus) integration framework*. Riyadh, Saudi Arabia.

Saad, M. A. A. (2025). Integrated Humanization: A Gulf-centric urban paradigm. *American Journal of Urban Planning and Smart City, 1*(1), 1–6.

Saad, M. A. A. (2025). Integrated Humanization as a Gulf mobility strategy: Blue–Green corridors in Muscat. *American Journal of Urban Planning and Smart City, 1*(1), 7–22. https://journals.e-palli.com/home/index.php/ajupsc/article/view/5855

Saad, M. A. A. (2025). Redesigning roads in Muscat: Integrating engineering standards with the principles of Integrated Humanization. *American Journal of Urban Planning and Smart City, 1*(1), 23–31. https://journals.e-palli.com/home/index.php/ajupsc/article/view/5909

Saad, M. A. A. (2025). From paradigm to practice: Evaluating and governing Integrated Humanization for metro-ready Gulf cities. *American Journal of Urban Planning and Smart City, 1*(1), 32–45.

Saad, M. A. A. (2025). From vision to institution: Institutionalizing Integrated Humanization (IH) in Gulf urban planning frameworks. *American Journal of Urban Planning and Smart City, 1*(1), 46–60.

Singh, P., & Tan, C. (2021). Urban heat mitigation and pedestrian comfort in Singapore: Quantifying mean radiant temperature and shade ratios. *Urban Climate, 39,* 100934. https://doi.org/10.1016/j.uclim.2021.100934

United Nations Economic Commission for Europe (UNECE). (2018). *Regulation No. 100* (Rev. 3): Electric power train / REESS requirements. Geneva: UNECE.

United States Department of Transportation (USDOT). (1998). *Federal Motor Vehicle Safety Standard* (FMVSS) No. 500: Low-speed vehicles. Washington, DC: NHTSA.

Zawya News. (2023). *Oman launches pilot electric scooter program under regulatory sandbox*. https://www.zawya.com