Online Appendix

AI Enabled Transport for Kuwait's 2035 Roadmap: Bridging the Tech–Policy Gap vis-à-vis the UAE and Singapore

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Section A. Extended methods

A1. Technology-Policy Readiness Matrix (TPRM) ladders

Technology Readiness Level (TRL), one to nine, adapted to AI-enabled mobility systems.

#	TRL Stage	Descriptor	Key Features
1	Principles observed	Scientific research begins to be translated into applied R&D	Literature review; initial theoretical models
2	Concept formulated	Practical applications identified	Hypotheses developed; no experimental proof
3	Proof-of-concept	Critical function(s) validated analytically or experimentally	Bench-scale validation; feasibility demonstrated
4	Technology lab validation	Components integrated in a laboratory environment	Controlled testing; partial subsystems working
5	Technology relevant environment validation	More realistic testing conditions	Integration of components in simulated settings
6	Demo model demonstrated in relevant environment	Prototype or pilot in an operationally relevant setting	Demonstration projects; partial field trials
7	System pilot prototype demonstrated in operational environment	Full-scale prototype tested in real-world conditions	Extended pilot programs; performance monitoring
8	System completed and qualified	Technology proven to work in final form and under expected conditions	Pre-commercial deployment; regulatory approvals
9	System proven in operation	Full commercial application	Widespread deployment; system fully integrated

Policy Readiness Level (PRL), one to nine, scored at the service implementation layer.

#	PRL Stage	Descriptor	Key Features
1	Problem Recognition	Issue identified in public or policy discourse	Informal acknowledgment of AI-mobility relevance; no official agenda entry
2	Agenda Setting	Inclusion in official plans or speeches	Vision statements; preliminary scoping by a ministry or authority
3	Vision & Strategy Articulation	High-level goals and targets endorsed	National strategy/policy papers; sector strategies referencing AI-mobility
4	Policy Design	Drafting of policy instruments	Consultations kick-off; green/white papers; preliminary legal text
5	Draft law/leg issued	Formal legislative proposals submitted	Draft bills or amendments tabled; regulatory frameworks outlined
6	Law/leg Enacted	Legal authority established	Laws, decrees, or regulations formally adopted
7	Capacity allocated	Resources, mandates, and structures assigned	Dedicated units; budget lines; training; inter-agency MoUs
8	Operational Enforcement	Active implementation and compliance checks	Deployment of inspectors; licensing; data audits; permits, and penalties active
9	Routinised practice & Evaluation	Ongoing enforcement embedded in standard practice	Periodic policy reviews; KPI tracking; adaptive policy revisions

Gap metric and bands. | TRL − PRL |. Green is less than or equal to one, Amber is two to three, Red is four or higher. The token |TRL–PRL| is preserved by convention.

A2. Scoring basis, evidence rules, and adjudication

- **Unit of analysis:** an initiative, a bounded AI-enabled transport program or service with identifiable technology and policy artifacts, for example permits or standard operating procedures.
- **Two source rule:** each TRL and PRL score must have two or more independent sources. For Kuwait, one official document plus one interview may satisfy the pair, interviews never determine a score alone. For the United Arab Emirates and Singapore, use two documentary sources, for example a statute and an official report.
- **Service-layer scoring:** PRL reflects active permitting, licensing, audits, and enforcement, not the existence of a framework law alone.
- **Conservative rule:** when evidence conflicts, assign the lower PRL rung.
- **Confidence flag:** High means more than two primary official sources, Medium means exactly two independent sources, Low means a single official source or an item in flux. Report the lower of TRL or PRL confidence per initiative.
- **Evidence hierarchy:** laws, gazettes, budgets, and audited KPIs, then agency manuals, SOPs, official dashboards, tenders and awards, then official press and operator briefs, with industry media for corroboration only, and interviews as a second source in Kuwait only.
- **Adjudication:** two independent coders record disagreements, an adjudicator issues the final score, and the adjudication log is retained.

A3. Intercoder reliability, κ procedure and results

- **Statistic:** quadratic-weighted Cohen's κ with a 95 per cent confidence interval via ten thousand resamples.
- **Scope**: sixty-five initiative-level TRL and PRL assignments across Kuwait, the United Arab Emirates, and Singapore.
- **Results:** study-wide κ equals 0.84 with a 95 per cent interval 0.78 to 0.89. By case, Kuwait κ equals 0.86, United Arab Emirates κ equals 0.83, Singapore κ equals 0.82.
- **Inputs:** pre-adjudication coder A and B rungs aligned by initiative_id.
- **Sensitivity:** linear-weighted κ yields the same agreement tier.

Coder workflow details are in the Online Codebook.

A4. TF–IDF specification for National AI Strategy salience

Purpose: within-document salience diagnostic for transport terms in each National AI Strategy, not an implementation metric.

- **Corpus:** Kuwait 2024, United Arab Emirates 2018, Singapore 2019, English versions.
- **Vocabulary:** $V = \{\text{transport,mobility,traffic}\}$.

- **Pre-processing:** lower case, ASCII normalization, punctuation removal, whitespace normalization, no stemming or lemmatization.
- **Formulas, smoothed, scikit-learn convention:**

$$\mathrm{idf}(t) = \ln\left(\frac{1+N}{1+\mathrm{df}(t)}\right) + 1, w(t,d) = \mathrm{tf}(t,d) \cdot \mathrm{idf}(t), \tilde{w}(t,d) = \frac{w(t,d)}{\sqrt{\sum_{s \in V} w(s,d)^2}}.$$

- **Outputs:** L2-normalized weights and a dominance index $D = \max(\tilde{w}) - \mathrm{second}(\tilde{w})$.
- **Robustness:** collapse transport or transportation, add transit or congestion, and tolerate light OCR noise.

Counts and scripts are provided in the replication package.

A5. Documentary corpus screening and inclusion or exclusion

- **Search frame:** 2014 to 2025, official gazettes and ministerial portals, transport and AI-relevant strategy and legislative instruments.
- **Cutoff:** 31 December 2025.
- **Included:** thirty-nine items, Kuwait sixteen, United Arab Emirates twelve, Singapore eleven. Concept saturation occurred at item thirty-five, four further items confirmed codes.
- **Inclusion criteria:** direct relevance to AI-enabled transport, authoritative provenance, explicit policy or legal content, year 2014 or later.
- **Exclusions:** duplicates, non-official media, marketing collateral.
- **Screening fields:** doc_id, jurisdiction, issuing_body, year, type, authoritative_source, stable_link, inclusion_reason, used_in_scoring (Y/N), ocr (Y/N), checksum.

A6. Interview protocol, sampling, translation, and anonymization

- **Scope:** twenty semi-structured interviews in Kuwait with senior officials, state-owned enterprise managers, and academic experts.
- **Sampling:** purposive across transport operations, digital government, and public safety, with snowballing to extend coverage.
- **Mode and dates:** fifteen in person and five virtual, 25 May 2025 to 31 October 2025.
- **Language:** Arabic, transcripts translated to English and back-checked for meaning equivalence.
- **Anonymization:** K 01 to K 20, role descriptors only, indirect identifiers generalized.
- **Use in scoring:** in Kuwait only, interviews may serve as the second source when paired with an official document.
- **Storage:** audio and full transcripts are not public; de-identified excerpts may be available under restricted access.

A7. Ethics and data access boundaries

- **IRB:** AGU Protocol #420 25, written consent, voluntary participation, right to withdraw.
- **Public materials:** code, figure scripts, derived or aggregated data such as TF–IDF counts and the adjudicated TPRM table, the corpus catalog, and documentation.
- **Restricted materials:** de-identified interview excerpts, NVivo exports, and any non-public documents.
- **Access:** repository request workflow with a data-use agreement covering re-identification, redistribution, secure handling, and destruction at project end.

A8. Overview of code families, reader orientation

Full definitions and exemplars are in the Online Codebook. The families are: Policy instruments and governance; Financing and procurement; Data and digital infrastructure; Safety, liability and ethics; Implementation status; AI mobility taxonomy; Outcomes and KPIs; Barriers and enablers; Transferability.

Section B. Templates and SOPs, printable

B1. TPRM scoring sheet, blank

Field	Description
initiative_id	Slug such as KWT_ASC_01
initiative_name	Short descriptor
case	Kuwait, United Arab Emirates RTA, Singapore LTA
TRL_rung, one to nine	Evidence anchored, cite sources
PRL_rung, one to nine	Service-layer scoring, cite sources
delta_abs	| TRL − PRL |.
band	Green, Amber, or Red
evidence_source_1 and evidence_source_2	Independent sources per rules
confidence	High, Medium, or Low, lower of TRL or PRL
coder_A and coder_B	Initials
adjudication_note	Short rationale and log reference

B2. Corridor KPI pack, definitions and aggregation windows

KPI	Definition	Window	Data sources	Notes
Travel time, median minutes per 10 km	Median corridor travel time per period	Fifteen minute periods, monthly with quarterly summary	Probe data, loops or cameras, timestamp alignment	Trim at second and ninety-eighth percentiles, corridor defined by link list
Incident clearance, median minutes	Detection to last lane open	Monthly, also report the ninetieth percentile	CVIM detection, traffic management logs	Exclude planned works
Bus on-time performance, per cent within plus or minus three minutes	Timepoint punctuality	Weekly and monthly, by route	Automatic vehicle location events, schedule	Deduplicate ghost pings
API performance and access	Active keys, total calls, ninety-fifth percentile latency,	Monthly	API gateway logs	Report outages and the error budget

	authenticated share, rate-limited share			
Disclosure cadence	Public dashboard and audit note	Monthly with quarterly audit	Operations center and audit unit	Publish a calendar and archive PDFs

B3. AV sandbox safety-case reporting, pilot stage

Monthly operator submission per pilot includes: exposure, vehicle-kilometers, passenger-kilometers, operating hours, and operational design domain; events, safety-critical events, collisions by severity, disengagements, and remote-operator interventions; event data recorder coverage, retention, and access log; compliance and training; complaints and redress; and a continuance decision, continue, pivot, or sunset, with rationale.

B4. Transferability Box template

Lever or practice	Evidence	Why it works there	Kuwait fit	Class, I1, I2, or I3	Adaptation notes

B5. Scenario Mapping template

Scenario	Trigger gaps, Gap_Tier	Required PRL sequence	TRL actions unlocked	Risks and mitigations	Milestones, year

B6. Transport Data and API circular, minimal specification

Scope and legal basis; data classes and tiers; access and control; rights and duties; privacy and redress; enforcement; interoperability; publishing and status.

Section C. Documentary corpus, full list

As of 31 December 2025. The same table appears as documents_catalog.csv in the repository.

C1. Kuwait, 16 documents

Title	Year	Type	Issuing body	Notes / tags
Vision 2035: “New Kuwait” (overview)	2017	Strategy (national)	Government of Kuwait	Macro vision incl. transport diversification
Kuwait National AI Strategy	2024	Strategy (sectoral)	Central Agency for Information	Mobility listed as priority vertical

Title	Year	Type	Issuing body	Notes / tags
			Technology (CAIT)	
Kuwait aviation safety plan (NASP) 2023–2025.	2024	Civil aviation safety regulation *(draft; implementation in NASP 2023–2025)*	Kuwait Directorate General of Civil Aviation (DGCA)	UAS operator licensing/registration; operating categories; basis for UAM/drone ops; NASP 2024 confirms rollout steps
Cloud computing regulatory framework	2021	Regulatory framework	State of Kuwait (CITRA)	Outlines governance, security, and data management standards essential for deploying cloud-based AI systems in intelligent transport networks
Data Privacy Protection Regulation (Resolution No. 26 of 2024)	2024	Regulation	CITRA (Gov. of Kuwait)	Personal data duties; cross-refs classification policy
Data Classification Policy (Version 2.3)	2022	Policy	CITRA	Four-tier classification incl. localization triggers
Law No. 63 of 2015 on Combatting Cybercrimes	2015	Law	State of Kuwait	Cyber offences; evidence chain; system interference
Law No. 116 of 2014 on Public-Private Partnerships (English, unofficial)	2014	Law	State of Kuwait (via WIPO Lex)	PPP framework applicable to AV pilots/BRT/MaaS
Law No. 74 of 2019 amending provisions of Law No. 49 of 2016 (public tenders)	2019	Law (amendment)	State of Kuwait (hosted by KDIPA)	Procurement thresholds & procedures

Title	Year	Type	Issuing body	Notes / tags
Law No. 5 of 2025 – New Traffic Law in Kuwait	2025	Law	Government of Kuwait	Replaces/updates legacy road traffic rules
National Cyber Security Strategy of the State of Kuwait (2017–2020)	2017	Strategy	CITRA	Sectoral security baseline; critical infrastructure
EV Charger Standards & Requirements	2022	Standard/Guideline	Ministry of Electricity, Water & Renewable Energy	Technical specs & siting requirements
Kuwait Energy Outlook 2023: Security–transition nexus	2023	Report (energy)	Kuwait Institute for Scientific Research (KISR)	Energy transition context; transport energy
Third Structural Plan for Kuwait – Worksheet 7: Roads & Transportation (WP7 Traffic)	2025	Plan (spatial/transport)	Ministry of Public Works	Network hierarchy; demand/traffic planning
Kuwait – Country Engagement Framework FY2021–2025 (aligns with Vision 2035)	2021	Strategy (external alignment)	World Bank Group	Government-aligned external framework
Law No. 8 of 2016 Regulating Electronic Media (English)	2016	Law	State of Kuwait (hosted by CYRILLA)	Online publication licensing; data sharing/comms relevance

C2. United Arab Emirates, 12 documents

Title	Year	Type	Issuing body	Notes / tags
Law No. (9) of 2023 Regulating the Operation of Autonomous Vehicles in the Emirate of Dubai	2023	Law	Government of Dubai	Licensing, safety & operational rules for AVs
Executive Council Resolution No. (3) of 2019 Regulating Test Runs of Autonomous Vehicles	2019	Resolution	Dubai Executive Council	Test-bed governance & safety conditions
Dubai Self-Driving Transport Strategy & Roadmap	2023	Strategy	Roads & Transport Authority (RTA)	Multimodal SDT roadmap across 7 modes
Launching AI Strategy 2030 featuring 81 projects and initiatives	2025	News/Programme	RTA	AI initiatives across traffic mgmt., licensing, assets
Al Tayer endorses RTA's Artificial Intelligence Map	2019	Policy/News	RTA	Early AI governance & pipeline
RTA launches traffic signal control system upgrade using AI & Digital Twin (UTC UX Fusion)	2025	Press release / Programme note	Dubai Media Office	City-wide AI signal control deployment
Dubai State of AI Report	2025	Strategy/Report	Digital Dubai Authority	Cross-sector AI posture incl. mobility
UAE National Strategy for Artificial Intelligence 2031	2018	Strategy (national AI)	Artificial Intelligence Office (UAE)	Federal AI framework
Cabinet Resolution No. (110) of 2023 – UAE Scheme for Drone Products & Systems	2023	Federal regulation	UAE Cabinet	Conformity scheme for UAS/UAM

Title	Year	Type	Issuing body	Notes / tags
Federal Decree-Law No. (14) of 2024 on Traffic Regulation	2024	Federal law	United Arab Emirates	National traffic rules baseline
Administrative Decision No. (48) of 2024 – Regulating civil use of UAS (Abu Dhabi)	2024	Emirate-level regulation	Department of Municipalities & Transport (AD)	Abu Dhabi UAS operating conditions
United Arab Emirates – Smart & Sustainable Mobility (Country Commercial Guide)	2023	Policy overview	U.S. International Trade Administration	Consolidated overview; Dubai autonomy target context

C3. Singapore, 11 documents

Title	Year	Type	Issuing body	Notes / tags
Land Transport Master Plan (LTMP) 2040 – eReport	2019	Strategy (full report)	Land Transport Authority (LTA)	Modal shift, service quality, innovation
National artificial intelligence strategy: Advancing our Smart Nation journey	2019	Strategy (national AI)	Smart Nation and Digital Government Office	State AI framework
Smart Mobility 2030: ITS Strategic Plan for Singapore	2014	Strategy (ITS)	LTA & ITS Singapore	Standards, data, coordination
Road Traffic (Autonomous Motor Vehicles) Rules 2017	2017	Rules	Singapore Statutes Online (AGC)	AV trial authorization & conditions
Autonomous Vehicles: Application & Assessment Tracks (Tracks 1–2)	2025	Guidance	LTA	Trial area selection & assessment
Request for Proposals – Pilot Deployment of Autonomous Public Bus Services (Svc 400 & 191)	2025	Procurement notice	LTA	Pilot deployment program parameters

Title	Year	Type	Issuing body	Notes / tags
TR 68 (Part 3): Cybersecurity principles & assessment framework	2021	Technical reference	Singapore Standards Council & Enterprise Singapore	AV cybersecurity framework
TR 68 (Part 4): Vehicular data types & formats	2021	Technical reference	Singapore Standards Council & Enterprise Singapore	Data standards for AVs
Scenario categories for the assessment of automated vehicles (v1.7)	2020	Testing guideline	CETRAN & LTA	Scenario-based safety assessment
Simulation assessment guidelines towards independent safety assurance of AVs	2023	Testing guideline	CETRAN & LTA	Simulation framework for safety assurance
API User Guide & Documentation (Version 6.4) – LTA DataMall	2025	API/Documentation	LTA	Data access for transport applications

Section D. Reproducibility and availability

This appendix documents methods, rules, reliability results, templates, and the full documentary corpus. The Online Codebook contains full code definitions, inclusion and exclusion guidance, exemplars, and the authoritative data dictionary in machine-readable form. A replication package, code for TF–IDF, κ, banding, and figures, machine-readable codebooks, adjudication logs, and public data derivatives, is archived in a blinded repository. Human-subjects materials, de-identified interview excerpts and NVivo exports, are available under restricted access consistent with AGU IRB Protocol #420 25 via the repository request workflow. Code is open source, documentation is CC BY 4.0.

Section E. Supplementary figures: Scenarios to 2035, per-initiative panels

The main text presents the composite scenario figure and cites this appendix for per-initiative panels. High-resolution files and scripts to regenerate the panels are in /FIGURES/scenarios/ in the replication package.

Common caption elements for all panels: PRL trajectory under Managed Transition, solid line, Accelerated Innovation, dashed line, and Policy Lag, dotted line. Vertical markers denote decision gates, API circular enforcement, corridor KPI disclosure cadence, AV sandbox license issuance with insurance and event data recorder requirements, and MaaS settlement and audit rules. Study cutoff: 31 December 2025.

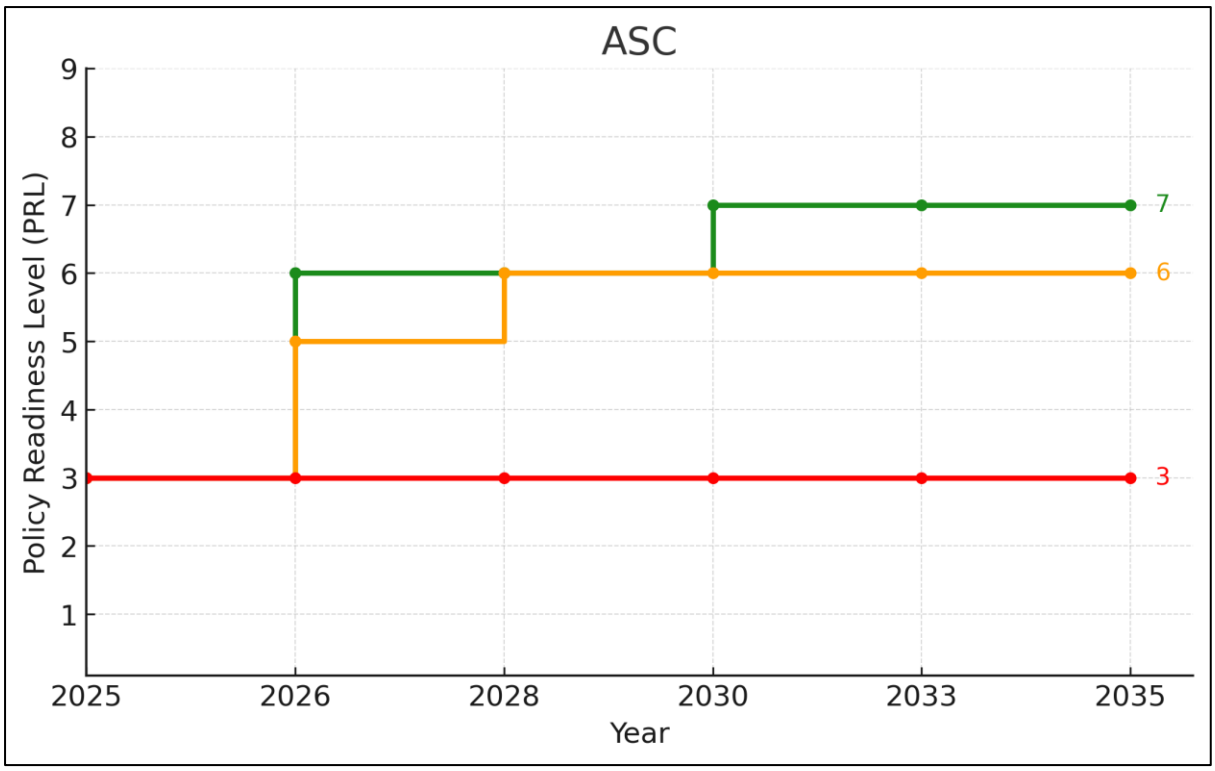

Figure E1. Adaptive Signal Control, PRL trajectory to 2035. Managed Transition and Accelerated Innovation converge toward routinized practice on priority corridors by 2033 to 2035, Policy Lag remains in Amber.

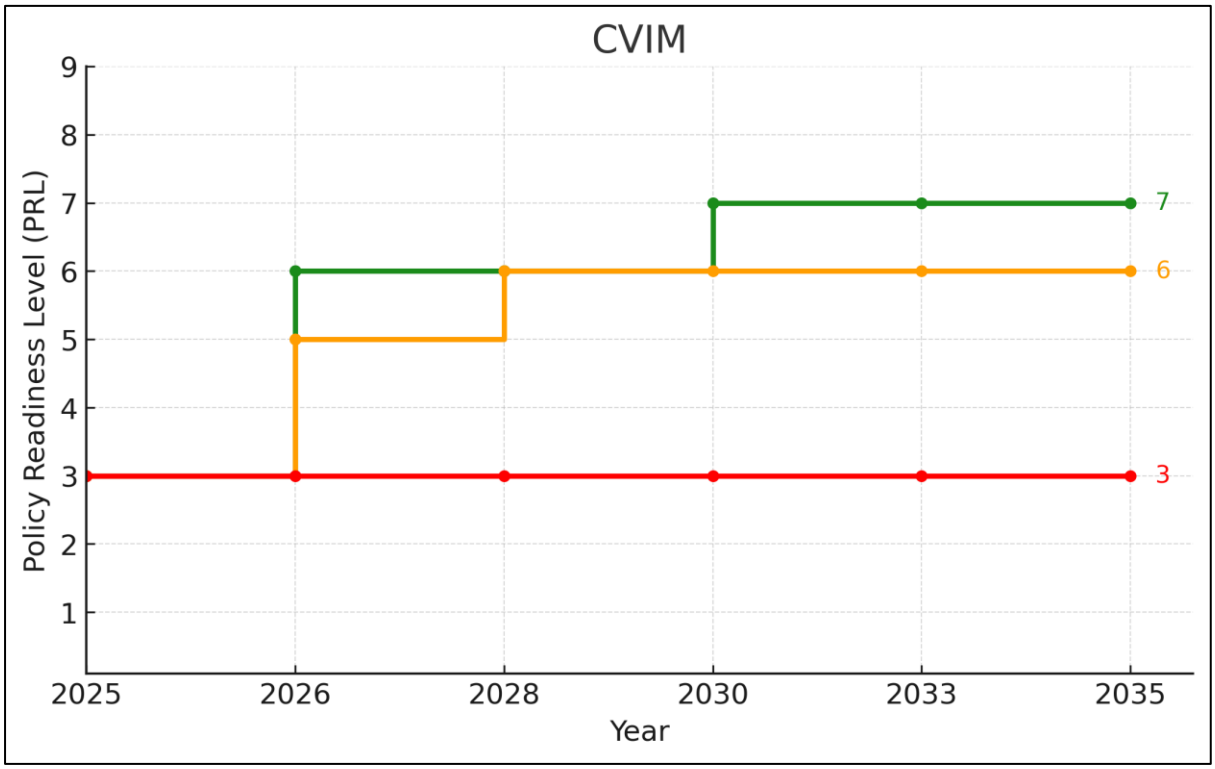

Figure E2. Computer-Vision Incident Management, PRL trajectory to 2035. PRL rises with cross-agency SOPs and lawful data use, Green bands are sustained with KPI audits.

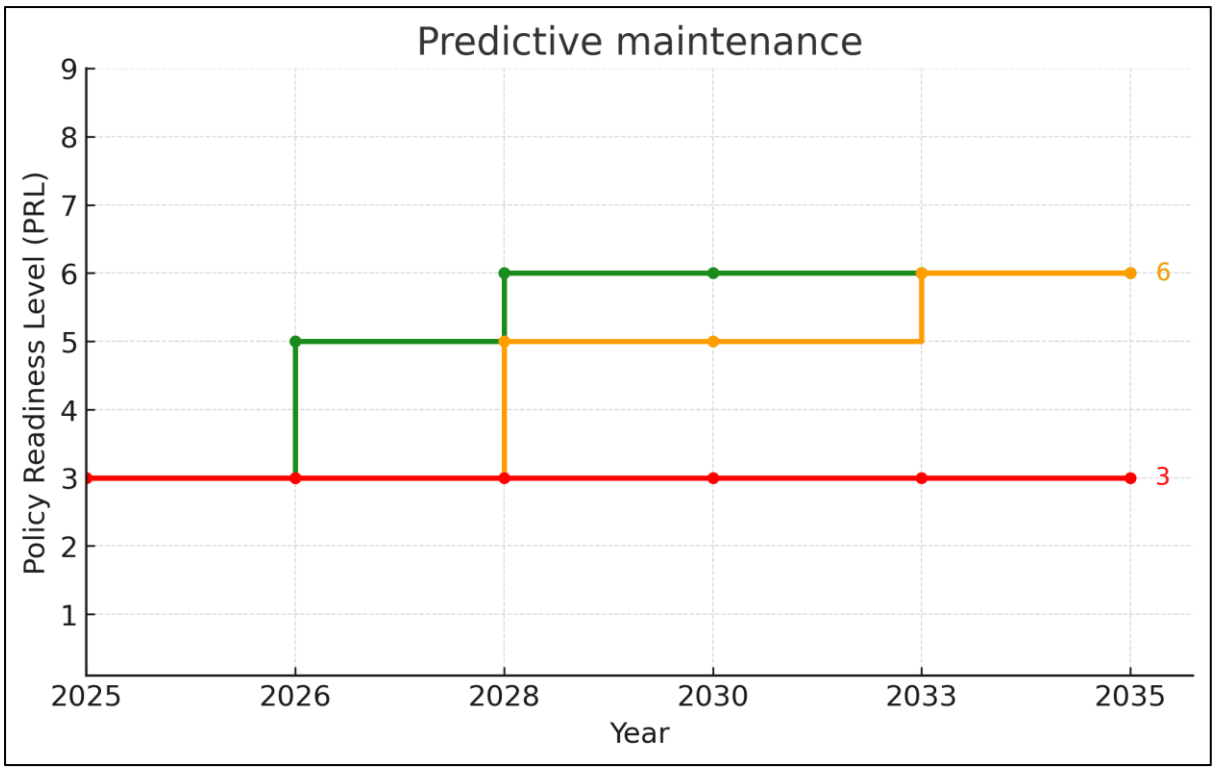

Figure E3. Predictive maintenance, PRL trajectory to 2035. Contractual data access and standardized assurance lift PRL to Green by 2028 to 2030.

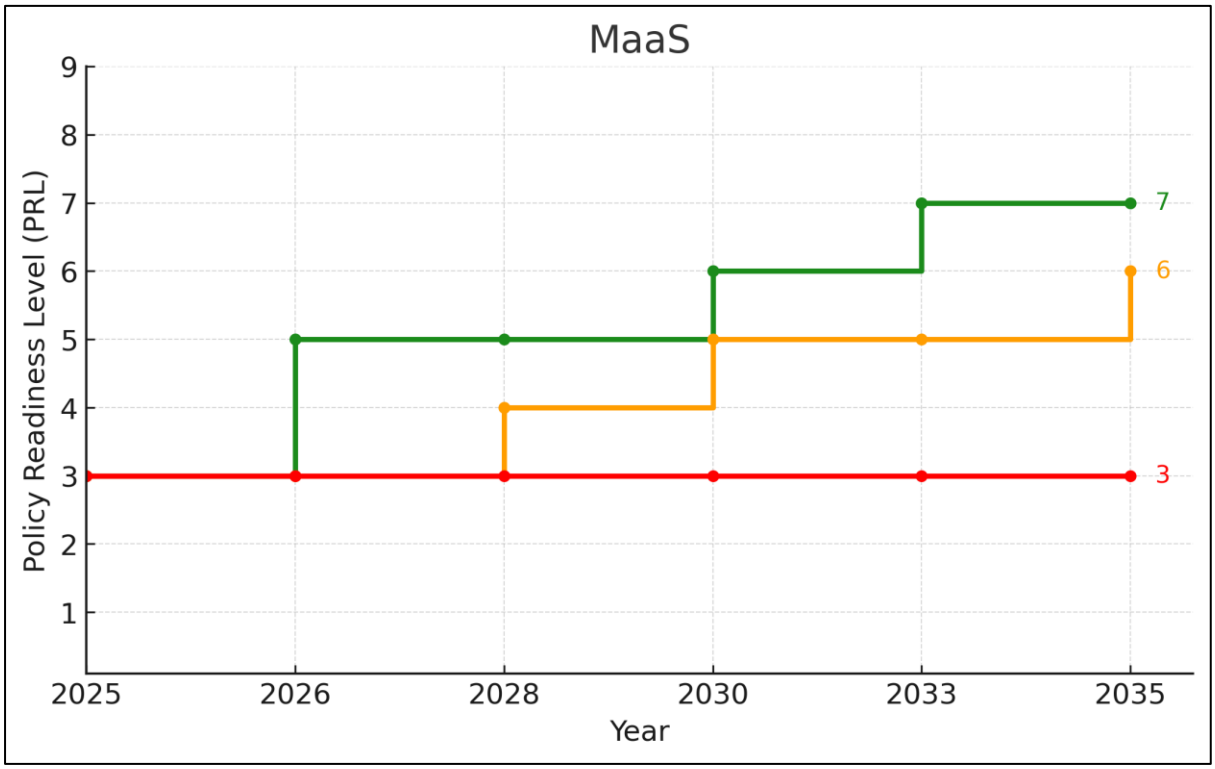

Figure E4. Mobility-as-a-Service, PRL trajectory to 2035. Platform governance for APIs, settlement, consumer protection, and audit drives progression from PRL four to five toward six to seven.

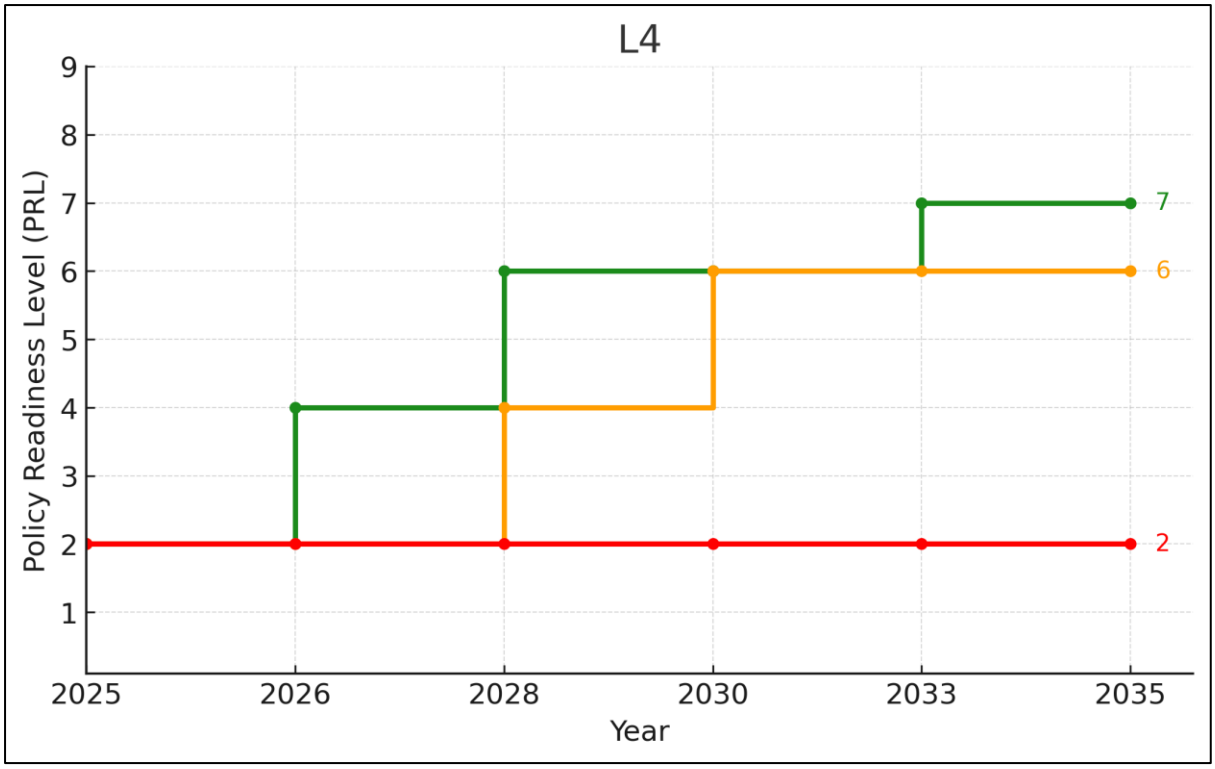

Figure E5. Level-four shuttles, PRL trajectory to 2035. Bounded pilots under a sandbox with liability and insurance move from PRL three to four to six, selective service-level licensing is feasible in bounded environments by 2033 to 2035 under Accelerated Innovation.

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