

VEHICLE SIMULATOR DESIGN – Immersive Virtual Driving Experience (IVDE)

0 Document Control

Version	Date	Author	Notes
0.9	2025-07-20	Vehicle Systems & Simulation Team	Initial draft derived from ‘Vehicle Simulator Design Template’ and aligned to IVDE GDD & AI specs

1 Scope & Objectives

This design specifies *all vehicle-related simulation systems* for IVDE—including **vehicle taxonomy, configuration options, physics fidelity tiers, gameplay hooks, and technical interfaces**—expanding on the high-level demands in the Game Design Document and AI Requirements Specification.

Key goals:

- Diversity:** Cover everyday passenger cars through to speciality EV rigs and motorcycles.
- Authenticity:** Achieve measurable parity with real-world performance curves and handling.
- Scalability:** Support four fidelity presets—from “Arcade” to “Professional”—without code forks.
- Extensibility:** Expose modding pipelines for community vehicles while protecting core balance.

2 Vehicle Selection & Classification

2.1 Primary Categories & Launch Counts

Category	Sub-Types	Launch Models	Licensing Status
Passenger	Sedan, Hatchback, Coupe, Wagon	15	OEM licences in negotiation (Ford, Toyota)
Utility	SUV, Pickup, Van	8	4 confirmed, 4 placeholders
Commercial	Delivery Van, Box Truck, City Bus	4	Fictional liveries ⇒ no licence required
Specialised	Emergency, Construction	3	Fictional designs aligned to real specs
Alternative Powertrain	BEV, PHEV, FCEV	5	BEV OEMs (Tesla, Hyundai) in talk
Motorcycles	Sport, Cruiser, Touring	4	Unreal Marketplace placeholder physics

2.2 Acquisition Methods

- **Career Unlocks:** Tiered driver licences; requirements mapped to Skill Tree (§4.1).
- **Purchases:** In-game credits or DLC bundles (no gameplay advantage).
- **Rentals:** 24-h real-time hire for quick challenges.
- **Limited Events:** Seasonal drops; unlock tokens expire after 30 days.

3 Advanced Configuration System

Module	Key Parameters	UI Exposure	Impact on Gameplay
Powertrain	ECU maps, boost pressure, motor count, battery kWh	Tuning Garage	Alters torque curve; affects energy consumption KPIs
Chassis & Suspension	Ride height, damping, spring rate, sway bars	Setup Sheet (Basic/Advanced tabs)	Influences handling rating (under/over-steer)
Drivetrain	FWD/RWD/AWD switch, diff type, gear ratios	Drivetrain Tab	Changes launch traction and corner exit grip
Wheels & Tyres	Compound, pressure, diameter	Pit-stop & Garage	Impacts grip vs. wear; visible in telemetry HUD
Visuals	Paint, decals, body kits	Livery Editor	Cosmetic only, monetised via UGC marketplace

Validation: Each adjustable parameter range is clamped by homologation rules to avoid meta-breaking setups.

4 Physics & Performance Levels

4.1 Fidelity Presets

Preset	Target Audience	Solver Tick	Tire Model	Damage
Arcade	Casual pad users	60 Hz	Pacejka lite	Cosmetic only
Semi-Realistic	Enthusiasts on wheel	90 Hz	Full Pacejka, simplified aero	Mechanical (engine wear)
Simulation	Sim-rig owners	120 Hz	Brush tire + simple aero	Full subsystem damage
Professional	Research / training	240 Hz	Pacejka + Pace2019 thermo	Deformation + limb-collision

4.2 Key Telemetry Outputs

- **Acceleration:** 0-100 km/h, ¼-mile.
- **Grip Metrics:** Lateral G, slip angle.
- **Energy Consumption:** Wh/km or l/100 km.
- **Damage States:** Enumerated per subsystem with performance multipliers.

All feeds are logged to the **Telemetry Bus** (Protobuf) for AI coaching and analytics (§8).

5 Gameplay Integration

5.1 Career & Progression

System	Vehicle Dependency	Data Source
Licence Exams	Vehicle class must match test (e.g., Heavy for Bus)	QA test scenarios
Reputation	Manufacturer affinity ↔ event invites	Player profile ledger
Achievements	Mileage, zero-incident runs	Telemetry Bus

5.2 Game Modes & Vehicle-Specific Challenges

- **Efficiency Runs:** Score = (distance / energy) adjusted for speed.
- **Emergency Scenarios:** Time-critical routes with siren advantage.
- **Cargo Physics Missions:** Box truck loads with shifting mass.
- **Historic Events:** 1960s classic car rallies with period handling curves.

6 Driver Assistance & In-Cab Tech

Feature	SAE Level	Availability	AI Hook
ABS / ESC	L0-L1	All modern vehicles	Physics override impulse
Adaptive Cruise	L2	>2020 MY passenger cars	Path Predictor (ALG-04)
Lane Keeping	L2	Select models	Gaze + IMU cues
Full Autonomy Demo	L3 (limited)	R&D sandbox only	RL agent variant

7 Accessibility & Inclusion Features

- **Alternative Inputs:** Eye-tracking steering, single-pedal driving.
- **Dynamic Difficulty:** Real-time adjustments (e.g., auto-brake) if SSQ score rises.
- **Audio Descriptions:** Spoken turn signals, speed alerts.

8 Technical Implementation & Modding

8.1 Data Pipeline

1. **Source Mesh (FBX/GLTF)** → *Automated LOD & Nanite bake.*
2. **Physics Tuning CSV** → *UE5 Data-Table* linked at build.
3. **Livery Textures** → *GPU-based PBR compression (ASTC 6×6).*

8.2 API Exposure

- `VehicleSim.SetParameter(id, value)` – C++ & Blueprint.
- `Telemetry.OnUpdate(vehicleId, packet)` – Event bus for external dashboards.

8.3 Mod Validation Rules

- Triangle budget ≤ 500 k (LOD0).
- No rims >22"; tyre width cap 355 mm.
- All community vehicles funnel through CRC hash to avoid tampering.

8.4 Hardware Support Matrix

Peripheral	Integration Layer	Min SDK	Notes
Steering Wheels (Fanatec CSL DD, Logitech G PRO)	UE Force-Feedback Interface	SDK 2025.1	Auto-detect presets
Pedal Sets (Heusinkveld)	DirectInput	n/a	Load-cell mapping
Motion Platforms (DOF Reality H3)	UDP Telemetry Out	Firmware 2.4	50 Hz pose stream
VR HMDs (Quest 3, PSVR2)	OpenXR	v1.1	Foveated rendering masks

9 Analytics & Coaching

- **Performance Dashboard:** Post-drive heat-maps (speed, braking).
- **AI Coach Agent:** Replays player laps; issues tips ranked by impact.
- **Leaderboards:** Filter by vehicle class, configuration hash.
- **Data Privacy:** Driving logs stored 30 days unless user opts-in for long-term analysis.

10 Open Issues & Next Steps

ID	Topic	Owner	Due
O-01	Finalise OEM licence list & references	BizDev	2025-08-15
O-02	Validate Pace2019 tire model vs. UE5 Chaos Vehicle Physics Lead	Sprint 34	
O-03	Implement livery CRC pipeline in build farm	Tools Eng.	Sprint 35

Prepared for internal review; comments welcome via Confluence page ‘Vehicle Sim Design – Draft v0.9’.