PSSG 2 MOBILITY:

MAKE DRONES (SELF DRIVING VEHICLES) USEFUL TO EVERYBODY

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Abstract

Autonomous driving (AD) is no longer science fiction: it is a technological transition moving from niche experimentation to mainstream adoption. McKinsey Center for Future Mobility (2023) estimates that by 2040, up to two-thirds of passenger mobility could be autonomous (**Fig. 1**), unlocking gains in safety, accessibility, and decarbonization (provided regulation, validation, and public trust advance in concert). This project deliberately inverts the prevailing business logic: rather than a convenience-first, private robotaxi model, the AD model we are proposing is positioned as a continuum of public transport, integrated with MaaS, aligned with fare systems, and governed by equity safeguards such as coverage obligations, fare caps, and low-tech access, so system benefits accrue broadly from day one. The city of Trento (Italy) offers the right conditions to prove the model: mature V2X infrastructure, an IoT-enabled historic core, and a largely hydro-powered grid support an inclusive autonomous shuttle service (Toyota e-Palette) that can scale from the city center to the region. Our quantitative modelling shows that replacing 100,000 private ICE cars with 5,882 shared electric shuttles yields ~92% net annual CO reductions (~154,598 t), after which the optimization frontier shifts to grid decarbonization and operations. Adoption is sequenced in three phases: vulnerable users, school mobility, full public integration (with optional premium layers introduced only once reliability, safety, and inclusion thresholds are met). We propose a financing model based on existing EU rails (Driving Urban Transitions, the CCAM Partnership, Digital Europe) and designed to feed a future IPCEI on Connected & Automated Vehicles, creating a scalable blueprint whose lessons can directly inform COP30 deliberations on equitable, system-level decarbonization.

1. Evidence from Case Studies: What Scales, What Stalls

Comparative evidence underscores that one size does not fit all. The global AD case studies we reviewed are instructive, but none is a copy-paste template for Europe. In Asia, China's Apollo Go demonstrates the power of tight vehicle–infrastructure–cloud integration inside municipal "demo zones," where roadside sensing, HD maps, and centralized coordination have enabled true 24/7 driverless service at scale. Yet the model leans on city-level fast-track permits and subsidized fares, making transferability to Europe uncertain without comparable regulatory and data-governance frameworks. Japan's pathway is a regulatory landmark: MLIT's national Level-4 law enables unmanned operation (e.g., Eiheiji), proving that legal clarity can unlock deployment; still, current services are narrow (short rural routes with weekend/holiday operations) and rely on subsidies, so they read as acceptance pilots rather than ready-to-scale systems. In the UK, CAVForth shows Level-4 buses in mixed traffic through a public–private consortium, but mandated onboard safety staff and union concerns about job transitions keep unit economics fragile and spotlight workforce adoption as a binding constraint. In the United States, Waymo’s rider-only service has produced peer-reviewed reductions in crash rates across tens of millions of miles (Kusano et al., 2025), yet operations remain bounded by defined ODDs and continue under close regulatory and public-perception scrutiny.

3. Market Outlook and Opportunities

According to McKinsey Center for Future Mobility (2023), by 2035, autonomously driven passenger-car could generate $300–400B in annual revenues (**Fig. 2**), with L3–L4 penetration rising materially across delayed, base, and accelerated scenarios (**Fig. 3**). McKinsey’s consumer surveys argues that demonstrable safety (64%), opportunities to test services personally (46%), and clearer rules and OEM information (43% each) are among the main factors that would increase consumer confidence in autonomous vehicles. Industry leaders expect a concentrated European market (≤2 dominant winners), 2–3 years of timeline slippage before city-scale L4 robotaxis, and a staged path that starts with parking and hub-to-hub operations before complex urban pilots; regulation remains the top barrier, capex needs have risen 30–100% since 2021, and value concentrates in software (>15% margins vs. ~14% services and ~10% hardware) (McKinsey, 2024). Public–private partnerships and platform-scale funding are therefore essential, alongside flexible monetization models (pay-per-trip in Europe; per-mile in the US). For Europe specifically, the near-term play is to target public-transport pain points (e.g. 80,000 bus-driver shortfall in Germany by 2030) with on-demand shuttles that improve network economics, while closing talent gaps in safety-critical software, building a robust fleet-operations backbone to hit TCO targets, and shifting the value proposition from ownership to service within an integrated MaaS architecture.

4. Europe’s policy and finance rails: from pilots to fleets

4.1 ***EU initiatives setting the direction*** At the EU level, several initiatives have emerged to drive the transformation toward connected, automated, and zero-emission mobility. The Sustainable and Smart Mobility Strategy targets 30 million zero-emission cars by

2030 and nearly all vehicles zero-emission by 2050. The Digital Decade Policy Programme and the revision of the ITS Directive strengthen connectivity, interoperability, and digital integration across the continent. The European Automotive Action Plan sets the objective of establishing a European Alliance for Connected and Autonomous Vehicles. The Draghi report on European competitiveness (2024) identifies Clean Connected and Autonomous Vehicles (CCAV) as a priority tool both for the environmental transition and to close the competitiveness gap with China and the United States. It advocates cross-sector "verticals" that promote early support for mid-Technological Readiness Level (TRL) ventures and highlights the possibility of an Important Project of Common European Interest (IPCEI)—a state-aid instrument designed to support cross-border RDI when market failures occur.

4.2 ***Funding channels available now*** Because an IPCEI on CCAV does not yet exist, other programmes can be tapped immediately. The Driving Urban Transitions programme funds research and innovation projects with three or more partners across three or more countries, via annual calls with a three-year scope and a total budget of EUR 44 million. The CCAM Partnership—a network of more than 200 stakeholders with a EUR 1 billion budget in close collaboration with Horizon Europe—supports coordinated action across research, regulation, and deployment. The Digital Europe Programme focuses on RDI and digital projects and can provide funding for the autonomous driving ecosystem.

4.3 ***IPCEI-CCAV: purpose, alignment, and structure*** If an IPCEI on CCAV were launched, it would promote cooperation, scale, and innovative testing with a cross-border perspective, while harmonising European standards. It would need to align with other existing or candidate IPCEIs (such as those on Artificial Intelligence and Semiconductors) and could support the creation of a widespread network for autonomous driving and its role in Mobility as a Service (MaaS). The Commission Staff Working Document on CCAM suggests structuring a potential IPCEI around three reference workstreams:

a) Digital technologies for AD;
b) Hardware Technology Supply Chain;
c) Industrial Scale Deployment.

Under the current framework, practices vary across Member States, creating a regulatory vacuum and confusion. A higher level of EU-wide policymaking is therefore needed to provide structure and clarity.

5. Trento as a Demonstrator: From Historic Core to Regional System

5.1 Why Trento The city of Trento (Italy) offers the right mix of infrastructure, energy, and governance to prove that autonomous mobility can function as a continuum of public transport. The Province of Trento also has one of Europe's highest motorization rates (1,521 vehicles per 1,000 inhabitants in 2023) (Eurostat, 2025), making the case for shared, low-carbon alternatives particularly strong. The city has already conducted autonomous-driving experiments; it operates IoT-enabled traffic management and vehicle-to-infrastructure (V2I) communications; and it participates in C-Roads (EU cooperative ITS corridors) alongside a local "Q-Road" specification (assets that lower operational risk and accelerate learning). The mobility strategy is MaaS-oriented, extending fixed routes into lower-density areas and enabling users to book trips via app or by calling customer service, improving accessibility. The goal is replicability in other cities.

5.2 Historic-core pilot, engineered for safety and trust The first deployment concentrates in the pedestrian-priority historic center by extending ZTL restrictions and layering targetedupgrades: additional V2X paths and charging, smart sensors around Piazza Duomo, and a high-fidelity digital twin (a live software replica of streets and assets) to orchestrate fleetsand test changes virtually before real-world rollout. Cooperative-ITS services including SPaT/MAP (signal phase and timing/map geometry) and Collective Perception (roadside units sharing detected hazards)—are installed at complex junctions and "urban canyon" segments, with GNSS-bridging and redundant HD maps to support localization. These digital supports benefit both automated and human-driven vehicles, smoothing the transition period.

5.3 Vehicle and operations The autonomous shuttle is Toyota's e-Palette: a compact battery-electric vehicle of roughly 5 m × 2 m × 2.6 m carrying up to 17 passengers, designed for Level 2–4 automation and full C-ITS integration. Initial routes run as 2–5 km loops (e.g., Piazza Duomo–Castello del Buonconsiglio), dispatched on demand via app. The pilot begins with about ten vehicles operating 12–18 hours per day, charged on hydroelectric power and connected to the city's digital twin for real-time fleet management.

5.4 ***Carbon math and why it plateaus*** Modeled at system level, substituting 100,000 private thermal cars with 5,882 shared electric shuttles yields ~92.02% net annual CO reduction (about 154,598 t saved) once the shuttle fleet reaches that scale (**Fig. 4**). The residual 7.98% is the shuttle fleet's own well-to-wheel footprint, derived from 189.84 g CO /km (58 g/km vehicle + 131.84 g/km from Italy's 2024 grid intensity at 0.320 kWh/km × 412 g/kWh). After private-car substitution is complete, additional shuttles bring diminishing returns; the next frontier becomes further grid decarbonization and operations optimization (charging, routing, occupancy).

- **Fig. 5** (*line graph*) shows savings rising linearly from 0% at 0 e-Palettes to a peak of 92.02% at 5,882 vehicles (replacing all 100,000 thermal cars, eliminating 168,000 tons/year initial emissions). Beyond that, savings plateau or dip slightly due to added e-Palette emissions without further replacements. It's based on net savings = (eliminated emissions) - (e-Palette emissions), highlighting the saturation point where shared EVs maximize environmental gains.
- **Fig. 6** (*bar chart*) quantifies absolute net savings (in tons/year) at key deployment levels: e.g., 278 tons at 10 vehicles, 1,393 at 50, up to 154,598 at 5,882. It emphasizes scalability initial phases yield modest reductions, but full rollout achieves ~92% net savings, supported by LCA (life-cycle analysis) principles accounting for energy mix emissions.
- **Fig. 7** (*dual-axis graph*) contrasts eliminated emissions (blue line, rising to 168,000 tons) against residuals (red line, dropping to 13,402 tons at peak). The crossover illustrates the tipping point where EV sharing nearly eliminates thermal pollution, but residuals persist due to grid carbon intensity (412 g/kWh). Scientifically, this reflects well-to-wheel analysis, showing EVs' superiority in high-motorization areas like Trento, potentially cutting urban CO by 92% if scaled.

5.5 ***From city center to region*** Once reliability and public acceptance are proven in the historic core, the service scales outward to connect underserved valleys and regional hubs, reusing the same data architecture, operational standards, and an open data framework that peer cities can adopt for last-mile coverage. Delivery rests on clear roles: the city and province manage permits and streets; the public transport operator and Trentino Digitale/Trasporti handle system integration, data management, sensing, connectivity, and dispatch; the University of Trento conducts independent evaluation; Toyota provides vehicles and fleet innovation; and social cooperatives, nursing homes, schools, and tourism agencies anchor early demand and inclusion. Governance guardrails hard-code public interest: integration with transit to avoid induced demand; renewable-charging KPIs; equity provisions (coverage obligations, fare caps, low-tech access via SMS/call); transparent safety reporting and incident handling; zero-trust cybersecurity with OTA patching; and workforce transition plans into fleet operations, maintenance, and remote assistance.

5.6 Why an open infrastructure While hardware modularity drives versatility, software forms the backbone of e-Palette operations—fleet management, routing algorithms, and safety systems via Toyota's Mobility Services Platform (MSPF). However, proprietary software creates dependency risks: reliance on a single brand can lead to vendor lock-in, delayed updates, or restricted access, stifling innovation in a multi-stakeholder MaaS landscape and limiting interoperability as closed systems hinder integration with diverse third-party apps or city infrastructures, potentially fragmenting urban mobility networks. To address these risks, it is recommended to transition core infrastructure software—such as autonomous-driving stacks, data-analytics layers, and API frameworks—to public-domain status. Open-source licensing would allow free modification and distribution, enabling:

- Broader innovation: global developers contribute enhancements (e.g., localized traffic algorithms, AI safety protocols), accelerating progress beyond any single company's R&D.
- Independence and resilience: cities and operators avoid brand-specific dependencies and can tailor systems to regional needs (including integration with GDPR-compliant data systems).
- Equity and accessibility: public-domain code lowers barriers for startups and emerging markets—mirroring open-source successes like Android in mobility apps and ROS (Robot Operating System) in robotics.

6. Phased rollout and business plan

The service scales through a three-phase sequence that builds inclusion and trust first, then revenue resilience, while keeping the public-transport continuum at its core.

1. *Phase 1* concentrates on targeted pilots for vulnerable groups (older adults, people with disabilities, extra-urban needs), using assisted transport, customized healthcare trips, and tailored routes to prove reliability and offset early operating costs. The funding stack is grant-led—Horizon Europe Cluster 5, EIT Urban

Mobility, national calls (MASE), and CCAM—supplemented by municipal/provincial co-funding, in-kind support from social associations (volunteers, user-network access, outreach), and corporate sponsorships from technology/telecom partners seeking real-world testbeds. Premium features at this stage are accessibility enablers rather than luxury add-ons.
2. *Phase 2* extends to school mobility, introducing predictable household economics and digital safety assurances. The revenue model shifts toward standard fares via monthly/annual subscriptions (with optional single-ride tickets), while the app provides live shuttle status, route visibility, and personalized accompaniment for children with special needs. A premium layer (e.g. personal assistance and smart tracking) adds value without compromising baseline service guarantees.
3. *Phase 3* integrates the system into the broader city network, diversifying revenues through a mix of pay-per-ride, subscriptions, and premium express offerings. Advanced options (e.g. priority booking, neighborhood-specific express routes, and enhanced onboard experiences) turn the platform into a launchpad for community and digital services, introduced only after reliability and inclusion targets are consistently met.

The budget profile is front-loaded in capex and then stabilizes at steady state. Roughly **~50%** of total costs are the autonomous vehicle fleet (acquisition/lease, safety systems, maintenance); **~20%** is digital infrastructure and sensors (V2X networks, control dashboards, data systems) with periodic refresh cycles; **~10%** is charging infrastructure; **~17%**covers operations and maintenance (energy, staffing, servicing) scaling with utilization; and **~3%** funds research and impact evaluation (safety testing, performance assessment), peaking in early pilots. A staged cost sequence moves from research and implementation to digital and charging infrastructure, then fleet ramp-up, followed by impact evaluation and ongoing O&M.

As **Table 1** shows, execution relies on defined partner roles: the Municipality of Trento for governance, permits, and co-funding; social cooperatives, nursing homes, schools, and parent associations for co-design, escorted trials, and participation; the University of Trento for training, research, and safety protocols; Trentino Digitale and Trentino Trasporti for IT, data management, urban sensing, and connectivity; Toyota (e-Palette) for technical expertise and fleet innovation; and tourism agencies for route integration and adoption.

7. Impacts: short-term trade-offs, long-term system gains

System benefits from autonomous fleets materialize only when services are integrated with public transport, powered by renewables, and operated under zero-trust, cybersecure architectures; otherwise rebound travel, congestion, and security risks can erode climate and safety gains. In the near term, expected upsides include lower local emissions and noise, early reductions in human-error crashes through predictive safety, and improved access for older adults and people with disabilities. Counter-pressures include the battery and non-renewable electricity footprint, public distrust and digital divides, early job displacement, and residual liability uncertainty while systems mature. Over the medium to long run, mature algorithms and V2V (vehicle-to-vehicle) coordination can markedly cut accidents; smart charging and green infrastructure can reduce car ownership and free urban space; and new jobs emerge in tech, maintenance, and remote assistance. Risks persist if fleets are not right-sized and transit-integrated (energy demand, congestion), if supply chains and end-of-life waste are unmanaged, and as cybersecurity, centralization, and data-privacy threats grow. To lock in gains and mitigate harms, governance must hard-code public interest: transit integration (pricing, service design, curb policy); renewable-charging KPIs; equity by design (coverage obligations, fare caps/discounts, low-tech call/SMS access); transparent incident reporting with audit trails and clarified liability/recall; zero-trust cyber with OTA (over-the-air) patching and red-team testing; workforce transition into fleet operations, maintenance, and remote assistance; and targeted V2X (vehicle-to-everything) upgrades at high-risk intersections, depots, and curb/parking conversions. Social license is anchored in four engagement pillars: Participatiion, Transparency, Education & Awareness, and Monitoring Framework. We actively involve citizens through feedback loops, focus groups, and codesign activities to ensure that the system evolves according to the real needs of the community. Transparency is guaranteed through clear and accessible communication about the system’s functioning, capabilities, and limitations. We promote awareness by organizing public testing events and thematic learning days, aiming to foster trust and understanding around autonomous and renewablepowered mobility solutions. Lastly, our monitoring framework includes a live dashboard displaying key performance indicators, social, environmental, economic, and technological, and integrates also the citizens’ feedback, enabling users to see how their input is collected and used to guide improvements, thus closing the loop on engagement. An overview of the monitoring KPIs is presented in **Table 2**.

8. Conclusions

Autonomous mobility delivers climate, safety, and access gains when it functions as part of public transport, not as a private luxury. Trento shows a replicable path: begin in the historic core, use cooperative intelligent transport systems (C-ITS) and a digital twin to manage risk, then scale regionally as reliability and acceptance grow. A three-phase rollout (vulnerable users, school mobility, full public integration) builds trust and economics before adding optional premium layers. Impact governance is non-negotiable: transit integration, renewable-charging KPIs, zero-trust cybersecurity with incident transparency, funded workforce transitions, and four engagement pillars (Transparency; Education & Awareness; Participation; Cadence & Monitoring). Europe's funding rails (Driving Urban Transitions, CCAM, Digital Europe) are available now, with a future IPCEI-CCAV to bring cross-border scale.

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Source: Graphical Rielaboration from McKinsey Center for Future Mobility (2023)

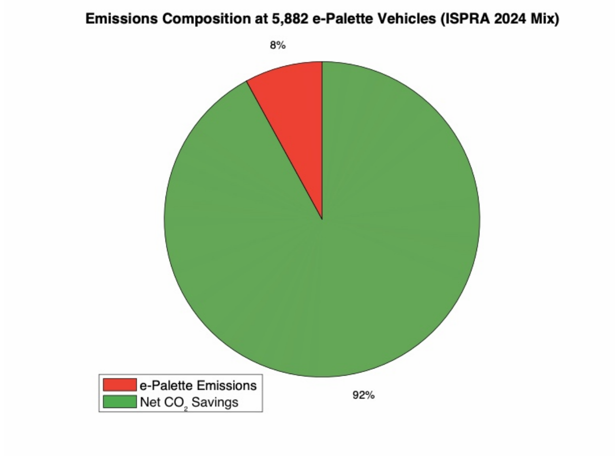


Figure 4 Quantitative Estimations: Emissions Composition at 5,882 E-Palette Ve

Source: Personal Elaboration

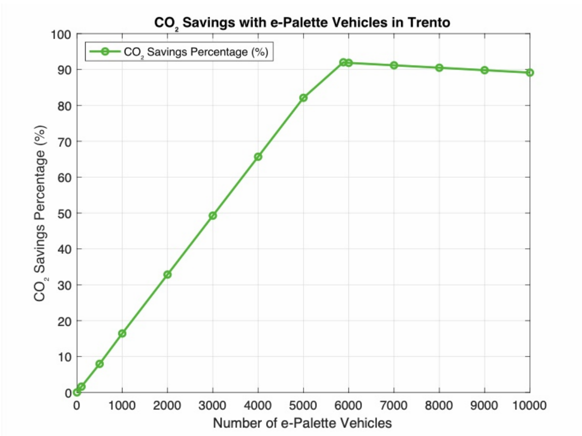


Figure 5 Quantitative Estimations: CO_2 Savings

Source: Personal Elaboration

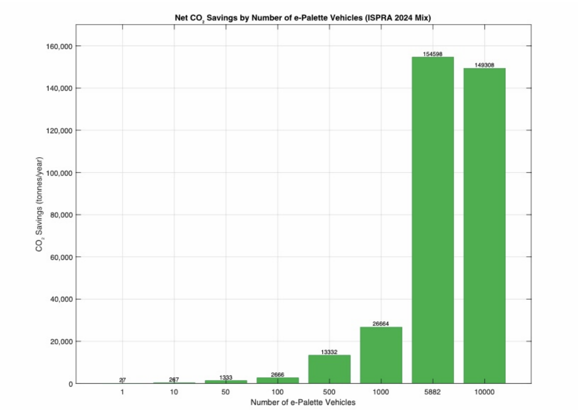
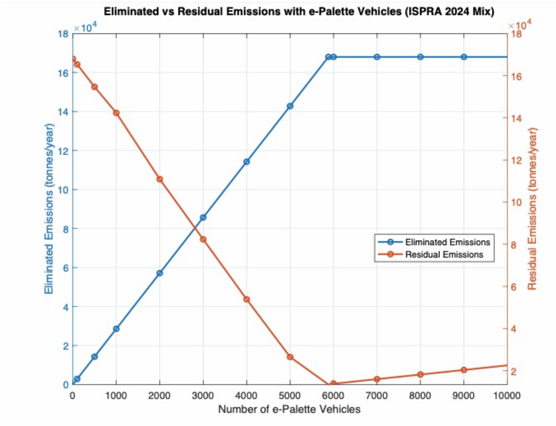


Figure 6 Quantitative Estimations: CO_2 Savings

Source: Personal Elaboration



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