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THE STATE OF SMART DEPOTS 2026

BUS DEPOT AUTOMATION AS A RESPONSE TO DRIVER SHORTAGE ACROSS EUROPEAN PUBLIC TRANSPORT OPERATORS

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EXECUTIVE SUMMARY

Zero-emission buses reached 60% of new urban bus sales in Europe in 2025 [2] - a structural shift in the market. As fleets electrify and depot processes grow more complex, the operational bottleneck is increasingly located inside the depot.

Bus depots today are largely managed the way they were a generation ago: drivers return from service, complete washing and a basic vehicle check on arrival, then park the bus and plug in the charger. The overnight cycle that follows - repositioning, maintenance staging, and dispatch sequencing - generates a continuous stream of non-productive vehicle movements. These movements, collectively called shunting, consume driver time, and generate a steady stream of minor collisions in tight, high-pressure environments.

At the same time, a structural driver shortage is tightening across the continent. Approximately 105,000 bus and coach driver positions are currently unfilled across Europe [1] - around 10% of the total workforce. With the average driver age exceeding 50, retirements could push that figure toward 275,000 by 2028. Recruitment and retention initiatives are important, but many operators are also pursuing productivity gains - particularly by reducing non-revenue tasks inside the depot.

This report examines the emerging smart depot as a practical, financially justifiable response to these converging pressures. It covers:

- The scale and economic cost of the depot bottleneck in today's electric bus operations
- The three pillars of a smart depot: integrated management systems, smart charging, and autonomous bus movements
- A maturity model for operators to self-assess their current readiness and plan their next step
- The business case in concrete terms - time savings, collision reduction, charging optimisation, and lifecycle ROI
- The safety and regulatory framework that governs depot automation today
- Case studies from operators actively deploying or planning smart depot technology across Europe

For operators approaching a new depot investment or fleet renewal cycle, this report provides the information to support near-term investment decisions while keeping a clear path to public-street autonomous bus operations over time.

105,000 Unfilled driver positions in Europe (IRU, 2025)	**35 minutes** Daily time lost per bus to depot manoeuvres (MZA Warsaw)	**€88,000** Driver time savings per vehicle over a 12-year lifecycle (MZA Warsaw)

IT'S 23:17 AT THE DEPOT

The last bus rolls through the gate. Before the driver can go home, there is the end-of-day routine: park the bus, connect the charger, fill in the defect report on the tablet. Minor scratch on the left rear panel from the tight turn at the terminal - noted. Windscreen wiper intermittent - flagged for the morning technician. The charging indicator blinks green. Done.

Except it isn't quite done.

The depot manager calls over. The bus is blocking the wash lane. It needs to move before the cleaning crew can get to the vehicles behind it. And the vehicle at bay 14 - the one with the wiper fault - needs to be at the workshop entrance before the maintenance team arrives at 06:00, which means someone has to reposition it tonight. While they're at it, the charging rotation needs to run: three buses on the slow chargers need to swap onto the fast units so they're ready for the early departures.

By the time the driver walks out, it is closer to midnight. The shift started at 11:00 that morning.

This is the daily maintenance cycle at most large bus depots in Europe - the post-service sequence of checks, positioning, charging, and preparation that has to happen before the next day can begin. Some operators employ dedicated shunting staff to take over from drivers at the gate. In many depots, the people moving buses at midnight are the same people who drove routes all day.

By 04:30, every charged and checked bus needs to be staged in departure order - ready for the drivers arriving at 05:00, who expect their vehicle to be where it should be. The cycle starts again.

THE DEPOT BOTTLENECK

A Structural Driver Shortage

According to the International Road Transport Union (IRU), approximately 105,000 bus and coach driver positions remain unfilled across Europe [1] - representing roughly 10% of the total workforce. The shortfall has grown by 54% since 2022, and demographic trends suggest it will worsen: the average bus driver is over 50 years old, and only 3% of drivers are under 25. Women - who represent just 16% of the workforce - remain significantly underrepresented. Upcoming retirements alone could push the shortage toward 275,000 unfilled positions by 2028.

Operators have responded with higher wages, improved working conditions, and active recruitment campaigns. These measures are necessary but insufficient. Structural change requires not just more drivers, but more productive use of existing drivers - which means eliminating the time they spend on tasks that don't require a driver at all.

OLIVER NAHON

DIRECTOR OF OPERATIONS, SWISS ASSOCIATION FOR AUTONOMOUS MOBILITY

SAAM
Swiss Association for Autonomous Mobility

"Switzerland's transport system is under pressure, peak hours are congested, and operators are already looking for ways to use driver time better. A lot of time is still lost inside the depot on movements that do not create passenger value. Since March 2025, Switzerland has had a regulatory framework for driverless operation on public roads - Level 4, on predefined routes, with remote supervision. The depot is where operators can start building the operational experience and performance record needed for that broader transition."

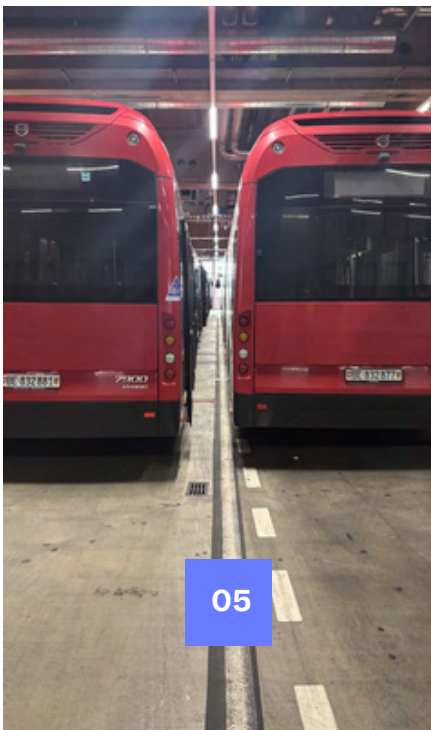
Depot Safety

Depots are among the more hazardous operating environments in public transport. The combination of large vehicles, tight spaces, mixed pedestrian and vehicle traffic, variable lighting, and fatigued staff at end-of-shift creates conditions where minor incidents are recurring.

Operational studies document 3 to 4 minor collisions per week in large manually operated depots [4] - mirror strikes, windshield damage, shallow body scrapes - concentrated in late-evening periods when congestion and fatigue are highest. Each incident generates repair costs, out-of-service downtime, and administrative overhead.

The most frequent incidents involve reversing manoeuvres: a bus exiting a parking row, backing toward the wash hall, or reversing from a charging bay. These incidents are costly, repetitive, and largely preventable.

There is also a higher-stakes scenario: battery thermal events. A battery fire in a densely parked electric bus depot requires rapid evacuation of adjacent vehicles. In a manual depot, this depends entirely on the availability and speed of staff. In a smart depot, predefined evacuation routines can be activated autonomously, moving vehicles out of high-risk zones without human presence in the danger area.



WHERE DRIVER TIME IS LOST IN THE DEPOT

Operational studies at bus depots across Europe consistently document significant daily time losses from manual depot movements. Depending on depot layout, fleet size, and shift organisation, these range from around 10 minutes to over 35 minutes per vehicle per day [4].

At a depot operating 100 buses, even 25 minutes per vehicle per day represents approximately 42 driver-hours lost daily to parking, charging approach, repositioning, and maintenance staging - consumed entirely by non-revenue activity inside the fence.

At MZA Warsaw, the value of driver time savings alone was calculated at over €88,000 per vehicle over a 12-year lifecycle [4].

JAN KUZMINSKI
PRESIDENT OF MZA WARSAW

"The depot is the heart of our daily operations. Every bus begins and ends its route here. That's why, when planning a new facility, we want to fully leverage modern technologies that will allow us to optimise workflows, increase safety, and make everyday tasks easier for our employees - especially drivers. Autonomy doesn't replace humans - it genuinely supports them. It allows us to relieve drivers from time-consuming and complex manoeuvres at the end of their shifts, which reduces the risk of minor collisions and lowers stress and fatigue. This, in turn, translates into a higher level of safety and comfort for our staff."

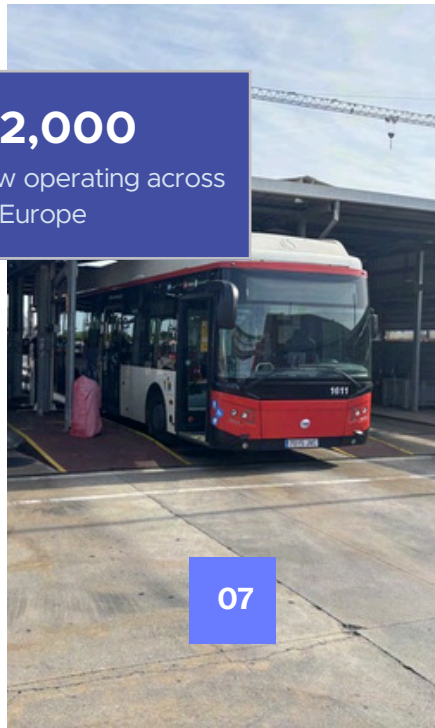
ELECTRIC FLEETS AND DEPOT COMPLEXITY

The shift to electric fleets reorders depot complexity. A diesel bus arrives at the depot, parks, and is ready again the next morning. An electric bus must park in a specific location near the right charger, connect in the right sequence to avoid grid peaks, be monitored through the night, and, if its State of Charge is lower than expected, require last-minute adjustments to ensure it's ready for service.

With more buses than chargers - a situation that arises in depots where fleet expansion has outpaced infrastructure - the evening shift requires physically rotating vehicles between charging bays, wash positions, and parking slots. Every such movement requires a driver or a shunter. The coordination effort grows with fleet size.

European electric bus registrations reached 11,607 units in 2025 - a 48% increase on the previous year [3]. Zero-emission vehicles now account for 60% of all new city bus sales [2]. Operators managing larger, more complex electric fleets are discovering that their depot processes - designed for diesel buses - were not built for this environment.

60% Zero-emission share of new EU city bus sales in 2025 [2]	**+48%** Growth in e-bus registrations 2024→2025	**~32,000** E-buses now operating across Europe



WHAT IS A SMART DEPOT?

A smart depot combines three integrated capabilities - depot management systems, smart charging, and autonomous vehicle movements - that together transform the depot from a passive parking and maintenance facility into an active, data-driven operational hub.

These three pillars do not need to be deployed simultaneously. Most operators will build toward a smart depot incrementally, starting from their existing digital infrastructure and adding layers of automation over time. The chapters that follow cover each pillar in detail, providing a basis for assessing which capabilities are relevant at each stage and what integration decisions need to be made at the procurement or investment planning phase.

Pillar 1: Depot Management Systems

The foundation of any smart depot is an integrated operational picture: a real-time view of every vehicle's location, status, charge level, maintenance need, and schedule.

Modern Depot Management Systems (DMS) aggregate data from fleet management platforms, charge management systems, timetabling software, and workshop management tools, providing varying degrees of integration between these data sources.

A smart depot DMS connects these systems into a unified operational workflow. In practice, this means:

- The timetabling system informs the DMS which vehicles must leave when - and in what required operational state.
- The vehicles provide real-time State of Charge data, while the charge management system confirms whether charging has been completed or remains in progress.
- The DMS identifies maintenance needs and passes the information to the workshop, so resources can be planned accordingly.
- Using these inputs, the DMS generates an optimised overnight plan - and updates it dynamically as conditions change.

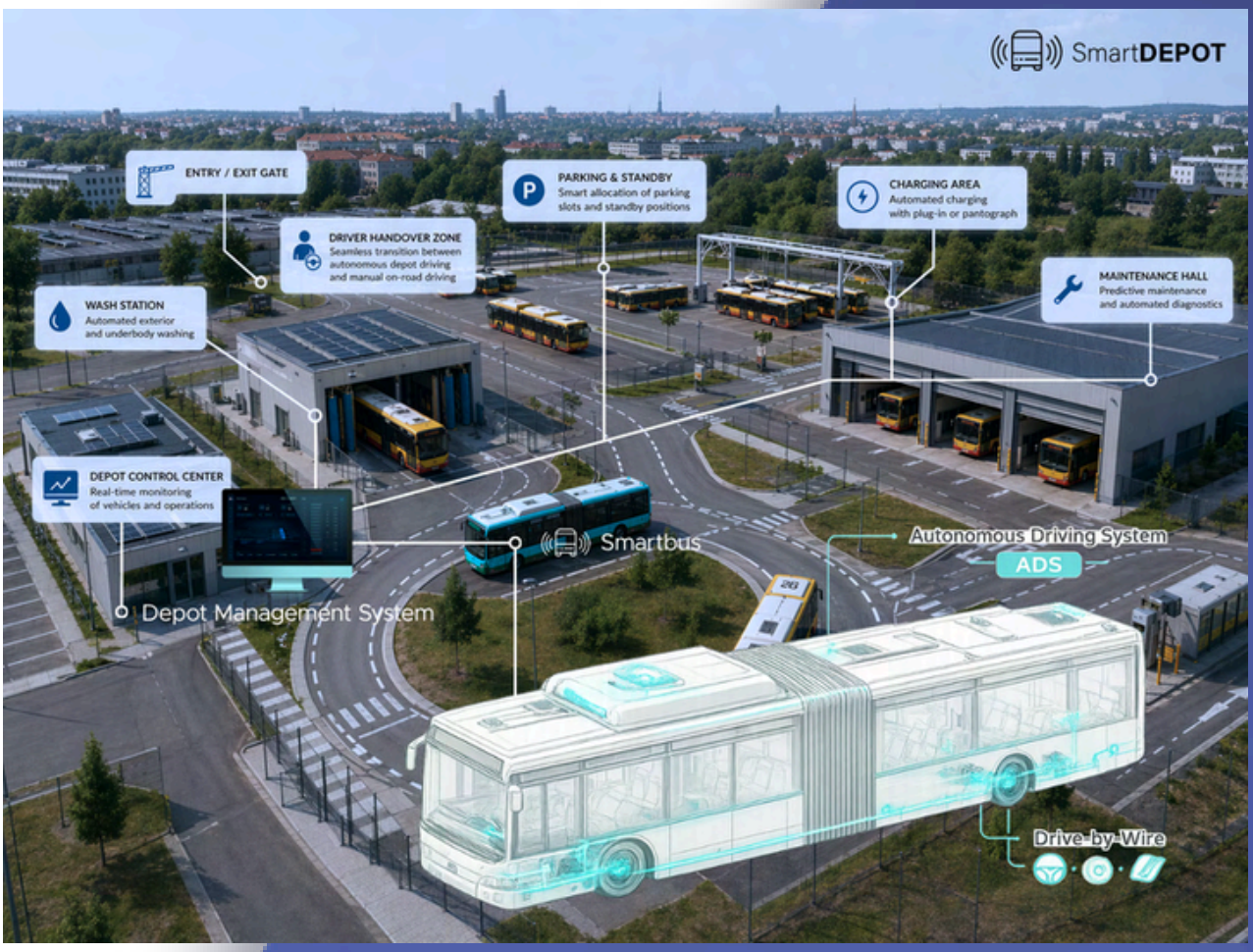
When autonomous vehicle movements are added to this environment, the DMS becomes the orchestration layer: it assigns missions to each autonomous bus, monitors execution, and adjusts sequences in response to delays, priority changes, or incidents.

KRZYSZTOF DOSTATNI
PRESIDENT OF MPK POZNAN

"Every day, hundreds of buses leave from here (the depot) - they need to be functional, safe, and ready on time. That's why we're interested in solutions that genuinely improve our work. Smart depot technology meets these needs and aligns with our strategy - from zero emissions to autonomy."

DEPOT MANAGEMENT SYSTEMS

A smart depot only works if it has a "brain" that can see the whole yard in real time and turn hundreds of small, daily decisions into one coordinated plan. That brain is the Depot Management System (DMS) - the operating layer that allocates parking and standby slots, sequences charging and maintenance, and synchronizes vehicle movements so every bus is exactly where it needs to be, exactly when it needs to be. In a smart depot, the DMS is tightly connected with Mission Control: DMS optimizes the plan (resources, time, space), while Mission Control supervises autonomous operations and exceptions. Together, they form a single control loop - data in, decisions out - linking charging, maintenance, and smartbus movements into one continuously updated depot "schedule" that reduces idle time, prevents bottlenecks, and improves on-time pull-out.



REAL-TIME DEPOT ORCHESTRATION

Most operators already hold the data that a smart depot system needs to sequence overnight operations: departure times, vehicle assignments, and driver schedules sit in timetabling and scheduling platforms that are standard across the sector. Making that data available in real time to the depot management system is the integration step that makes coordinated charging and autonomous movement scheduling possible.

DAVE VAN MEERBEECK
CEO & FOUNDER, TREELIGHT

"Scheduling data (vehicle tasks) is the operational foundation that depot management systems need, and operators already have it. The challenge is that this data sits in scheduling tools, like HASTUS, and doesn't automatically flow into the systems that manage vehicles overnight in the depot. When those connections are made - when the system knows at 23:00 which bus needs to leave at 05:20 fully charged - the entire logic of overnight depot management changes. Charging sequencing, movement, planning, maintenance slotting: all of it becomes schedulable rather than reactive. For operators looking at smart depot technology, the starting question should be: does your depot management system have a live data connection to your scheduling platform? That integration is the prerequisite for everything that follows - whether that's optimized charging, autonomous movement, or both."

THE DIGITAL FOUNDATION FOR AUTONOMOUS MOVEMENT

Peak Mobility (formerly PSI Transcom) has operated depot management systems across major European public transport operators for over 40 years. From that vantage point, Michael Preusker, who leads innovation at Peak Mobility, identifies a consistent pattern: operators who attempt to introduce autonomous vehicle movements without first establishing mature digital depot management tend to underestimate where the real complexity lies. In Peak Mobility's framework, depot management evolution runs in three stages — digital depot management, integrated driverless orchestration, and intelligent AI-driven orchestration — each a prerequisite for the next. The interface between the DMS and the autonomous driving system is, in practice, straightforward: the DMS sends drive orders (a vehicle ID and a target position) and receives real-time location data in return. The sophistication lies not in that handshake, but in the underlying digital processes the DMS must already manage reliably before that interface has any value.

MICHAEL PREUSKER
INNOVATION MANAGER
PEAK MOBILITY

PEAK MOBILITY

"Before vehicle movements in the depot can be automated physically, you need reliable digital control of the underlying processes — you need to know where the vehicles are, what their status is, what should happen next, and how depot processes should be coordinated. That is the role of the depot management system. The interface between the DMS and the automated driving system is actually quite simple: drive orders go one way, position data comes back. The complexity — and the preparation time — lies in building the digital foundation first."

SMART CHARGING

Pillar 2: Smart Charging

Charging management is where the transition to electric fleets creates the most visible operational complexity.

In a manual depot, charging is dictated by when a driver arrives. The bus parks, the driver connects the charger, and the vehicle charges until disconnected. This model is simple but economically wasteful: buses may be charged during peak tariff hours, high-power chargers may be occupied by vehicles with adequate charge, and the relationship between charge sequence and departure schedule is managed by spreadsheet or intuition.

Optimising the Charging Chain

A smart charging system replaces this with algorithmic priority management. The system knows which bus needs to leave at 05:30 with a full charge, which bus has a higher-priority route in the morning, and which vehicle has time to charge slowly overnight. It assigns each bus to the appropriate charger - high-power DC fast chargers for priority vehicles, lower-power AC for buses with longer parking time - and adjusts dynamically as real-world conditions diverge from the plan.

Key economic benefits include:

- Energy cost reduction: By shifting charging toward lowest tariff periods (typically 01:00-04:00), operators can reduce energy bills meaningfully, depending on their tariff structure and the flexibility of their fleet schedules
- Demand peak reduction: Coordinated charging prevents simultaneous peak loads that can trigger expensive grid demand charges or require costly infrastructure upgrades
- Charger utilisation: Dynamic allocation ensures that high-power chargers are used only when the charge rate is actually needed, extending battery and charger hardware life and improving infrastructure ROI
- Charging throughput: Reducing the latency between bus arrival and charging connection is a key throughput gain. Autonomous docking eliminates this delay entirely by routing buses directly to assigned chargers without manual intervention.

Vehicle-to-Grid

Vehicle-to-Grid (V2G) technology - where bus batteries can return electricity to the grid during peak demand - is emerging as an additional revenue stream for operators with smart charging infrastructure [6]. While still in early commercial deployment for heavy-duty buses, V2G requires the same infrastructure layer as smart charging optimisation: real-time state-of-charge visibility, dynamic scheduling, and the ability to interrupt and resume charging on demand. Operators investing in smart charging today are positioning themselves for V2G participation as the regulatory and commercial framework matures.

CHARGING ORCHESTRATION

As fleets grow, manual charging processes stop working. Decisions based on arrival time or fixed rules cannot keep up with the number of vehicles, chargers, and variables involved. Tenix focuses on automating these decisions using real operational data. The system continuously aligns charging with departure times, required energy, and available infrastructure, while adjusting to delays and changing conditions. This becomes critical in larger depots, where small inefficiencies multiply quickly. Operators should prioritise systems that integrate charging with the wider depot workflow, so that energy delivery is directly linked to service readiness and existing infrastructure is used as efficiently as possible.

TORBJØRN G. KRØVEL
CEO, TENIX

"As fleets scale, charging decisions need to be made continuously and based on real operational data. Automating charging operations is what allows operators to manage that complexity and keep vehicles ready for service. In practice, this starts with connecting charging to the timetable, so energy is delivered based on when vehicles are needed. From there, operators can introduce load balancing and prioritise lower-cost charging windows. These steps significantly lower energy costs, reduce demand on the grid, and improve the performance of existing infrastructure without adding unnecessary capacity."

SMART CHARGING AT SCALE

Diggia is a sustainable energy and infrastructure group working on large-scale electric vehicle charging environments. Their experience reinforces that in high-throughput electric depots - especially those using overhead pantographs - charging performance is tightly coupled to parking accuracy. Autonomous positioning delivers repeatable alignment, improving connection reliability and making charging coordination a predictable operational process.

JORGE SALAZAR
PROJECT MANAGER, DIGGIA

"When we design a depot where every parking space is a pantograph charging point, the boundary between vehicle movement and charging management disappears. The system that decides where a bus parks is the same system that decides when and how fast it charges. You cannot optimise one without the other. For operators planning large-scale electric depots, the practical implication is straightforward: autonomous movement and smart charging need to be specified together, not as separate procurement items. The integration between them is where the real operational value is created - in throughput, in charger utilisation, and in the ability to coordinate hundreds of charging cycles per night without human intervention at each bay."

SMARTBUSES

Pillar 3: Smartbuses - Autonomous Depot Movements

The third pillar - and the most visible expression of the smart depot concept - is the autonomous movement of buses within the depot without a driver present in the vehicle.

Smartbus depot operations are a precisely scoped, safety-engineered capability that functions exclusively within the Operational Design Domain (ODD) of a private, controlled depot environment. Speeds are limited to 15 km/h. Movements follow predefined routes. The system operates under remote supervision. The bus remains fully compliant with all road homologation requirements; the autonomous mode is inactive outside the depot.

The Driver-In / Driver-Out Model

The operational model that smart depot operators are converging toward follows three stages:

- Driver-In: The driver returns from service, pulls the bus to a designated handover zone at the depot entrance, completes a digital checklist, and hands over. The depot system takes control.
- Overnight: The bus drives autonomously to its assigned charger, connects, and charges according to the optimised plan. When cleaning is due, it drives to the wash bay. If a maintenance check is scheduled, it positions itself at the workshop entrance.
- Driver-Out: Before the next service, the bus drives itself to a designated dispatch zone at the depot exit. The driver arrives, logs in, and departs - with reduced time spent on locating the vehicle, connecting chargers, and yard manoeuvres.

The cumulative time saving at the driver level is significant: assessments across multiple European depots indicate 25–35 minutes per vehicle per day in potential driver time savings. Across a fleet of 100 buses, this is over 40 driver-hours per day - directly available for additional service.

MARIO CANET
HEAD OF NEW DEVELOPMENTS,
TMB BARCELONA

TMB Transports Metropolitans de Barcelona

"At TMB, we are modernising our depots to handle the complexity of electric fleets. A smart depot approach helps us maximise driver availability, improve operational safety, and keep daily operations running smoothly."

SPACE OPTIMISATION: A HIDDEN BENEFIT

Traditional depots require wide manoeuvring lanes to accommodate the turning radius and visibility requirements of human drivers. Autonomous systems with centimetre-level positioning can park buses with tighter tolerances, enabling 'block parking' configurations - vehicles arranged bumper-to-bumper and side-by-side - that increase effective parking capacity without any physical expansion of the depot.

When a specific bus needs to be extracted from a block position, the depot management system orchestrates a 'jigsaw' sequence - autonomously repositioning surrounding vehicles to create access - and returns them when the maintenance activity is complete. This capability transforms depot capacity planning, allowing operators to design for more vehicles in the same footprint.

MARCIN SEREDYNSKI
AUTONOMOUS SYSTEMS PROGRAM MANAGER, UNIVERSITY OF LUXEMBOURG

Université du Luxembourg

"Depot automation offers the most feasible early implementation domain, providing a controlled, low-speed, passenger-free environment. Depots involve numerous repetitive manoeuvres, such as parking and washing, which consume significant driver time without generating revenue. Automating these tasks can increase depot throughput, reduce internal congestion, optimise labour utilisation, and improve vehicle readiness for scheduled service."

FROM DEPOT TO STREET: THE AUTONOMY TRAJECTORY

ZF is a leading Tier-1 supplier of steering, braking, and driveline systems across Europe's bus OEM platforms. Its engagement in depot automation reflects a supply-chain view that depot autonomy is the first stage of a progressive deployment path - not a separate category from road autonomy - anchored in the same core architecture: drive-by-wire actuation, well-defined interfaces between the vehicle platform and the autonomous driving stack, and validated fail-safe behaviour.

DANIEL MAJEWSKI
HEAD OF BUS SOLUTIONS (GLOBAL)

"The bus depot is where the first-generation autonomous buses will mainly log in real operating hours—and turn them into an impactful evidence. Each deployment creates a traceable record of performance in terms of hazard detection, boundary conditions, and validated minimal-risk behaviour under real conditions like layout, weather and other variability).

This evidence strengthens the safety case regulators and operators need to approve broader operational domains. Crucially, depot and road autonomy share the same foundation: reliable drive-by-wire systems, clear interfaces between vehicle and autonomy stack, and fail-safe behaviors that are tested, monitored, and repeatable."

0 MANUAL
MANUAL & PAPER-BASED

No digital fleet management. Vehicle status tracked on whiteboards or paper. Charging managed by staff intuition. No automated reporting. Shunting fully manual with no route optimisation. Incident reporting on paper.

1 DIGITAL
DIGITISED BUT SILOED

Individual systems exist (fleet management, charger management, workshop system) but operate independently with no shared data. Operators can see vehicle status but cannot act on it automatically. DMS and timetabling not integrated.

2 ORCHESTRATED
INTEGRATED PLANNING

Core systems share data in real time. Timetabling informs charge prioritisation. Workshop needs are visible before vehicles arrive. The depot operates to a plan - but the plan is still executed by humans. Emerging interest in automated reporting and KPI monitoring.

3 ASSISTED
SEMI-AUTOMATED OPERATIONS

Assisted movement support: bay assignment rules, automated alerts when vehicles need to move. Some autonomous functions at specific locations (e.g., automated wash bay entry). Charge optimisation delivering measurable energy cost savings.

4 AUTONOMOUS
FULL YARD AUTONOMY

Fully autonomous depot movements: parking, charging approach, wash bay, workshop positioning, emergency evacuation. Driver-In/Driver-Out model operational. All movements orchestrated by integrated DMS. Remote supervision by Smartbus Coordinator. Human presence in the yard reduced to exception handling only.

SMART DEPOT MATURITY MODEL

The following maturity model provides a practical framework for operators to assess their current state and identify the most meaningful next step. It is a planning tool, not a fixed sequence: operators at Level 1 or 2 can reach Level 3 within a standard depot investment cycle by connecting timetabling, DMS, and charge management. Level 4 — fully autonomous yard operations with the Driver-In/Driver-Out model — is the target state for operators designing new depots or procuring new fleets. It is also the first stage of a longer trajectory: depot autonomy is where autonomous bus systems accumulate real operational hours. The Redutowa depot in Warsaw is the first facility in Europe being designed to Level 4 from the ground up. For operators approaching a fleet renewal or depot decision, the relevant question is whether their procurement specification preserves the option to reach it.

THE BUSINESS CASE

The smart depot business case rests on four quantifiable value streams: driver time recovery, risk and incident cost reduction, energy optimisation, and infrastructure utilisation. For most operators, driver time recovery alone is sufficient to justify the investment; the other streams provide resilience to the business case and accelerate payback.

DRIVER TIME RECOVERY

Manual shunting - parking, charging approach, wash bay positioning, dispatch staging - consumes an average of 25 to 35 minutes per vehicle per day across the European depots where operational assessments have been conducted. This time is non-negotiable in current operations: it happens every day, for every bus, regardless of schedule.

When autonomous movements assume these tasks, driver time can be recovered to a significant degree, depending on operating model. For a depot of 100 buses, assuming 25 minutes per vehicle per day, this represents:

- ~2,500 minutes per day (41+ driver-hours) recovered
- ~240 full driver shifts per year that can be redeployed to service
- Equivalent to the capacity of 4–5 additional driver shifts per day available for passenger service.

The return has two components. The first is direct labour cost savings: at an average European fully-loaded cost of €35–45 per driver-hour, the annual saving per 100-bus depot ranges from €500,000 to €700,000.

The second is service capacity: those same hours can be redeployed to line operations, generating fare revenue. Over a 10-year lifecycle, this represents €5–7 million in recovered labour value — additive to any service revenue gains, which will vary by operator and contract structure.

SAFETY COST REDUCTION

Depot collisions are not dramatic events, but they are expensive and pervasive. Minor incidents - mirror contacts, shallow bodywork damage, charging cable strikes - occur at a frequency of 3 to 4 per week in a large manually-operated depot [4]. Each incident generates direct repair costs (typically €1,000–2,000 per vehicle), out-of-service time, insurance claims, and staff management overhead.

Across a 10-year operating period, a 100-bus depot can expect 1,000-2,000 such incidents. At an average cost of €1,500 per incident, the cumulative direct cost exceeds €1.5 million - equivalent to more than €15,000 per vehicle over the lifecycle. Autonomous systems address the root cause of these incidents through LiDAR-based 360° perception and centimetre-level positioning precision — eliminating the variability inherent in manual low-speed manoeuvring.

There is also a higher-stakes dimension. In the event of a battery thermal event - increasingly relevant as electric fleets grow - autonomous evacuation routines can move adjacent vehicles out of the risk zone without requiring staff to enter the area. This capability cannot be assigned a precise financial value, but its operational significance is substantial.

ENERGY OPTIMISATION

Smart charging - when integrated with timetabling and DMS - enables systematic energy cost reduction through three mechanisms:

- Tariff-aligned scheduling: Shifting charging to off-peak hours (typically 01:00–04:00) reduces energy costs by 9–15% depending on tariff structure and fleet scheduling flexibility
- Demand peak shaving: Coordinated charging avoids simultaneous peak loads that trigger demand charges. In depots connected to constrained grid infrastructure, this can also defer or eliminate costly grid upgrade investment
- Charger matching: Dynamic allocation ensures buses with longer dwell time charge on lower-power, more cost-efficient hardware, preserving high-power fast chargers for priority vehicles with tighter schedules

For a 100-bus electric fleet consuming an average of 200 kWh per day per vehicle [5], an energy cost reduction of 10% represents approximately €250,000 per year at current European industrial electricity tariffs. The compounding effect over a 10-year contract exceeds €2.5 million in direct energy savings.

INFRASTRUCTURE UTILISATION

For operators planning new depot construction or major refurbishment, smart depot design principles deliver capital savings that are harder to quantify but equally significant.

Autonomous parking with centimetre-level precision allows for tighter bay geometries and reduced lane widths, increasing vehicle capacity per square metre of depot area by an estimated 10–15%. For a depot designed for 100 buses, this can eliminate the need for an additional parking hall - or avoid the need to acquire extra land, which in many city locations is either prohibitively expensive or simply unavailable.

Similarly, intelligent charger allocation - assigning buses to chargers based on actual departure schedule rather than proximity at arrival - can reduce the total number of high-power DC chargers required without reducing fleet readiness. The capital saving on charging infrastructure alone can offset a significant portion of the smart depot technology investment.

THE ROI SUMMARY

Value Stream	Annual Saving (100 buses)	10-Year Lifecycle Value
Driver time recovery	€500K – €700K	€5.0M – €7.0M
Safety & collision reduction	€150K – €300K	€1.5M – €3.0M
Energy optimisation	€200K – €300K	€2.0M – €3.0M
Infrastructure / depot design	Variable (new builds)	€M+ (capital)
Total indicative range	€850K – €1.3M	**€8.5M – €13M+**

Note: figures are indicative estimates based on operational assessments across multiple European depots. Actual results will vary based on fleet size, labour costs, energy tariffs, and operational profile. A site-specific feasibility study is recommended before investment decisions.

OPERATOR CASE STUDIES

The following cases represent operators at different stages of the adoption curve - from early operational assessments to new depot design. Each illustrates a different entry point, operational context, and primary driver for engagement with smart depot technology.

MZA WARSAW & REDUTOWA: EUROPE'S FIRST SMARTBUS DEPOT

Warsaw's Municipal Transport Company (MZA) operates one of the largest and most complex bus networks in Central Europe. The operational assessment of its existing Ostrobramska depot - conducted as a precursor to a new facility - documented the scale of the daily inefficiencies in detail.

Peak-hour arrival queues reached 25 minutes; reversing manoeuvres were the primary source of incidents; drivers were completing technically demanding manoeuvres at the end of shifts already degraded by fatigue. The data generated the core business case metrics: up to 35 minutes saved per bus per day, 3 to 4 weekly collisions eliminated, and over €88,000 in lifecycle labour savings per vehicle [4].

These lessons became the design brief for Redutowa - one of the first known facilities in Europe planned from the ground up for smartbus operations. The Redutowa facility is planned for 140 autonomous-ready buses on two levels, with no conventional parking slots. Every bay is designed for smartbus operation. A centralised control centre - operated by a new role, the Smartbus Coordinator - is designed to oversee all vehicle movements from a screen rather than a yard. Automatic fire evacuation routines are built into the operational design: in an emergency, vehicles are expected to move autonomously to safety without requiring staff in the risk zone.

MZA has published an early tender specifically addressing depot autonomous vehicles (smartbuses). The tender did not result in a qualified award at that time, highlighting a maturity gap between operator demand and commercially available supply.

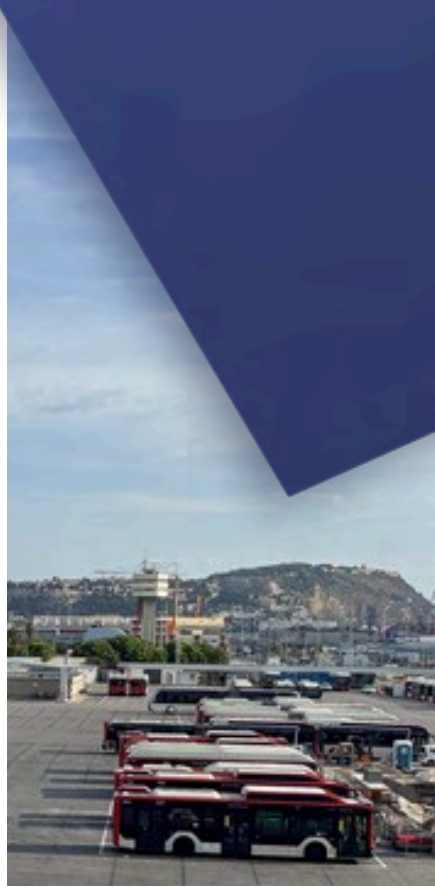
Transports Metropolitans de Barcelona

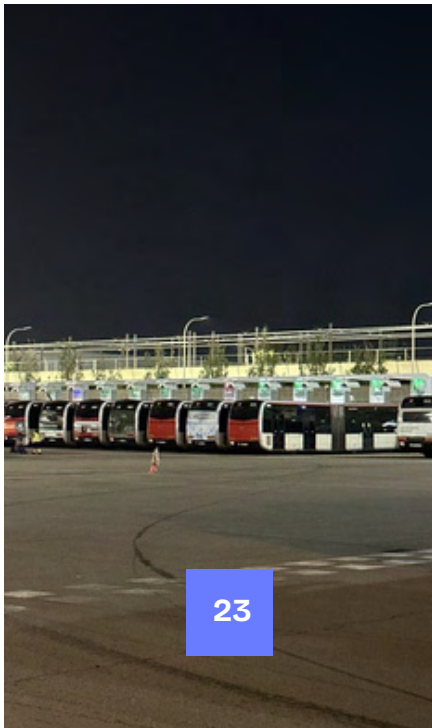
TMB BARCELONA: SOUTHERN EUROPEAN VALIDATION AT SCALE

Transports Metropolitans de Barcelona (TMB) operates over 1,150 buses across metropolitan Barcelona, with a growing share of zero-emission vehicles. At its largest depot, TMB manages daily operations for approximately 500 buses - each requiring up to 20 minutes of non-revenue depot movements supported by around 65 staff members.

TMB has recognised depot operations as a significant cost and inefficiency driver, and is actively participating in the validation of autonomous depot technology under real operational conditions. Barcelona is a major European mobility reference point, and TMB's engagement brings Spanish regulatory context and Mediterranean operating conditions to the validation data set.

For TMB, the transition to smart depot operations is framed around three priorities: maximising driver availability for passenger service, improving depot safety and reducing incident frequency, and managing the growing complexity of coordinating a mixed and expanding electric fleet.





MULTIOBUS

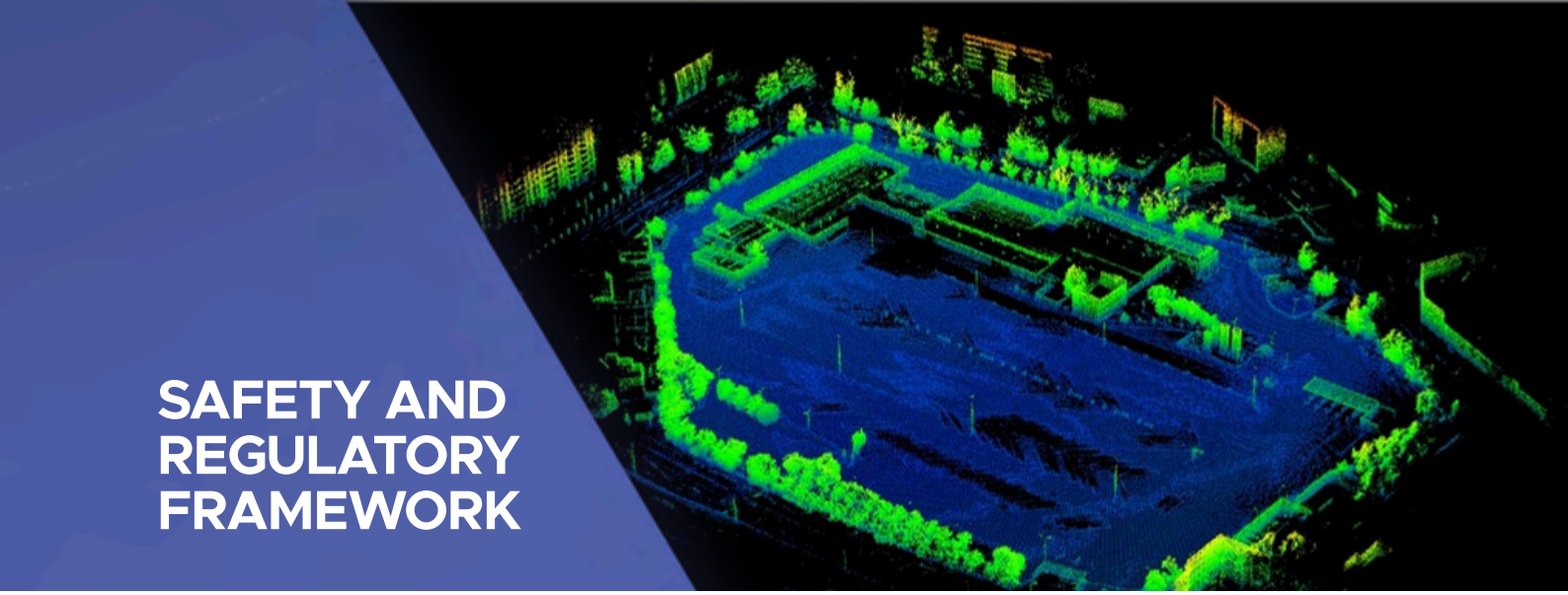
MULTIOBUS: BUILDING TOMORROW'S DEPOT DURING TODAY'S TRANSITION

Multiobus is a private bus operator in Belgium, subcontracting for De Lijn, with 34 electric buses and approximately 70 diesel vehicles and a roadmap to a fully electric operation within eight years. The electric fleet is already multi-OEM - IVECO, Mercedes-Benz, and EBUSCO - procured incrementally across funding cycles. This creates a practical challenge for depot automation, since not all platforms will reach drive-by-wire integration readiness at the same time.

Multiobus's interest in Smart Depot technology is tied to its electrification roadmap: as the fleet grows toward 100 electric buses, depot management complexity grows with it - more charging coordination, more overnight repositioning, more preparation time - all currently managed with manual processes designed for a smaller diesel operation.

OLIVIER VAN MULLEM
OWNER, MULTIOBUS

"Every electric bus we add makes the depot more complex. We are managing that today with manual processes, and the strain is starting to show. We got interested in smartbuses because we want to make sure the depot we are building toward can handle the fleet we are building toward. The mixed-OEM question is real for us - we need a phased approach: start with the vehicles that are ready and expand as the fleet evolves. That is how depot automation will work in practice for most operators."



SAFETY AND REGULATORY FRAMEWORK

Depot automation occupies a unique position in the regulatory landscape: it operates in a private area with controlled environment that is not direct subject to public road regulations, yet involves movement of large vehicles capable of significant injury if system fails. This creates both an opportunity and a responsibility.

The opportunity is that depot environments do not require the same level of regulatory approval as autonomous operation on public roads, allowing to act much faster. While the regulatory landscape will inevitably evolve, the depot ODD provides a stable and well-defined foundation to deploy, learn, and build operational maturity ahead.

The responsibility remains constant regardless of how the regulatory landscape evolves. The obligation to demonstrate safety is still there — through documented safety assessments, validated performance, and clear definition of the system's operational boundaries.

The Operational Design Domain

The concept of the Operational Design Domain (ODD) is central to understanding why depots represent the right environment for the first generation of commercially deployed autonomous bus systems.

The ODD defines the conditions within which an autonomous system is designed to operate. When violated, the autonomous system stops and informs supervisor. For a smartbus system, the ODD is deliberately narrow:

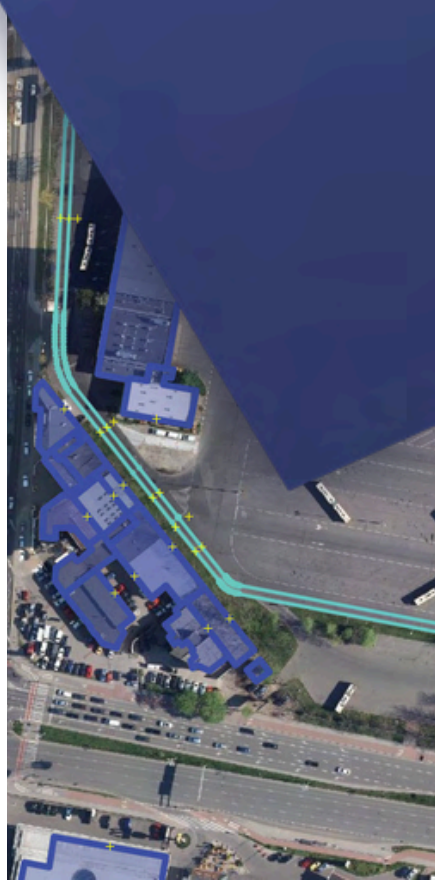
- Private, fenced premises with controlled access
- Low-speed operation
- Environment with a known and validated layout
- Remote supervision from a mission control interface

Within this ODD, the risk profile is manageable and the safety case is demonstrable. The system performs a limited set of low-speed manoeuvres in a known, pre-mapped environment under controlled conditions - a meaningfully narrower task than public road operation in terms of unpredictability, speed, and the range of scenarios the system must handle. Critically, the autonomous mode is automatically deactivated when the bus exits the depot and enters public roads.

APPLICABLE STANDARDS AND CERTIFICATION

While there is no specific regulation for autonomous depot operations in the EU at present, responsible deployment aligns with following areas:

- Market access regulations: The bus platform, including drive-by-wire modifications, must meet type-approval requirements (UNECE) [10]. The autonomous driving system must not compromise the vehicle's compliance with road homologation. Tests must demonstrate that steering, braking, and propulsion systems perform correctly under both manual and autonomous control and product is safe to use.
- Functional safety and safety of intended functions: Safety-critical functions - including autonomous mode selection, obstacle and human detection, braking, speed limitation, emergency stop and fail-safe behaviour on communication loss - must be systematically validated against defined failure modes and possible depot scenarios [7].
- Cybersecurity: Autonomous systems that communicate with mission control and on-board vehicle systems introduce new cybersecurity attack surfaces. Compliance with ISO 21434 [8] - the automotive cybersecurity standard - limits cybersecurity risks.



The regulatory outlook

The EU AI Act's framework for high-risk AI systems will apply to autonomous vehicle functions, including depot automation [9]. Compliance requirements centre on transparency, human oversight, data quality, robustness, and cybersecurity. Systems deployed under the current framework – with structured safety validation, independent assessment, and documented operational design domains - are well-positioned to meet forthcoming regulatory requirements. Operators who deploy now on this basis are building institutional knowledge, operational data, and safety records that will be directly relevant to regulatory compliance as the framework matures.

OPERATIONAL READINESS: TRAINING AND PROCEDURES

Human factor is also an important part of a safe system. Operators deploying autonomous depot movements need procedures and trained personnel before go-live — this is both a safety need and a practical condition for insurance and internal governance.

The operational framework should cover following areas:

- Site access control: clear protocols defining who can enter the bus depot and autonomous operating zone, and under what conditions.
- Override and emergency stop: every member of staff who may be present in the depot must know how to intervene, where emergency stops are located, and what to expect from the system.
- Incident and near-miss reporting: a process for capturing and acting on anomalies before they become accidents.
- Environment change management: a defined procedure for revalidating the system after modification to the depot layout, whether a new charging bay, a repositioned barrier, or a change in vehicle routing.

THE PATH FORWARD: GETTING STARTED

The transition to a smart depot does not require a greenfield construction project or a complete fleet replacement. For most operators, the most effective approach is phased: build on existing digital infrastructure, introduce autonomous capability incrementally, and scale based on demonstrated results.

Step 1: Operational Readiness Assessment

The starting point for any operator seriously considering depot automation is a structured assessment of the current state. This covers:

- Depot layout: Lane widths, gate geometries, parking bay dimensions, coverage for wireless communication
- Fleet composition: OEM platforms, drive-by-wire availability (current or planned), charger interface types
- Digital infrastructure: Current DMS, charger management system, timetabling integration, IT architecture
- Operational flows: Shift patterns, handover processes, maintenance workflows, peak movement schedules
- Business case baseline: Current cost of depot movements — staff time, incident frequency and repair costs, energy tariff structure

A rigorous assessment transforms a conceptual interest in depot automation into a site-specific investment case. It identifies the depot's current maturity level, the specific movements that can be automated in the first phase, and the integration requirements for connecting autonomous movements to existing operational workflows.

Step 2: Pilot, Validate, Scale

The first autonomous movements in a depot are not a full deployment - they are a proof of concept in a real operational environment. A structured pilot involves a single smartbus performing a defined set of movements (typically: charging approach, shunting, parking) in a designated zone of the depot, under close supervision.

The pilot has three objectives: to validate the readiness assessment through real-world operation in the target depot; to develop operating procedures and train staff; and to confirm the savings case needed to justify scaling to the full fleet.

Early smartbus pilots in the Warsaw and Gliwice environments indicate that the approach performs reliably in defined depot environments. Operators typically report faster staff acceptance once the system is visible in operation; measured outcomes should be validated site-by-site.

Step 3: Fleet Renewal as the Entry Point

The most economically efficient way to introduce autonomous capability is at the point of fleet renewal - when buses are being procured as part of a normal replacement cycle. This avoids the cost and complexity of retrofitting existing vehicles and aligns the investment with existing budget cycles.

Operators planning procurements for new zero-emission buses should evaluate whether autonomous depot manoeuvring capability can be included as a requirement - in effect, whether ordinary buses can be replaced with smartbuses. OEM-level integration - where the autonomous driving system is factory-fitted and certified as part of the bus type approval - is significantly simpler, safer, and more commercially sustainable than third-party retrofit. The procurement specification is the leverage point.

The Questions to Ask Now

For operators in the planning phase, the following questions define the strategic readiness conversation:

- What is our current maturity level? (Use the framework in Chapter 4)
- Do we have a fleet renewal decision in the next 24 months? This is the natural integration point.
- What is our current shunting cost - in staff hours and incident costs - and how does this compare to the investment in autonomous capability? (see Step 1: Operational Readiness Assessment)
- Do we have the digital infrastructure to support a DMS integration, or does this need to come first?

Smartbus Onboard Program

Operators interested in a site-specific operational readiness assessment - including a quantified business case, depot layout review, and fleet compatibility analysis - can access the Smartbus Onboard Program at www.smartbus.tech. The programme is structured around a depot-level analysis conducted in partnership with the operator, providing a factual foundation for procurement planning and investment decisions.

CONCLUSION

Bus depots are the operational core of every public transport network. The processes that happen inside the fence - after the driver returns and before the next shift begins - determine fleet availability, driver working conditions, energy costs, and safety performance. Those processes are increasingly under pressure from larger electric fleets, a structural driver shortage, and the coordination complexity that comes with charging-dependent operations.

The three pillars of the smart depot - integrated management systems, smart charging, and autonomous vehicle movements - address these pressures with technologies that are available today. Operational assessments across multiple European depots have produced quantified findings. The business case is grounded in data, and the safety framework is established through reference to standards already in use across the automotive and transport sector.

The deployment landscape in 2026 spans early pilots in Poland, feasibility assessments at operators across Belgium, Spain, the Netherlands, Norway, and Switzerland, and the planning stage of a greenfield depot in Warsaw being designed for smartbus operations. The trajectory from here runs through fleet procurement specifications: operators who define smartbus requirements in their next tender are better positioned to deploy within the coming fleet cycle.

The regulatory environment supports phased deployment. Depot environments operate under privately managed safety frameworks, with no requirement for public road autonomous vehicle legislation. Alignment with established standards - UNECE type approval, functional safety principles, ISO 21434 cybersecurity - provides a demonstrable compliance basis that procurement and safety officers can work with.

The smart depot is the bridge between today's constrained operations and the next era of public transport. By starting where risk is controllable and ROI is measurable, operators can move faster with confidence - while creating a direct pathway to broader automation as technology and policy mature.

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CONTACT

JAN GRAMATYKA, CO-CEO

+48 733 668 858

jgramatyka@autonomous-systems.pl

www.smartbus.tech