ADVANCING PUBLIC TRANSPORT

KNOWLEDGE BRIEF

ARTIFICIAL INTELLIGENCE IN PUBLIC TRANSPORT

MARCH | 2025

INTRODUCTION

This knowledge brief provides an updated overview of artificial intelligence (AI) applications in public transport for 2025, building on insights from the International Association of Public Transport's (UITP) 2017 report. It highlights both well-established practices and emerging advancements, aiming to inform public transport operators, authorities, and passengers about AI's transformative potential.

Due to space limitations, the brief prioritises uses cases over broader topics like regulation and ethics, which are only briefly mentioned, and excludes cybersecurity – a subject deserving its own dedicated analysis.

TMB Barcelona Metro

The examples presented underscore AI's current impact in three key areas: enhancing user experience, improving operational efficiency, and strengthening safety & security.

THE HYPE & THE REALITY

The release of ChatGPT in October 2022 demonstrated the remarkable capabilities of large language models (LLMs), which excel in multilingual text generation and summarisation, with quality often surpassing the average human performance. This sparked debates about the readiness of AI to replace human tasks and the potential emergence of artificial general intelligence (AGI). By November 2024, evidence suggested that LLMs might have hit a performance plateau. However, new approaches and optimised architectures like DeepSeek (introduced in late December 2024, significantly lowering training and generation costs)—have reignited momentum. These advancements hint at continued progress, unlocking new applications and enhancing AI's reasoning abilities.

As of February 2025, the prospect of AGI seems more feasible than it did a year ago, although its societal impact remains difficult to predict.

AI's evolution stems from foundational innovations like Google's Transformer architecture (2017), which revolutionised natural language processing and paved the way for breakthroughs in LLMs. These models, epitomised by OpenAI's GPT series, have demonstrated remarkable versatility across domains, including coding, law, and medicine. Despite the models' strengths, researchers have highlighted their limitations in complex reasoning tasks, noting that LLMs often rely on probabilistic pattern matching rather than true conceptual understanding. This poses challenges to safe deployment of LLMs in public transport without task-specific training.

The main uses of AI today focus on tasks such as data analysis, anomaly detection, and predictive maintenance. In this document, we highlight three key technological categories of AI applications:

- **LLMs,** primarily used in chatbots.
- **AI-driven video analytics,** leveraging advanced image processing.
- **Predictive modelling,** addressing operational challenges.

The first two categories typically rely on various forms of deep learning, a cutting-edge AI technique. Predictive modeling, by contrast, often employs more traditional AI methods. While these may seem less advanced, they are highly effective for solving a wide range of practical problems in public transport.

LARGE LANGUAGE MODELS

INTRODUCTION

While LLMs have garnered significant attention, their primary deployment in public transport has been focused on two practical areas thus far: enhancing staff assistance and improving customer assistance. These applications leverage LLMs' capabilities in natural language understanding and generation to streamline communication, reduce response times, and improve service quality.

CUSTOMER ASSISTANCE CASES

Case #1: PostBus (CH) – Acoustic passenger information using a text-to-speech engine

PostBus aims to provide consistent, real-time acoustic passenger information across Switzerland in multiple languages, including German, French, Italian, and English. Automated announcements for regular updates, as well as planned and unplanned incidents, are central to this initiative.

To achieve this, PostBus implemented a framework with two key components: a cloud backend and a vehicle system. This framework leverages scalable AI and machine learning application programming interfaces (APIs) powered by LLMs, avoiding the resource-intensive process of building models in-house. To ensure high-quality service, PostBus staff regularly audit samples of text-to-speech messages for accuracy and clarity.

Case #2: Digital sign language avatars for passengers with hearing loss

The range of sign languages is as diverse as that of spoken languages, with unique grammar and vocabularies across regions, reflecting the rich cultural identities of deaf communities. For example, British Sign Language (BSL) significantly differs from American Sign Language (ASL).

In 2024, applications were developed to convert text and audible announcements into sign language and multiple written languages. These are displayed on dedicated screens or browsers using synthetic avatars. Trials of these systems are underway in public transport settings. In Singapore, SBS Transit co-developed SiLViA, a digital human concierge powered by generative AI. Advanced speech recognition algorithms are used to instantly translate spoken and written words into sign language. SiLViA was piloted (in July 2024) at the North East Line's Chinatown Station, and SBS Transit aims to deploy it across mass rapid transit (MRT) stations and bus interchanges in the coming months.

Other similar projects include the installation of avatars in Belgrade Central Railway Station and the Port Authority of New York and New Jersey.

Communication with commuters who are hard of hearing of deaf enabled by GenAI

Case #3: Chatbot for passengers

The Chicago Transit Authority (CTA) has launched a chatbot called "Chat with CTA" to improve customer service. The chatbot is CTA's first real-time incident reporting tool. Customers can submit time-sensitive reports about topics such as maintenance, cleanliness, and disruptive passengers. The chatbot's initial scope was built with a natural language processing (NLP)-based product from Google, and it can service 79% of customer inquiries. A planned 2025 upgrade to Google's LLM product will use retrieval-augmented generation (RAG) to answer common, simple questions about CTA services. This will allow the agency to provide helpful and relevant responses in at least 95% of customer-initiated chats.

Club Italia is a non-profit organisation that promotes the use of contactless payment and access systems for public transport. In January 2025, they launched the open-source application Velvet, which will enable users to submit prompts to an LLM in the Italian language. These are then integrated into a chatbot which is able to respond to user requests and offer dynamically updated information, including about service timetables and advice on suitable clothing for the day of travel's expected weather conditions. The solution is being tested with several partner institutions as IntercentER (Emilia Romagna Region Telematics Purchasing Agency), UniMarconi (Online University), and Veneto Region. Club Italia's main objective is to deploy Velvet in Italy's central and southern regions, with a special focus on public transport operators in Sicily.

Japan Metro Signage

STAFF ASSISTANTS

Case #4: AI-based chatbot for frontline worker assistance

Alameda-Contra Costa Transit (AC Transit) faced challenges in providing information technology (IT) support to frontline staff, such as bus operators, whose schedules – especially night shifts – frequently did not align with IT support availability. The existing process relied on leaving voicemails or supervisors submitting requests, creating inefficiencies and requiring unnecessary manual work. To address this, it introduced "IT Aimee," a generative AI-powered conversational chatbot that enables operators to directly submit support requests and access essential IT and organisational information. IT Aimee leverages resources like Boss Desk Knowledge Articles and problem-solving documentation to assist with troubleshooting in real time. Furthermore, AC Transit is expanding its capabilities with integrations and automation workflows to address service desk issues, facilitate password resets, and handle basic human resources (HR) queries. Designed to provide immediate, 24/7 support tailored to frontline staff schedules, IT Aimee has significantly enhanced resolution speed and accessibility for frontline workers.

Case #5: AI-based chatbot for customer service centre

Tokyo Metro's customer service centre handles approximately 250,000 inquiries annually. To improve response speed and accuracy, they are prototyping generative AI applications to improve chatbot functionality, streamline lost item inquiries, and automate email responses.

- Enhanced chatbot: Using advanced LLMs, the chatbot can interpret user questions more accurately and process various documents, including charts and handwritten content.
- Lost item assistance: A dedicated chatbot allows customers to report lost items through a guided conversation, making the process less labour-intensive and more efficient.
- Email automation: AI analyses incoming emails, retrieves relevant information from sources like the Tokyo Metro website and past correspondence, and drafts replies, enabling faster responses.

These innovations will enhance customer interactions and optimise service operations.

VIDEO ANALYTICS

INTRODUCTION

AI-driven video analytics, also known as machine vision, is at the forefront of AI advancements in public transport. Multiple applications in this field have been rolled out over the past decade and include:

- **Passenger monitoring:** Cameras installed above vehicle doors and ceilings enable AI to count passengers, monitor crowding, track occupancy, and generate origin-destination data.
- **Bus safety monitoring:** AI-equipped cameras monitor blind spots and driver behaviour and detect potential collisions, enhancing overall safety.
- **Enforcement applications:** AI detects unauthorised vehicles in bus lanes and fare evasion events, enabling prompt enforcement.

- **Rail crossing safety:** AI monitors rail crossings to detect hazards like vehicles or pedestrians crossing unsafely and immediately alerts operators.

TACKLING NEW CHALLENGES: REQUESTED USE CASES

Building on the previous successes, there is now scope to use AI to tackle more difficult emerging challenges. Key requested use cases include:

- **Erratic behaviour detection:** Detecting loitering, distress, clashes, or suicidal behaviour to enable proactive interventions.
- **Weapon detection:** Identifying potential weapons in real time to ensure swift response and maintain safety.
- **Abandoned luggage tracking:** Detecting abandoned items and tracing their last owner to quickly address security threats.

While some of these challenges have gone through proof of concept, with various degrees of success, none of them has been successful enough to bring them into regular operations yet.

ADDITIONAL INSIGHTS AND FUTURE DEVELOPMENTS

There is currently a focus on making video analytics more ubiquitous and effective in public transport, by reducing its overall cost and enhancing its capabilities. Key developments in the works include:

- **Edge computing:** Processing video on local edge devices reduces latency and bandwidth, enabling quicker responses and lower infrastructure costs.
- **Collaborative multi-camera analytics:** Synchronising camera feeds can improve coverage and insights, especially in crowded areas.
- **Real-time incident reporting:** This entails instantly alerting operators about incidents like altercations or overcrowding to enable faster responses.
- **Proactive maintenance:** Visual checks on mobile equipment and infrastructure are used to detect issues and/or predict failures, thus minimising disruptions.
- **Cross-modal integration with internet of things (IoT) sensors:** Integrating IoT data (e.g. temperature, noise, etc.) with video analytics enriches decision-making and enhances passenger experience.

WEAKNESSES ASSOCIATED WITH OPERATIONAL USAGE OF AI MODELS

Video analytics offers many benefits, but it also has weaknesses that decision-makers need to consider. One major issue is the impact of changing environmental conditions on the analytics. AI models are often trained on specific datasets, and changes in the physical environment can decrease their accuracy. To ensure reliable performance, fine-tuning may be required.

Another weakness involves the cameras themselves: environmental exposure can degrade their quality over time, reducing image clarity and impacting AI performance. Regular condition monitoring of cameras is crucial to maintaining optimal input quality. Developing AI models that can handle image variations and glitches without significant performance loss is also key.

USE CASES

Case #1: Singapore Land Transport Authority (LTA) — bus safety

Singapore's public transport authority (PTA) has tackled safety and efficiency issues by adopting Streamax's AI technologies. These include systems for advanced driver assistance, driver fatigue monitoring, blind spot detection, and a high-capacity surveillance system. This upgrade has significantly enhanced safety, improved service quality, and enabled effective bus lane enforcement. Passengers also benefit from real-time seat availability displays showing upper-deck occupancy. 5,500 buses across all four public transport operators (PTOs) in Singapore have undergone these upgrades.

Singapore Land Transport Authority (LTA) — bus safety

Case #2: New York Metropolitan Transportation Authority (MTA) – railroad crossing safety, tunnel intrusion, & fare evasion

The MTA collaborates with innovative vendors and research institutions to enhance safety and operational efficiency. Through its annual Transit Tech Lab initiative, the MTA rigorously tests and pilots vendor technologies across its transit network. Furthermore, the MTA's specialised department overseeing CCTV and drone operations has successfully validated and deployed real-time detection technologies for tunnel intrusions and fare evasion, which are now seamlessly integrated into the agency's security protocols.

When commercial solutions prove insufficient, the MTA partners with leading research institutions to tackle specific challenges. For example, Rutgers University researchers developed an AI-driven framework that detects railroad trespassing, flags violators, and generates video clips of incidents for detailed analysis. This system leverages object detection to analyse footage, offering valuable insights such as peak trespassing times and violators' behavioural patterns.

Case #3: Sofia Urban Mobility Center – bus occupancy levels

Some challenges are better addressed with a smart, streamlined approach, rather than complex models. For instance, in Sofia, the Urban Mobility Center partnered with technology provider Theoremus to use real-time images from existing onboard cameras and classify bus occupancy into five levels. This eliminates reliance on error-prone boarding and alighting counts that accumulate over time and require additional hardware. This efficient solution required just 50,000 images and a relatively lean AI model.

Case #4: AC Transit – bus lane enforcement

Vehicles illegally parked in bus stops and bus-only lanes pose significant safety and operational challenges to transit agencies. Obstructed bus stops make boarding and exiting the bus dangerous and often inaccessible for riders with disabilities. Obstructed bus lanes reduce schedule adherence and prevent up to 50 people per bus from reaching their destinations on time.

In June 2024, AC Transit deployed Hayden AI's bus-mounted perception technology, following a successful pilot in 2022. Forward-facing cameras use computer vision and on-board edge processing to detect vehicles illegally parked in bus-only lanes and bus stops. Upon detecting a potential violation, the system records a 10-second video of the event, captures a photo of the vehicle's licence plate, and sends this information, as well as the time and location of the event, to parking enforcement, where staff members review each evidence package before deciding whether to issue a citation to the registered vehicle owner. No intervention by the bus operator is required to operate this system.

This advanced technology has delivered much higher and more accurate detection rates than the previous manual system. To ensure privacy, the cameras face the road and curb area and do not make a recording unless a parking violation is detected. Nothing inside the bus is recorded, and there is no facial recognition software used in the system.

Case #5: FGC Barcelona – fare evasion detection and enforcement

Deployed in 2015 under the principle "if you do not keep innovating against fare evasion, it only grows," FGC introduced dedicated cameras at key urban stations to detect and deter fare evasion using AWAAIT's AI system. This system identifies real-time fare evasion at each gate during all operational hours and provides ticket inspectors with an app to specifically target fare evaders, avoiding unnecessary checks and disruption to paying passengers. By enabling selective inspections during peak hours without affecting passenger flow, the system turns every camera into a potential deterrent, significantly reducing fare evasion.

Case #6: Boston – Schepens Institute's app on blind and visually impaired user guidance for bus stops

In 2019, a mobile app was launched to help visually impaired users navigate to bus stops, addressing GPS inaccuracies through remote human assistance via the phone's camera. However, the business model was financially challenging, and the app was ultimately discontinued.

In 2024, the Schepens Institute reimagined the concept with AI-powered technology. The new app uses smartphone cameras and an autonomous system, trained with a relatively small set of bus stop images, to visually guide users to the nearest bus stop within the camera's field of view, removing the need for external assistance and providing a scalable, user-friendly solution.

Simulated fare evasion by tailgating at an FGC faregate

PREDICTIVE MODELLING WITH AI

Predictive modeling is a branch of AI that uses machine learning techniques to make forecasts or cluster events based on relationships and patterns learned from historical data. The models can be classified into several groups, each suitable for different types of tasks and data. Forecasting models focus on predicting values that are either continuous, e.g. a number of passengers or a duration, or categorised, e.g. service status as "on-time" or "delayed", while clustering models group similar data points together to identify hidden patterns. With advances in technology and computer power, predictive machine learning has taken a major leap forward in recent years.

BENEFITS AND LIMITATIONS

Machine learning models can quickly analyse large amounts of data and identify patterns that may not be readily apparent to the human eye. The main benefit is improved accuracy in forecasting and clustering results, which, in turn, leads to better decision-making.

Although machine learning has transformed many fields, it sometimes fails to deliver the expected results. There are many reasons for this, including lack of data, data quality issues, overfitting, model drift, and lack of appropriate computing resources. And even when all the golden rules of machine learning have been followed and the model produces excellent results, a lack of confidence due to a 'black box' effect can render a model useless. Explainability and transparency of AI machine learning models are critical to building trust and ensuring regulatory compliance.

PREDICTIVE MODELLING FOR PUBLIC TRANSPORT

Predictive modeling with AI is transforming decision-making in public transport for all its key resources: employees, vehicles, service, and infrastructure. Better decision-making in this field leads to enhanced operational efficiency, service quality, and safety.

HUMAN RESOURCES

In terms of HR, AI facilitates efficient shift planning, task allocation, and workforce distribution, e.g. by anticipating demand peaks and absenteeism. Other applications of predicting modelling automate reporting tasks to improve the operational efficiency of planning personnel.

Case #1: AI for driver efficiency

Alsa Morocco operates the public bus network in four major cities in Morocco, with a total of 3076 drivers. The aim of this project was to achieve an efficient driving style across all fleets and drivers. The approach used is to correlate on-vehicle telemetry data and other external data such as traffic, passengers, and weather using a machine learning clustering algorithm. The model considers the operational differences between routes and peak & off-peak times to derive driving styles for each situation unique to the specific operational context. To ensure a fair and unbiased assessment of drivers, a variety of techniques were applied, including a gamification approach with incentives and recognition, identification of risk zones and recurring behaviours that require attention, and training sessions focused on the specific issues in each situation. Results included 4-12% fuel savings and a 15-40% reduction in the number of alerts related to improper vehicle use. The latter directly translates into safer and more comfortable journeys, as well as healthier vehicles.

VEHICLE FLEETS

In fleet management, AI facilitates efficient vehicle planning and dispatching, e.g. by anticipating energy and maintenance needs, as well as passenger demand. AI can be used to identify maintenance needs before failures occur, reducing downtime, extending fleet life, and improving safety. With the increasing use of electric buses (e-buses) in public transport, vehicle planning and real-time dispatching are becoming more complex and can also benefit from AI, with more accurate forecasts of battery degradation, discharge rates, and electricity costs.

Case #2: Smart charging in an e-bus fleet

Arriva Spain operates a fleet of 16 e-buses at its Alcorcón facility. With the introduction of battery electric vehicles (BEVs), the PTO is facing an increase in power demand. It needs to reduce variable energy costs and battery degradation in its vehicles while simultaneously ensuring high uptime. Bia's Smart Charging solution offers Arriva the ability to dynamically optimise charging processes without affecting the schedules. The platform uses an AI model trained on historical charger telemetry and fleet management system data to predict e-bus charging. The solution facilitates charging scheduling during periods of lower energy prices, while maintaining the slowest charging process to preserve battery life. The results show a 25% reduction in electricity costs and a 24% reduction in the average maximum charge per vehicle, with no impact on scheduled departure times.

SERVICE DESIGN AND REAL-TIME DISRUPTIONS

PTAs consider vehicle runtime and passenger demand when designing the service to be offered. AI can provide reliable forecasts for these values based on historical data. Factoring in weather, special events, and real-time traffic flow, AI models can improve real-time operational efficiency and service quality by generating adjusted runtimes and more up-to-date passenger demand forecasts.

Case #3: AI/ML usage for accurate predictions

The National Transport Authority (NTA) of Ireland is responsible for overseeing and regulating public transport services throughout the country. The NTA manages a fleet of over 2,000 buses and coordinates multiple modes of transport, including urban buses, trams, and suburban rail networks. The authority is focused on optimising service delivery, improving passenger experience, and integrating advanced technologies to improve operational efficiency. Traditional methods of predicting arrival times based on a fixed weighting of short-term and historical data were not able to adapt to real-time network and traffic conditions. NTA deployed Trapeze technology to address this; the system has a machine learning prediction engine that dynamically adjusts the weighting of short-term and historical data. The AI model integrates multiple data sources (such as traffic, weather, and passenger load) and long-term historical data. During testing, the algorithm achieved a 13% increase in prediction accuracy. Full network deployment is planned for 2025.

Case #4: #transmove: AI-based mobility forecasts

In Hamburg, the police traffic control centre is responsible for traffic flow and is in frequent contact with the control centres of the different PTOs. Solving ad hoc traffic issues (e.g. traffic jams) used to be primarily based on operators' experience. To enable multi-modal long-term traffic simulations, a traffic model based on individual mobility behaviour was developed partially using agent-based modelling. For short-term traffic forecasting, an AI algorithm developed by PTV was used to combine the agent-based traffic model with real-time data. A user-centric map-based frontend provides real-time data about the current traffic flow and a forecast for the next 5-30 minutes. The frontend also displays current roadworks, accidents, and other events that affect traffic flow. PTOs and the traffic control centre now have a data-driven view of the current traffic situation in the city and are empowered to make better decisions to jointly solve ad hoc traffic flow problems.

INFRASTRUCTURE

As rail infrastructure ages, AI can be used to understand the likelihood of failure of each component (such as track, signaling, or electrical equipment). Predictive maintenance aids in repair scheduling and prevention of unexpected failures, thus improving operational efficiency and safety. AI can also be used to regulate components of complex infrastructure, such as metro stations, electric fleet depots, track & road signaling systems, and communication system networks.

Case #5: AI ventilation control system

The Barcelona Metro was inaugurated in 1921. It currently has more than 130 stations. Due to the city's infrastructure, age, and meteorological conditions, the temperatures inside the stations can be uncomfortable for passengers. Good metro ventilation is crucial to ensuring the thermal comfort of passengers and adequate air quality. The ventilation of underground infrastructures is complex, with many variables involved. A predictive AI ventilation control system was developed by SENER and implemented in the Barcelona Metro in 2020 to address this issue. The system selects the optimal ventilation strategy in real time, considering meteorological conditions, indoor and outdoor air quality, energy consumption, fan performance, and energy costs, among other factors. The system helped limit the spread of the 2019 coronavirus disease (COVID-19) during the pandemic. In 2022, the focus shifted to balancing thermal comfort, air quality, and energy management, resulting in a 1.3 degree Celsius (°C) reduction in temperature, a 20.9% increase in fan performance, a 25.1% reduction in energy consumption, and a 10.7% increase in passenger satisfaction.

REGULATORY LANDSCAPE AND PRIVACY PROTECTION

The regulatory landscape for AI is evolving rapidly, with new measures aimed at controlling AI models, preventing monopolies, and safeguarding privacy. Prominent regulations include the European Union's (EU) **AI Act,** which focuses on large-scale models like LLMs, and the **General Data Protection Regulation (GDPR),** which governs data privacy. While these laws originate in the EU, they often influence global regulatory approaches.

In the United States, initiatives such as the **2022 Blueprint for an AI Bill of Rights** provide frameworks for responsible AI use. Globally, standards like **ISO/IEC 42001 for AI** are under development, offering international guidelines.

Many countries are rolling out national strategies to encourage AI adoption while promoting best practices and ethical standards. However, detailed analysis of these diverse regulations is beyond the scope of this knowledge brief.

SUCCESS FACTORS IN AI PROJECTS

AI is still near its hype cycle peak, making it challenging for PTAs to acquire and retain talent. Outsourcing AI development can facilitate efficient implementation of new tools.

Successful AI projects in public transport thus far have included the following aspects:

- **Collaboration:** A transparent partnership between the technology provider and public transport authorities to accurately assess AI capabilities.
- **Dedicated team:** A committed team within the PTO or PTA is essential. This team should have the support of upper management and be responsible for spearheading innovation, managing data access, facilitating change management, & ensuring privacy. While the team members do not necessarily have to be AI specialists or exclusively dedicated to AI, they must oversee data quality and/or provide clear guidance to vendors on data management.

Munich Metro, Germany

ENERGY USAGE AND MODEL SIZES

Large-scale AI models are known for their significant energy consumption, both during training and regular operations, when they make inferences or predictions from real-world data. This high demand is largely due to their broad and generalised scope, which requires extensive computational power.

A promising approach is to use these large models alongside smaller problem-specific models. Such smaller models are less energy-intensive and more suitable for practical applications, enabling wider AI adoption. In some cases, AI solutions can start small and leverage large models for efficient training or validation, benefiting from their capabilities without the high energy costs. This hybrid strategy allows for more sustainable AI solutions that balance efficiency and impact.

CONCLUSIONS AND NEXT STEPS

AI technologies have seen a significant performance boost since 2012, driven by advancements in neural networks and the availability of big data and computational power. Public transport already benefits from AI in NLP and machine vision. Future use cases are expected to further enhance customer experience and operational efficiency.

The UITP AI Working Group will continue to monitor AI advancements and plans to issue updated documentation as new developments arise. By staying informed and proactive, PTOs can harness the full potential of AI to improve their services and meet the evolving needs of passengers.

This Knowledge Brief was produced by UITP's AI Working Group established by the ITT and IT&I Committees.

This is an official Knowledge Brief of UITP, the International Association of Public Transport. UITP has more than 1,900 member companies in 100 countries throughout the world and represents the interests of key players in this sector. Its membership includes transport authorities, operators, both private and public, in all modes of collective passenger transport, and the industry. UITP addresses the economic, technical, organisation and management aspects of passenger transport, as well as the development of policy for mobility and public transport worldwide.

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