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UITP INDIA

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PMPML

TRAINING REPORT

TRAINING ON DEPLOYMENT AND INFRASTRUCTURE MANAGEMENT FOR ELECTRIC BUSES

JUNE | 2024

International Association of Public Transport (UITP)
Rue Sainte-Marie, 6 | B-1080 Brussels | Belgium

Tel: +32 2 673 61 00
info@uitp.org
www.uitp.org

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INTRODUCTION

The UITP India organised a Capacity Building Training programme on "Deployment and Infrastructure Management for Electric Buses" on June 27-28, 2024 in Pune. This training, under UITP India's project - Advancing Electric Buses in India, responded to India's rapidly evolving electric bus landscape, where cities are increasingly transitioning their public transport fleets to electric vehicles.

India has set ambitious targets for electric bus adoption, planning to deploy thousands of e-buses across various cities in the coming years. This large-scale transition necessitates specialised knowledge and skills in managing electric bus operations, which differ significantly from traditional diesel bus fleets. Therefore, the training programme addressed this crucial need, covering a wide range of topics essential for successful e-bus implementation. These topics included charging infrastructure and optimisation, route and schedule optimisation strategies, data monitoring and performance evaluation techniques, developing resilient and safer e-bus ecosystems, and asset management for e-buses

The two-day training programme featured presentations from both international and Indian experts, offering a blend of global best practices and local insights. The training had 36 participants representing 16 State Transport Undertakings (STUs) across India along with participation from representatives of other non-profit organisations, indicating the widespread interest and need for such specialised knowledge.

The training programme commenced with a welcome address by Ms Rupa Nandy, Head of UITP India. She introduced the participants to UITP and set the tone of the training programme by providing a brief context on the project "Advancing Electric Buses in India". This was followed by an inaugural address by Mr Prashant Kolekar, Electric Engineer representing Pune Mahanagar Parivahan Mahamandal Limited (PMPML), the supporting partner for the programme.

KEY SESSION OUTCOMES: DAY 1

SESSION 1A

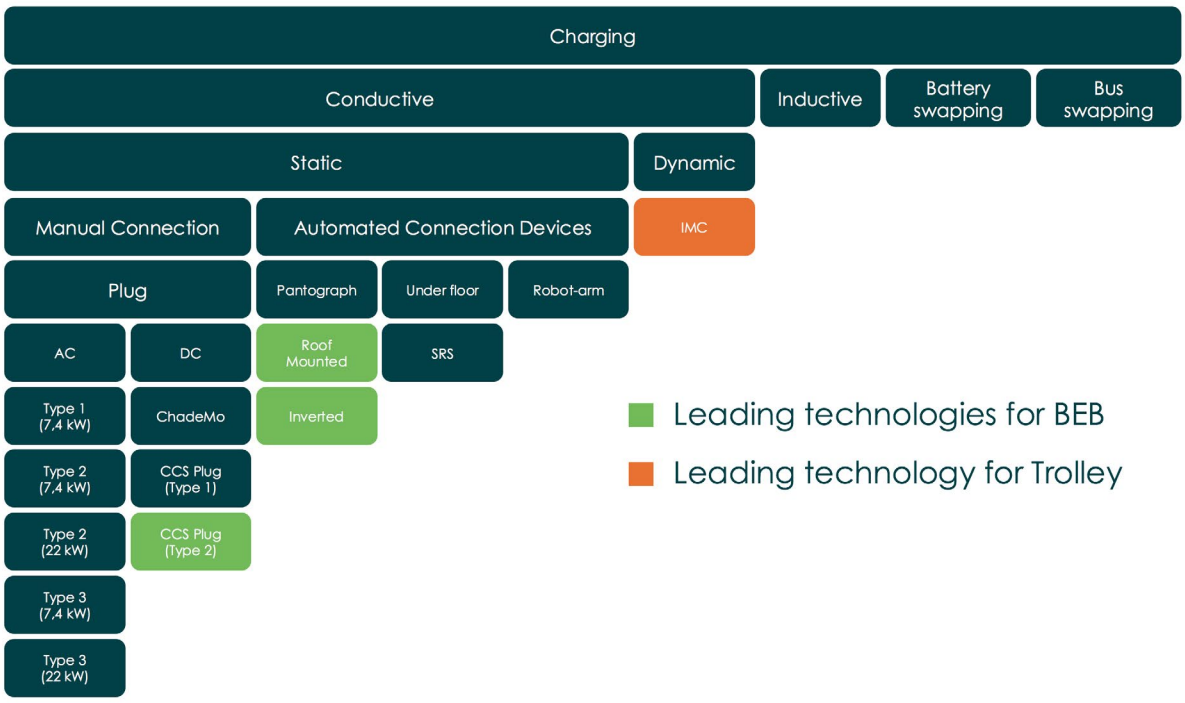
Charging Infrastructure & Optimisation

Mr Josep Enric Garcia Alemany, Public Transport Executive and Consultant at MOOV, Spain, led the first session of the day. He began his session by categorising loading interfaces and strategies into conductive and inductive charging methods. Giving an overview on charging options available, he discussed their pros and cons.

Comparing different charging regimes, he contrasted overnight depot slow charging with opportunity charging, highlighting the trade-offs between battery capacity, weight, cost, and operational flexibility. He then discussed various charging infrastructure options, including depot charging, conductive and inductive opportunity charging, and dynamic induction. Depot charging is described as operationally simpler, but requiring larger, more expensive batteries and potentially significant power grid investments. On the other hand, opportunity charging allows for smaller, lighter batteries but comes with higher infrastructure costs and more complex operations. He discussed their impact, particularly in energy management.

Mr Josep then emphasised on energy management, and the need for upgraded CAD/AVL systems and smart charging solutions. These systems are essential for providing real-time data on vehicle status, charging station availability, and range information, enabling smooth electric vehicle operations and help reduce utility and investment costs. He concluded the presentation by discussing the importance of interoperability standards to ensure flexibility and avoid dependence on single suppliers.

LOADING INTERFACE OVERVIEW



SESSION 1B

Best Practices for Charging Infrastructure and Optimisation

Mr Josep Enric Garcia Alemany led this session, sharing best practices for charging infrastructure and optimisation for electric buses, focusing on case studies from four cities: Madrid, Glasgow, Utrecht, and Zaragoza. He detailed the charging setups at bus depots in these locations, including the number and types of chargers, power capacity, and unique features of each system.

He highlighted key aspects such as smart charging strategies, safety measures, renewable energy integration, and infrastructure optimisation. The case studies showcased various approaches to managing large-scale electric bus fleets, from EMT Madrid's 120-bus simultaneous charging capability to First Bus Glasgow's 162-vehicle charging depot, demonstrating the evolving landscape of electric bus operations in urban environments.

These case highlighted considerations such as power management, safety, renewable energy integration, and operational efficiency. They offered valuable insights for cities and operators transitioning to electric bus fleets, emphasising the importance of tailored solutions for specific local needs.

A photovoltaic roof with 1,055 panels supplies 10 % of the energy required by the infrastructure.

Strategy for Route and Schedule Optimisation with Charging Infrastructure

Mr Manpreet Singh Kapoor, General Manager, IT, DIMTS began by introducing Delhi Integrated Multi-Modal Transit System Ltd., (DIMTS), a multi-disciplinary company, aiming to improve public transport in Delhi. He outlined Delhi's journey in public transport reform, including the transition to CNG vehicles and the current plan to introduce e-buses to the fleet and double the market share of public transport. Providing an overview of Delhi's transport modes, he detailed the city's transition plan to increase its e-bus fleet from 21% in 2023-24 to 81 % by 2025-26.

Mr Manpreet shared details of the current and upcoming charging infrastructure in Delhi, including depot and opportunity charging, and described how Delhi plans to deploy 6,380 e-buses by 2025, which would constitute 70% of the overall fleet. He also discussed the plan to electrify all bus depots in a phased manner.

He explained the routing and scheduling process for e-buses, describing how DIMTS is optimising it based on battery capacity and estimated state of charge. The strategy involves creating duty memos that account for battery charge levels, utilising opportunity charging during driver breaks, and optimising schedules to maximise daily bus utilisation while minimising waiting times at charging stations. The presentation concluded by comparing scheduling differences between electric and non-electric buses, highlighting the additional time needed for opportunity charging in electric bus schedules.

NON ELECTRIC BUS SCHEDULING V/S ELECTRIC BUS SCHEDULING

Duty Memo of Non Electric Bus

Difference in time between 1st duty Inshed and 2nd duty Outshed is 28 Min in case of CNG bus scheduling

S. No.	Depot Name	Vehicle No.	Duty Name	Driver ID	Conductor ID	Sch. Outshed	Outshed Performed	Outshed Diff. (Min)	Sch. Inshed	Inshed Performed	Inshed Diff. (Min)	Sch. Trips	Trips Performed
1	Kair	DL1PD0830	**764B/2B**	MTK7787	05671	06:54:00	07:05:24	12	14:11:00	14:16:42	6	4	**3**
2	Kair	DL1PD0830	**764B/2BA**	MTK8535	14101	14:44:00	14:31:26	-13	22:01:00	21:48:37	-13	4	**4**

S. No.	Depot Name	Vehicle No.	Duty Name	Driver ID	Conductor ID	Sch. Outshed	Outshed Performed	Outshed Diff. (Min)	Sch. Inshed	Inshed Performed	Inshed Diff. (Min)	Sch. Trips	Trips Performed
1	Bawana Sector-5	DL1PD5382	**120D/4**	ITDR1551	115024	05:14:00	05:26:17	13	13:05:00	13:04:28	-1	6	**6**
2	Bawana Sector-5	DL1PD5382	**120D/4A**	ITDR1425	115528	13:26:00	13:42:20	17	21:17:00	21:26:50	10	6	**6**

S. No.	Depot Name	Vehicle No.	Duty Name	Driver ID	Conductor ID	Sch. Outshed	Outshed Performed	Outshed Diff. (Min)	Sch. Inshed	Inshed Performed	Inshed Diff. (Min)	Sch. Trips	Trips Performed
1	Bawana Sector-5	DL1PD5540	**116/20**	ITPL1928	122489	06:23:00	06:28:25	6	14:23:00	14:18:50	-5	6	**6**
2	Bawana Sector-5	DL1PD5540	**116/20A**	ITPL1070	114932	14:43:00	15:02:44	20	22:43:00	23:02:39	20	6	**6**

Duty Memo of Electric Bus

Difference in time between 1st duty Inshed and 2nd duty Outshed is ~70 Min in case of e-bus scheduling. During this period, opportunity charging is carried out.

S. No.	Depot Name	Vehicle No.	Duty Name	Driver ID	Conductor ID	Sch. Outshed	Outshed Performed	Outshed Diff. (Min)	Sch. Inshed	Inshed Performed	Inshed Diff. (Min)	Sch. Trips	Trips Performed
1	Burari-I	DL51EV4501	**861AEV/24**	BRD-0520	99404	05:05:00	05:16:46	12	12:45:00	12:32:10	-13	6	**6**
2	Burari-I	DL51EV4501	**861AEV/24A**	BRD-0177	110981	13:40:00	14:42:44	63	21:20:00	21:17:47	-3	6	**4**

S. No.	Depot Name	Vehicle No.	Duty Name	Driver ID	Conductor ID	Sch. Outshed	Outshed Performed	Outshed Diff. (Min)	Sch. Inshed	Inshed Performed	Inshed Diff. (Min)	Sch. Trips	Trips Performed
1	Rohini Sec-37	DL51GD2211	**165EV/5**	5318RH37	76081	05:03:00	05:21:30	19	12:43:00	12:29:27	-14	6	**6**
2	Rohini Sec-37	DL51GD2211	**165EV/5A**	5080RH37	121341	13:43:00	14:04:56	22	21:05:00	21:02:35	-3	6	**6**

S. No.	Depot Name	Vehicle No.	Duty Name	Driver ID	Conductor ID	Sch. Outshed	Outshed Performed	Outshed Diff. (Min)	Sch. Inshed	Inshed Performed	Inshed Diff. (Min)	Sch. Trips	Trips Performed
1	Rohini Sec-37	DL51GD2254	**165EV/25**	NA	120950	07:49:00	07:59:55	11	15:09:00	14:50:19	-19	6	**6**
2	Rohini Sec-37	DL51GD2254	**165EV/25A**	5456RH37	113987	16:29:00	17:28:11	60	23:50:00	00:49:02	60	6	**6**

Case Study UITP India

Ms Divyanka Dhok, Research Consultant at UITP India,led the session. She presented insights from the Advancing Electric Buses project, focusing on best practices for planning and implementing electric bus operations in urban environments. She outlined the essential requirements for effective e-bus scheduling, including understanding route needs, bus specifications, and charging opportunities. She emphasised the importance of considering factors such as battery capacity, energy consumption, and charging time when creating efficient schedules. She also stressed on the need for schedule optimisation, staff training, and real-time monitoring to maximise operational efficiency. Using real world examples, she illustrated the complexities of managing e-bus fleets and the variability of energy consumption due to different factors.

Ms Divyanka concluded by outlining next steps for optimising e-bus operations, aiming to create more efficient, sustainable, and reliable electric bus systems in urban areas while addressing the unique challenges posed by it.

REQUISITES FOR PLANNING E-BUS SCHEDULES

- Route requirements
- **Bus specifications**
- Charging opportunities
- Optimization
- Staff training
- Monitoring and adjustment

Energy Consumption may depend on :

- Terrain
- Vehicle weight
- Weather
- Driving style
- Traffic
- And more

	Battery Size (kWh)	Range per charge (km)	Energy Consumption (kWh/km)
OEM 1 (Summer)	204	150	1.09
OEM 1 (Winter)	204	200	0.82
OEM 2 (Summer)	231	140	1.32
OEM 2 (winter)	231	200	0.92

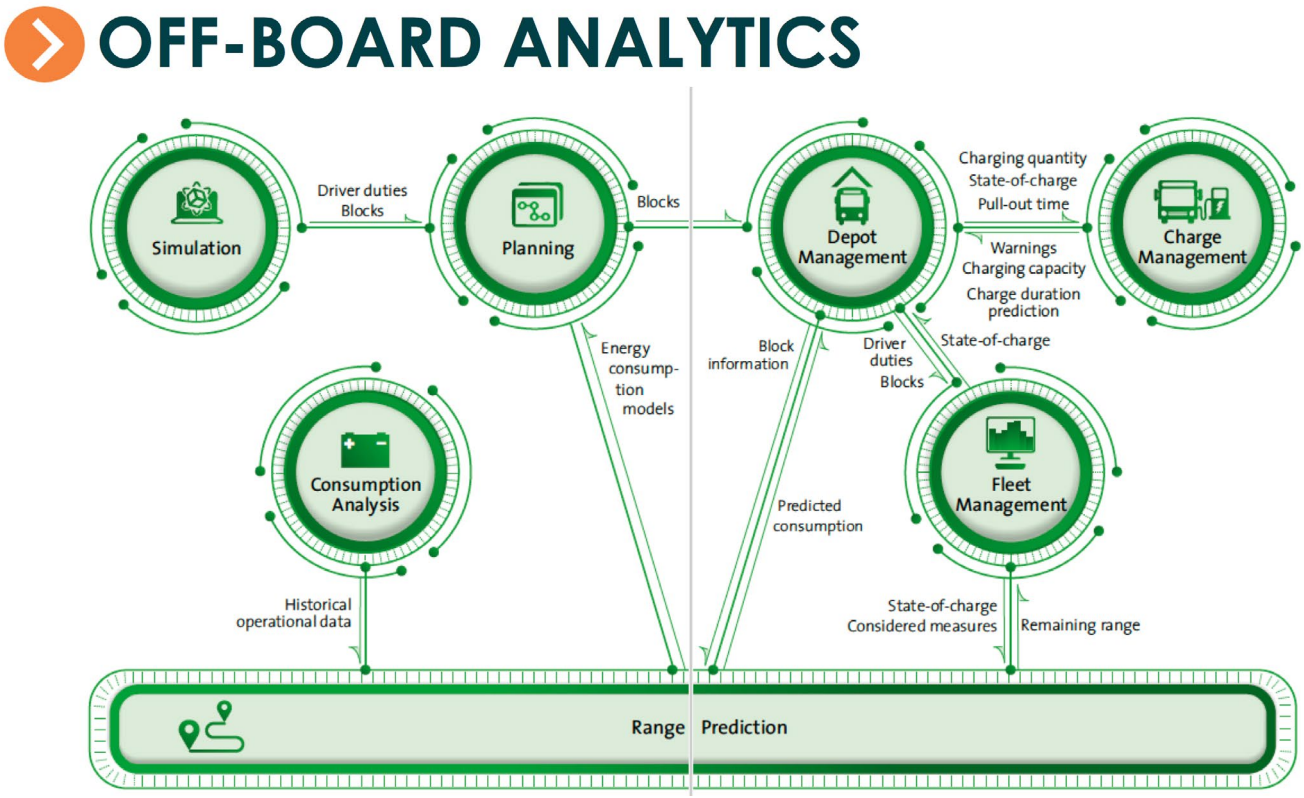
SESSION 2A

Data Monitoring and Performance Evaluation for E-buses

Mr Alok Jain, CEO and MD, Trans-Consult. Ltd, Hong Kong, led the session, discussing the evolution of bus operations from traditional to modern systems with the participants. He discussed the data monitoring and performance evaluation for e-buses covering the technological advancements in modern bus operations, including telematics, vehicle location systems, and fleet management systems. He then focused on e-bus specific components such as the Battery Management System (BMS) and On-Board Diagnostics (OBD) systems, explaining their functions and importance in monitoring battery health, energy consumption, and overall vehicle performance.

He emphasised the importance of data collection and analysis in optimising e-bus operations. He outlined the types of data collected, including vehicle performance, battery health, energy consumption, and fault codes, and explained how this data can be used for service optimisation, maintenance planning, and performance improvement through data mining, statistical analysis, and machine learning algorithms.

Mr Alok also discussed the relevant standards and regulations for OBD systems in different regions, highlighting the role of government agencies in enforcing these standards. He concluded by discussing the importance of IT solutions in managing e-bus operations, including the need for specialised scheduling software to account for charging requirements. He also showcased the potential advantages of multi-storey electric bus depots in enhancing operational efficiency and bus security.



SESSION 2B

Data Monitoring and Performance Evaluation for E-buses

Mr Manpreet Singh Kapoor delivered an insightful presentation on data monitoring and performance evaluation for electric buses in India, drawing from the extensive experiences and innovative solutions developed by Delhi Integrated Multi-Modal Transit System (DIMTS). He highlighted DIMTS's pivotal role in managing bus operations, particularly under Gross Cost Contract (GCC) models. He provided a comprehensive overview of the evolution of electric bus funding schemes in India, tracing the journey from FAME-I to PM-eBus Sewa scheme, detailing the changes in procurement models, subsidy structures, and operational parameters.

Mr Manpreet emphasised the core objectives of electric bus operations under GCC, focusing on the critical implementation of Intelligent Transit Management Systems (ITMS) and Automated Fare Collection Systems (AFCS). He outlined the modern functional requirements for bus operations, such as real-time tracking, revenue collection monitoring, and proactive maintenance scheduling. He showcased DIMTS's specialised IT tools for e-bus fleet management, including the Auto-

DIMTS SPECIALIZED IT TOOLS FOR MANAGING ELECTRIC BUS OPERATIONS

AVLS	AFCS	CMS	Mobile App	BI/ Analytics
• Admin/ Masters • Planning and Scheduling • Tracking • Route Creation • SoS Alerts • CCTV feed • CAN data • Infraction data • Vehicle Health Monitoring data • In-Bus PIS • In-Bus PAS	• Online Revenue Data (Trip-wise/ duty-wise/ route-wise) • Android based ticketing machines • Digital Payments through Mobile Apps, QR code and Wallets • NCMC • Input for Data Analytics and MIS	• Integrated billing software-web based with inputs from AVLS & AFCS Systems • Way bill Submission • CFT • PPTM • Revenue Management	• Mobile App for Commuters • ETA • Journey Planner • Mobile App for Infractions and Incidents • Digital payments for AFCS • Bus Pass Management • Mobile App for ticket checkers	• MIS and Dashboard • Chatbot for Commuters • ML based ETA engine • BI for operation optimization • Whats app ETA and ticketing

mated Vehicle Location System (AVLS), AFCS, Contract Management System (CMS), and Business Intelligence (BI) analytics.

Mr Manpreet detailed the specific data collected from electric bus sensors and elaborated on the various modules of DIMTS's comprehensive IT solutions for e-bus operations management. He concluded with an in-depth discussion of the payment mechanism for operators under GCC, elucidating the factors considered in calculations and the Service Level Agreement (SLA) parameters utilised for performance evaluation and penalty assessment.

SESSION 3A

Resilient and Safer E-bus Ecosystems

Ms Amruta Girish Kulkarni, Technical Advisor E-mobility, GIZ and Mr Jayant Deshmukh, Bus Operation Expert, GIZ conducted the session. They covered three main topics: e-bus depot infrastructure, safe operation and maintenance practices, and emergency response for safety incidents.

They began by discussing e-bus depot infrastructure, which included criteria for site selection, layout design, and area requirements. They provided specific recommendations for depot components such as inspection pits, repair bays, and charging stations, focusing on the safety aspects of operation and infrastructure. They outlined safety requirements for depots, including proper signage, illumination, and risk assessment. They also emphasised safe practices for operations and maintenance, highlighting the importance of understanding high-voltage components and using appropriate personal

protective equipment. The presentation delved into specific maintenance activities, such as pressure washing and welding, providing guidelines to ensure safety when working with electric buses. They also discussed charging safety and the proper use of high-voltage tools and equipment.

Another significant part of the presentation covered emergency response procedures. They provided step-by-step instructions for handling fire incidents, both on the road and in depots. They also addressed the challenges of operating electric buses in flood conditions.

SESSION 3B

Group Activity: Resilient and Safer E-bus Ecosystems

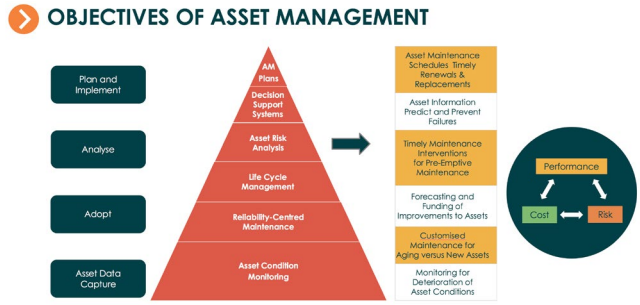
The UITP Team, **Ms Anindita Ghosh, Senior Researcher, Ms Kahini Ojha, Researcher, UITP India, Ms Amruta Kulkarni and Mr Jayant Deshmukh** conducted the group activity. They divided the participants in three groups and gave them exercises focusing on safety and resilience requirements in infrastructure and operations of e-buses. Through the three different scenarios given to three different groups, the aim was to facilitate the participants to brainstorm and present the best solution to ensure safety in the management of e-buses.the idea of multi-storey depots through a video.

KEY SESSION OUTCOMES: DAY 2

SESSION 4A

Asset Management for E-Buses

In this session, **Mr Alok Jain** focused on asset management for electric buses. He covered various aspects of maintenance strategies, the evolution of maintenance philosophies, and the importance of data-driven approaches in asset management. He started by discussing the balance between corrective and preventive maintenance, emphasising the importance of finding an optimal mix of maintenance strategies to ensure high vehicle availability, reliability, and cost-effectiveness.



He traced the evolution of maintenance philosophies from corrective to preventive and predictive approaches, highlighting the growing importance of data in improving maintenance practices and introducing the concept of condition-based maintenance. He then discussed how big data analytics, IoT, and sensor technologies can be used to predict asset performance and optimise maintenance schedules.

Mr Alok also discussed the life cycle management perspective, emphasising the need for a holistic approach to asset management. He outlined key initiatives and frameworks for implementing effective asset management strategies, and delved into the practical aspects of implementing predictive maintenance, including data acquisition, transmission, and analysis. He also addressed the challenges and

benefits of adopting these advanced maintenance approaches.

Finally, the he explored the impact of Industry 4.0 on asset management, discussing the opportunities and challenges it presents. He emphasizes the need for digital transformation in asset management, touching on aspects such as organizational capability, information ownership, and the integration of digital technologies into existing systems.

SESSION 4B

Asset Management for E-buses - International Case Study

Mr Josep E. Garcia presented a session on case studies in asset management for electric buses, covering various aspects of e-bus maintenance, safety, and operational efficiency, drawing examples from different cities and transit agencies worldwide. Mr Garcia discussed fire prevention systems, maintenance practices, predictive maintenance technologies, and driver training programs implemented by various operators to improve the performance and safety of their e-bus fleets.

He first shared the EMT Madrid's approach to fire prevention and extinguishing systems, as well as their innovative methods for maintaining bus roofs. He then explored SBS Transit Singapore's implementation of AI and machine learning-powered predictive maintenance systems, which resulted in a 20% reduction in bus breakdowns. He also detailed Stratio's predictive maintenance solution, which offers remote diagnostics, automated maintenance planning, and real-time monitoring of vehicle conditions. Mr Joseph discussed how these systems can improve operational efficiency through smart mapping and energy consumption tracking.

A significant portion of his presentation focused on driver training and performance monitoring. He introduced the BLEDSYSTEM, a comprehensive solution that combines on-board assistants, a SaaS portal, and gamification elements to improve driver behaviour and operational efficiency.

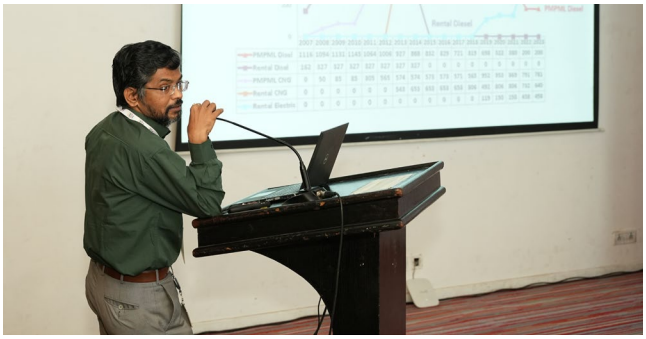
He concluded by sharing case studies from multiple cities in Spain and other countries, showcasing the implementation of these technologies. The results included fuel consumption reductions ranging from 8% to 12% and accident reductions of up to 12% in some cities. These case studies demonstrated the practical benefits of implementing advanced asset management and driver training systems in e-bus operations.

Pune Case Study

Mr Prashant Kolekar led the session. He discussed the management's perspective of asset management for e-buses, sharing PMPML's case study. He covered PMPML's operational details, fleet information, and the gradual phase-out of diesel buses in favour of CNG and electric vehicles, route coverage, fleet size, daily passenger numbers, and future fleet procurement plans.

Mr Prashant highlighted PMPML's commitment to sustainable transportation, focusing on procurement and financing models for e-buses. He compared the pros and cons of outright purchase versus gross cost contract models. He discussed the importance of monitoring and evaluating e-bus operations using key performance indicators and data collection. He also shared the outcomes and prospects of PMPML's e-bus initiative, highlighting the benefits for citizens, including sustainable transportation, enhanced commuting experience, and reduced environmental impact.

Lastly, he discussed the challenges faced by PMPML, including charging infrastructure, financial performance, e-bus supply issues, tender deployment, and operational challenges related to e-buses. He concluded his presentation with PMPML's plans to expand the e-bus fleet and explore advancements in battery and charging technology.



OUTCOMES AND FUTURE PROSPECTS

PMPML plans to expand the E-bus fleet to 750 by 2025, explore advancements in battery and charging technology, and secure continued government support for sustainable urban mobility initiatives.

Sustainable Transportation:	Citizens benefit from a sustainable and eco-friendly mode of transportation, contributing to a reduction in the city's carbon footprint.
Enhanced Commuting Experience	Improved amenities and features provide citizens with a more comfortable and convenient commuting experience, encouraging greater adoption of public transportation.
Affordability and Accessibility	PMPML aims to maintain affordable fares, ensuring the e-bus system remains accessible to a wide range of citizens, promoting inclusivity.
Reduced Congestion	Increased usage of the e-bus system can potentially reduce traffic congestion, leading to smoother traffic flow and shorter commute times.
Emission Reduction	The e-bus system significantly reduces air pollution by eliminating tailpipe emissions, contributing to cleaner air quality in the city. Currently, 473 electric buses are already operational in the Pune Metropolitan Region which has collectively travelled for more than 5.2 Cr. kilometres, and it saves Ton's of Carbon from emitting into environment.
Noise Pollution Reduction	Electric buses operate more quietly than traditional buses, reducing noise pollution and creating a more peaceful urban environment.

VALEDICTORY SESSION

The technical sessions of the training programme concluded successfully with participants engaging in holistic discussions and active interactions, creating the perfect forum for knowledge sharing. The UITP team collected feedback from the participants to help design future training programmes. In the valedictory session, Ms Rupa Nandy addressed the participants, presented mementos to the trainers, and awarded certificates of participation to the trainees.

TECHNICAL VISIT

The two-day training programme concluded with a technical visit to Baner Depot in Pune, organised with the support of PMPML. The objective of the technical visit was to provide participants with practical exposure to the e-bus depot layout, the functioning of the charging infrastructure, and the features of e-bus.

The trainees travelled in the PMPML e-bus for the technical visit. **Mr Prashant Kolekar**, Electrical Engineer, PMPML, highlighted the technical details of the depot and the safety aspects present and required. He discussed the resilient e-bus ecosystem points covered during the training. detailing the electrical infrastructure available at the depot, including the metering kiosk, package substation, and different e-bus chargers. He also demonstrated the chargers, both AC and DC, explaining their types, power capacities, connector gun types, bus battery placement, and PMPML's practices for battery longevity.

Mr Rajesh Kudale, Depot Manager, PMPML shared the layout of the depot, showing the bus parking and charging bays. He guided the participants through the depot workshop area and explained the maintenance practices in the depot, including routine, inspection, corrective, and predictive maintenance. He then explained to the participants the bus mileage, charging time, various charging modes, and charger capacity.

This is an official Report of UITP, the International Association of Public Transport. UITP has more than 1,800 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.

This Report was prepared by UITP India.

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UITP ADVANCING PUBLIC TRANSPORT

Rue Sainte-Marie 6, B-1080 Brussels, Belgium | Tel +32 (0)2 673 61 00 | Fax +32 (0)2 660 10 72 | info@uitp.org | www.uitp.org