Evolution and Future of Metro Technology

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Today's metro systems have root stretching back to 1862[1], when the first subway of today's London Underground started running. Since then, metro systems, their infrastructure and vehicles have been further developed and continue to evolve in line with today's expanding cities.

Passengers view public transport as part of a sustainable lifestyle and an attractive alternative to private transport such as cars, but demand that it be fast, safe, reliable and comfortable.

To attract and retain patrons, operators must continue to enhance the passenger experience, providing features such as comfortable seating, multi-purpose areas for those with limited mobility or bulky items, onboard Wi-Fi and real time information about train location and timetable and entertainment. Security features such as silent alarms, CCTV and clear, open sightlines keep travelers safe, while features such as programmable lighting can assist passengers in finding their way. Bombardier Transportation offers, and is actively developing, a wide range of solutions for state-of-the-art passenger transportation.

For example, the BOMBARDIER SPACIUM commuter train in Paris has LED lighting that is white while at stations but turns into other colors during the journey. Operators, designers and engineers constantly work hand in hand to develop an attractive interior and exterior design, such as for the BOMBARDIER MOVIA Metro C30, for Stockholm in Sweden. The vehicle features a customized, attractive and bright interior, which has been adapted to the city's needs and image.

For asset owners and operators, balancing passenger requirements and optimizing whole of life asset cost is essential for profitability – an increasing challenge as fleets cover ever-greater distances in operating environments with stringent requirements for reliability and availability.

Automated Operation is Essential

For operators of mass transit systems, capability for automated operation is almost obligatory. Rolling stock that operates in driverless mode reduces the human

capital cost of operations but-more importantly-underpins fast, frequent and reliable services and the ability to immediately respond to changing traffic demands during the day. Driverless metro applications are now proven around the world, with strong safety records over the long term.

Today's signaling and train control systems support headways as short as 60 seconds, with tight integration between rolling stock and signaling equipment. Metro de Madrid, after upgrading Line 1 to current generation BOMBARDIER CITYFLO 650 Communication-Based Train Control (CBTC) technology, increased line capacity by 40%. Similar gains were made following the upgrade of Line 6.

CBTC supports attended or unattended operation. In attended operation, it can dramatically reduce driver-initiated emergency braking, providing better service to passengers and reducing wear and tear on brake systems. The CITYFLO 650 signaling systems support 99.98% or higher reliability, as demonstrated on Tianjin Metro Lines 2 and 3, and numerous projects around the globe. Currently, 18 lines are in service with CITYFLO 650, with 11 more lines in delivery.

Radio-based CBTC also dramatically reduces the required wayside equipment-such as track detection units – in turn reducing capital and maintenance costs.

CBTC and integrated train-to-wayside solutions also provide real time monitoring with transmission of diagnostic data to the operations control center. Operations control centers are increasingly sophisticated, enabling automated train supervision data display to a video wall and/or operator workstations, and the ability for central control from one or more operator workstations. Real time monitoring and predictive analysis help to head of problems before they occur, supporting improved service delivery.

CITYFLO 650 CBTC solution for Klang Valley MRT project, Malaysia

Flexibility Across Fleet Life

In the quest for best value, rolling stock owners and maintainers look for flexibility that supports changing requirements across a fleet's life. For example, rail cars that support internal reconfiguration to change carrying capacity allow operators to overhaul rather than replace a fleet as needs change.

Fleet life extension through refurbishment and upgrade are also a critical part of the value equation. Examples of refurbishment include replacing internal features) passenger saloon or driver's cab equipment), external livery or systems such as onboard energy storage or cap front ends. A recent example of fleet life extension is the modernization of Sao Paulo's Metro Line 1 fleet. A total of 26 six-car trains from the 1970s were completely modernized with new exterior and interior design, passenger information systems, HVAC and new energy-efficient propulsion equipment.

Robust obsolescence management also keeps fleets in service longer, with progressive change out of older systems for new.

Initiatives such as these allow asset owners and operators to benefit from the development of new technologies without the need to replace existing fleets.

Energy Efficiency

This ability to take advantage of new technologies on existing fleets is critical in areas such as energy efficiency, where technologies that reduce energy use, for example by using energy generated by regenerative braking, are advancing rapidly.

Technologies that reduce energy consumption typically have a rapid return on investment from the savings in energy cost. Sophisticated energy consumption modeling provides clear comparative analysis to assist with the cost benefit calculation.

Energy consumption modeling is also an essential part of the design process, to understand and optimize vehicle energy use for the actual environment in which it will be operating. Early engagement through the procurement process with asset owners and eventual operators provides the best opportunities to have design decisions drive best overall lifecycle cost. The total lifecycle cost of rolling stock over its commercial life is typically several times the initial capital cost. This means that even small initial investments to enhance lifecycle performance deliver large return on investment over the vehicle's life.

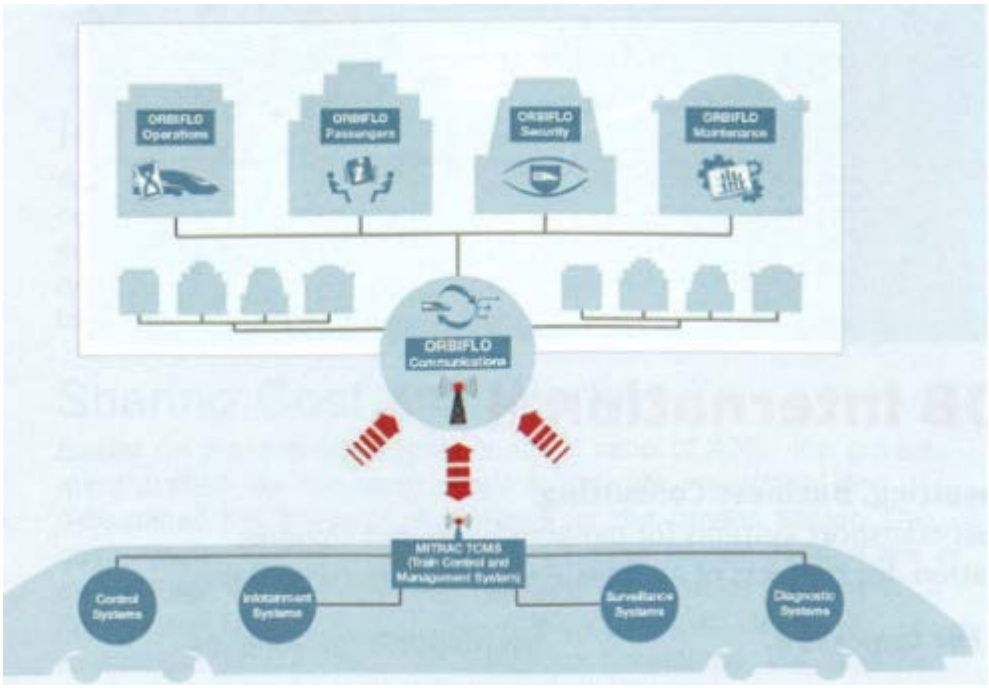
The reduction of the energy consumption of today's state-of-the-art metro fleets can use up to 70%[2] less energy than 1970s metro fleets, with key contributors to fleet energy efficiency including:

- Lower weight – rolling stock manufactures continually strive to lighten total vehicle weight – key components that contribute to lowering weight are today's lightweight bogies such as the BOMBARDIER FLEXX Eco inboard bearing bogie, carbodies and different subsystems
- Higher efficiency propulsion systems, such as BOMBRDIER MITRAC permanent magnetic motor
- State of the art traction equipment which is more energy efficient and provides better control of the train
- Design–time analysis of the customer's operating environment and infrastructure, to optimize componentry and configuration to deliver best operational performance
- Thermos– efficient HVAC and intelligent train control heating, ventilation and air conditioning systems are energy hungry, depending on local climate and operating conditions and requirements. In severe climates keeping trains powered up to keep passenger compartments warm or cool can be costly. Remote monitoring and start–up of heating or cooling systems means operators no longer

need to waste energy by keeping their trains powered up continuously overnight to ensure a punctual start. Intelligent train control systems also allow remote management of non–safety related parameters such as air–conditioning set–point temperatures, meaning these can be adjusted in response to seasonal conditions.

- Aero–efficient exterior train design with more streamlined designs using innovations such as bogie skirts, can reduce aerodynamic drag and therefore reduce energy use especially for running speeds higher than 100 km/h.
- Onboard or wayside energy storage solutions such as the MITRAC Energy Saver and the EnerGStor solutions, which store and recycle braking energy.

Fully Automated MOVIA Metro for Singapore's Downtown Line



ORBIFLO Wayside Management System

Bombardier Transportation offers a set of eco-efficient and energy-efficient technologies which form part of the ECO4 portfolio, proven in light rail vehicles, metros, mainline and high speed trains and locomotives applications worldwide.

Today's fleets also produce significantly less waste heat, which has flow on effects including substantial energy savings in cooling enclosed operational environments including tunnels.

Rolling stock manufacturers are now producing a variety of materials that describe the energy efficiency and other environmental credentials of their vehicles. These materials typically include ISO 14040-compliant life cycle assessments and Environmental Product Declarations. In this field, Bombardier Transportation has a leading position as it has published the first Environmental Product Declaration in the railway industry in 2009 and continues to have published more EPDs than any other rolling stock supplier.

Maintenance Expands Across the Whole Network

More operators globally are tendering fleet maintenance, or sometimes both operations and maintenance, to specialty providers who can deliver the high levels of reliability, maintainability, availability and safety (RAMS) required for modern fleets.

Adelaide EMU Fleet Maintenance, Australia

This can represent a continuum of responsibility and risk sharing. BOMBARDIER ORBITA fleet management tool offers such services and is successfully implemented in many fleets worldwide.

Maintenance today encompasses both preventative and reactive maintenance, with a strong trend towards the former which is enabled through Bombardier's ORBIFLO software. It offers health monitoring, automatic inspections, supporting operators in developing robust predictive maintenance regimes. Even reactive maintenance is reduced with intelligent onboard monitoring that provides data that allows maintainers to predict future points of failure and remediate them before they cause in-service failures.

In fact, maintenance is no longer simply about the fleet, but now spans the entire operating environment including signaling and track. This makes sense, as the infrastructure maintenance itself becomes more critical as:

- Time windows for maintenance decrease due to longer hours of operational service
- Contractual requirements for performance become more stringent, and penalties for failure higher.

Advancement in Fleet Support Services such as Wheel/Rail Optimization Studies can offer significant reductions to operators. A recent Bombardier customer applying the results of such a study achieved in-service reduction of gauge face rail wear from

3 mm to 0.2 mm per year, and reduction of wheel flange wear form 0.4mm to 0.03 mm per 1000km.

Onboard track monitoring systems such as the FLEXX track equipment can collect data on track torsion, vertical track disturbances, rushes at joints and switches and rail ripples while in normal operation, and analyze it to identify track deterioration over time, providing a rich source of information to support infrastructure maintenance.

The combination of track monitoring and intelligent maintenance can reduce or eliminate common issues including:

- Wear on rail and wheel
- Noise development
- Sinusoidal rail wear
- Corrugation
- Polygonisation
- The risk of rolling contact fatigue (RCF).

Fire Protection and Simulation

Protection against fires is gaining increasing importance for owners and operators, especially for trains operating in tunnels. Tanks to high-end simulation tools, fire spread, heat release, temperatures, smoke and toxic gases can be modeled. The results drive safer vehicle design and improved material choices to achieve higher fire resistance, and ease the homologation process for railway fleets.

Together, these and other metro technologies of today and tomorrow represent the future of sustainable mobility for which Bombardier Transportation is offering fitting technology solutions.

1 source: www.telegraph.co.uk/“The-history-of-the-Tube-in-pictures-150-years-of-London-Underground”

2 Given the following boundary conditions: waste heat analysis for 1.9 km tunnel track section simulation comparing a 1970s metro vehicle without HVAC and with no regenerative energy capture to a state-of-the-art metro vehicle with permanent-magnetic motors, saloon HVAC and regenerative braking.