One day workshop on Mumbai Monorail: Release

India's first Monorail has started in Mumbai recently. The Monorail fits into the urban transit gap between the low capacity road transportation and very high capacity Metro systems. It also acts as feeder to Metro and suburban system for large cities, and main mode for medium and small cities.

In order to disseminate and exchange the information about the various aspects of Monorail, a one day workshop was organised by Ministry of Urban Development (MoUD) and Mumbai Metropolitan Region Development Authority (MMRDA) on 22nd March, 2014 at the Hotel Trident, Bandra-Kurla Complex.

Dr.Sudhir Krishna, Secretary, MoUD Chaired the entire proceeding.
Shri. C.K. Khaitan, Jt. Secretary, MoUD, Shri. U.P.S. Madan, Metropolitan Commissioner, MMRDA, Shri. Manu Kumar Srivastava, Principal Secretary, UDD, Govt. of Maharashtra, Shri. Pyaraelal, Addl. Chief Secretary to Govt. Assam Urban Development and Guwahati Development Department, MrD.B.Gupta, Principal Secretary to Urban Development and Housing Govt. of Rajasthan and Shri. Braj Kishore Prasad, Principal Secretary of Transport, Govt. of TN and other senior Govt officials of various organizations such as Metro Rail Corporations of Delhi, Chennai, Kolkatta, Hyderabad, Jaipur, Gurgaon and Kochi, Chennai Mono Rail, Bangaluru Airport Rail link, Guwahati Metropolitan Development Authority and representatives of Govt. of MP and Gujarat, have attended the workshop.

The Monorail Rolling Stock suppliers M/s. Hitachi, Bombardier, Scomi and Alstom made presentations on their systems.

Dr. BI Singal, DG, Institute of Urban Transport (IUT) India made a presentation on comparative analysis on various alternative public Transport Systems which gave an insight in making a considered Choice of System for given urban setting.

The issues pertaining to planning, implementation, operation, technology, legal framework, standardisation, Security, certification and prospects of Monorail in other Indian cities were deliberated during the workshop.

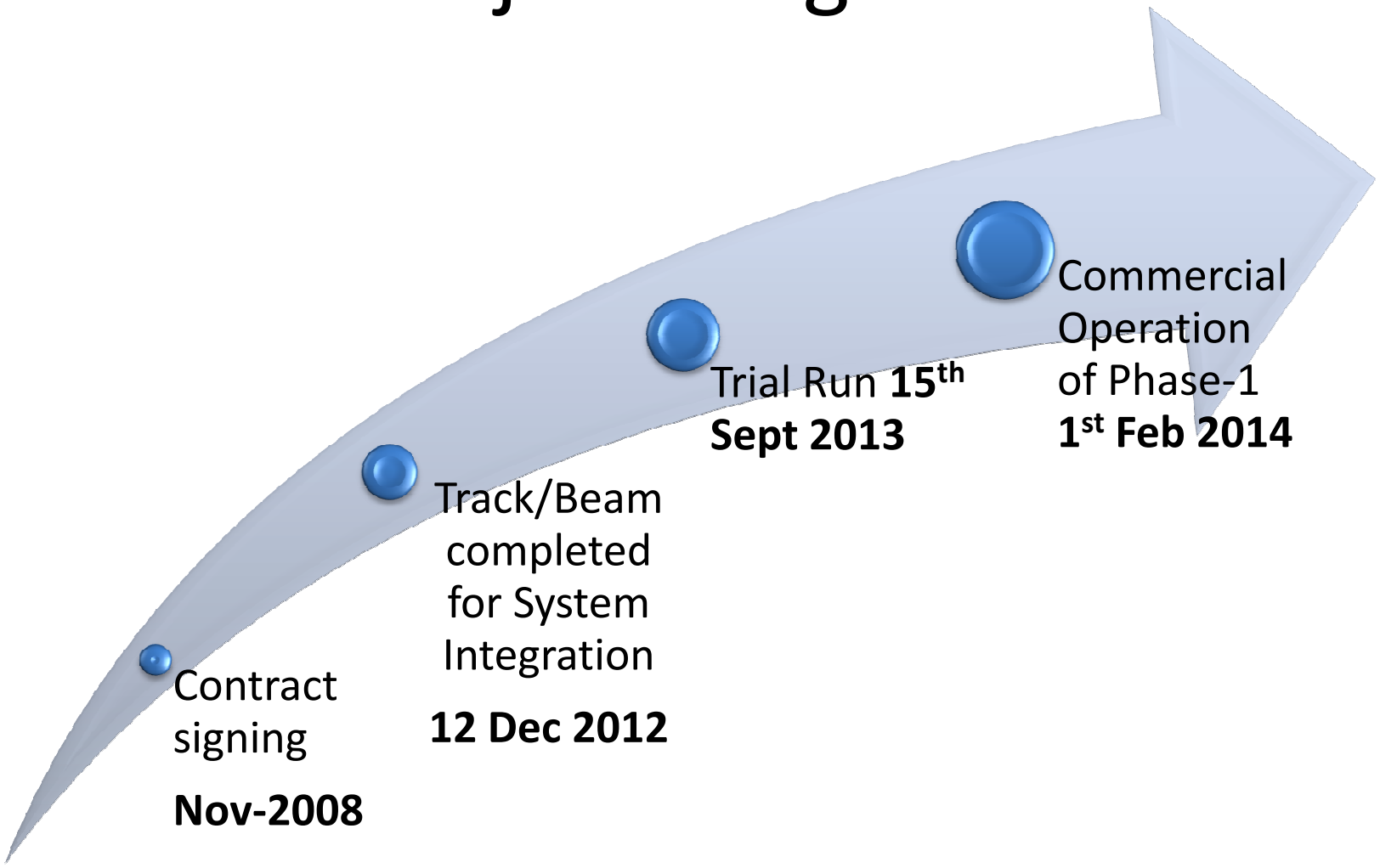
Later the delegates were taken for Mumbai Monorail ride from Wadala to Chembur and a technical tour of terminal-2 (T2) of International Airport.

Photographs:


One Day Workshop on
Mumbai Monorail
22nd March, 2014

MUMBAI MONORAIL EXPERIENCE
(India's First Monorail)

Project Progress



Contractors: LTSE (Larsen & Toubro Limited & Scomi Engineering Bhd. Consortium)

Cost of the Project

TOTAL	100%	2460 Cr.*
Civil work, Depot, Stations	**39%**	**960 Cr.**
Signaling & Telecom	**17%**	**418 Cr.**
Traction and Power supply	**10%**	**246 Cr.**
Rolling Stock	**20%**	**492 Cr.**
Designs, Supervision, Testing and Integration	**14%**	**344 Cr.**

*without taxes

Salient features

- Length of Corridor:
  - Phase 1 = 8.8 km (Wadala – Chembur)
  - Phase 2 = 11.2 km (Jacob circle – Wadala)
  - Total = 20 km with 17 Stations and a Depot of 6 Hect.

	2016	2031
• Peak hour peak direction traffic	7,400	8,300
• Corridor Ridership per day (in lakhs)	1.25	3.00
• Design Headway	3 minutes	
• Train Composition	4 cars (with option for 6 cars)	

Salient features - Continued

- Train Capacity (4 cars) — 568 Max (872 with 6 cars)
- Design Speed — 80 kmph
- Scheduled Speed — 31 kmph
- Operation Hours — 0500 Hrs - 2400 Hrs
- Journey Time
  - Phase 1 — 19 minutes
  - Phase 2 — 25 minutes
  - End to end — 45 minutes

Alignment

Phase -1 : Wadala – Chembur
Length : 8.8 km
Stations: 7

Phase -2: Jacob Circle – Wadala
Length : 11.2 km
Stations : 10

Station – Elevation

Station – Concourse

Station – Platform

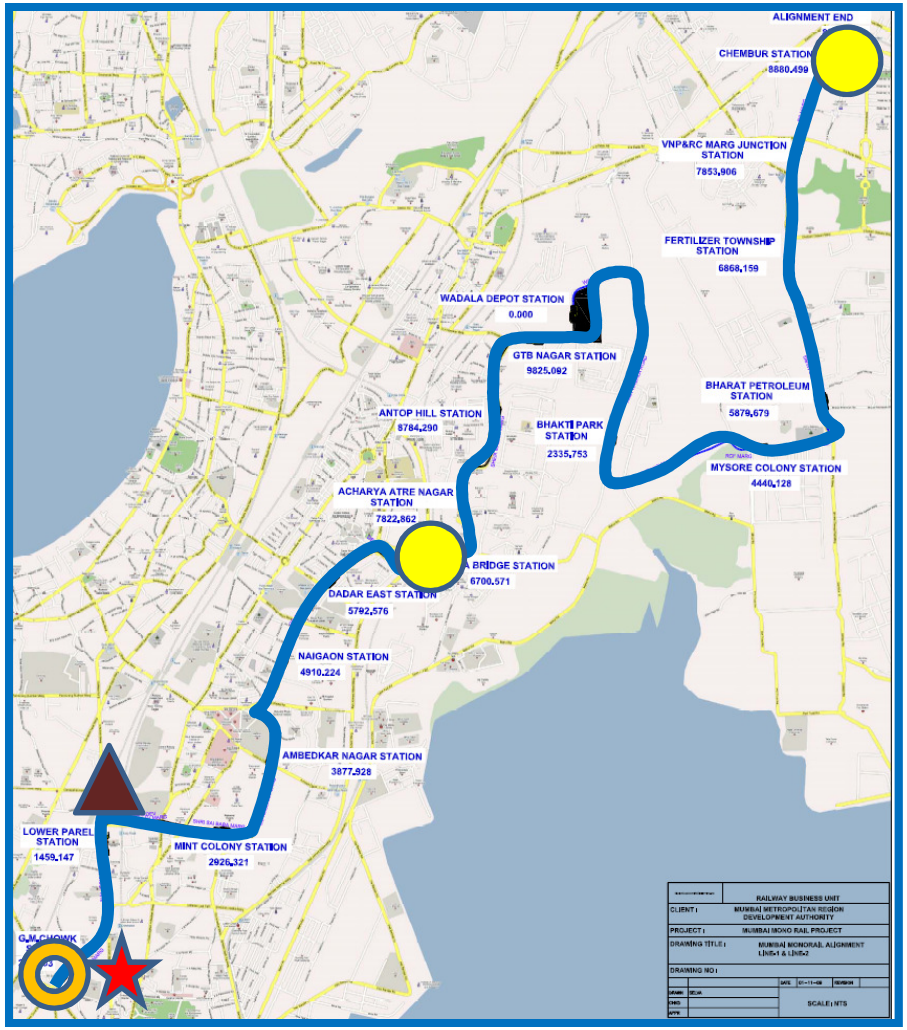
AFC

Station – Concourse Lobby

Rolling Stock

Train Interiors

Multi modal Integration



- Integration With Western Railway and Metro Rail at Jacob Circle
- Integration with Central Railway at Curry Road junction
- Integration with Harbour line at Chembur and Wadala

Western Railway

Central Railway

Harbour Line

Metro rail

Benefits

- Faster connectivity from Jacob Circle to Wadala and Chembur

  (Reduces travel time by half as compared to BEST bus)

- Eco friendly, Faster, Comfortable and Safe ride

  (Level floor boarding, Air conditioned comfort, Large viewing windows and Aesthetically attractive trains)

- Connects areas not currently well connected with any public transport

- Usage - 1.8 lakh passengers per day.

- Population benefitted - 15 to 18 lakh

Suitability Criteria

- Traffic intensity – low to medium
- Right-of-way availability – narrow stretches
- Need to negotiate sharp curves and steeper gradient
- Feeder service to Metro and Suburban systems
- Faster transit connectivity – compared to bus
- Advantages like small visual impact; no obstruction to light, wind or fumes from traffic; highly secure; very difficult for public access

Congested & Curved

Sharp curve (Radius 150 M)

Challenges During Construction

- Civil work of highly accurate quality guideway beams
- Underground utilities along the alignment
- Overhead transmission lines
- ROW for track, entry/exit, substations etc. and Resettlements of PAP's
- Crossing of existing railway tracks
- Interface with different agencies
- Restricted working hours

Utilities Issues

- No accurate information on utilities by concerned agency
- Change of designs continuously
- Shifting utilities if necessary

Utilities Issues

ROW Issues

ROW Issues


Ambedkar Nagar


Ambedkar Nagar - Chawl
31/07/2009

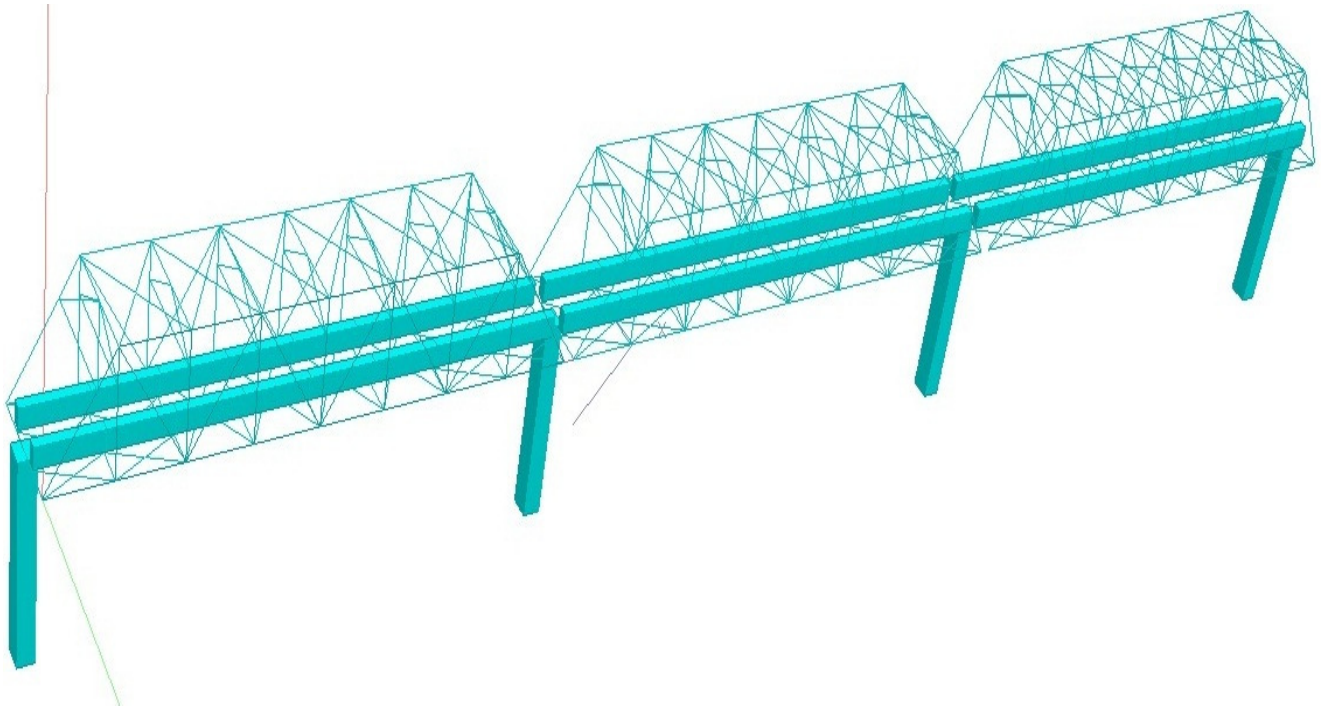

Acharya Atre Nagar

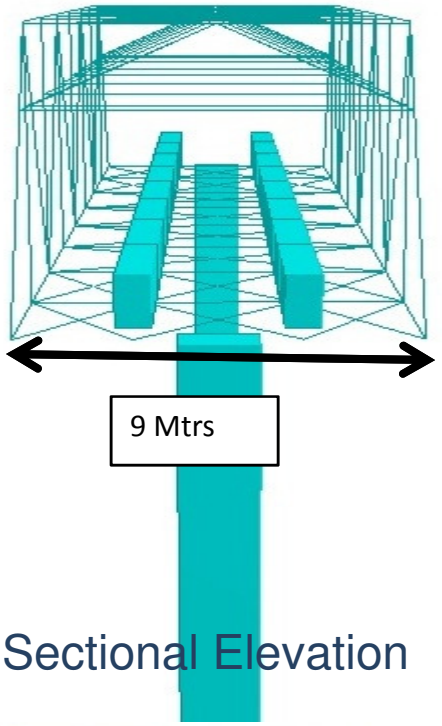

Ambedkar Nagar


Ambedkar Nagar
31/07/2009

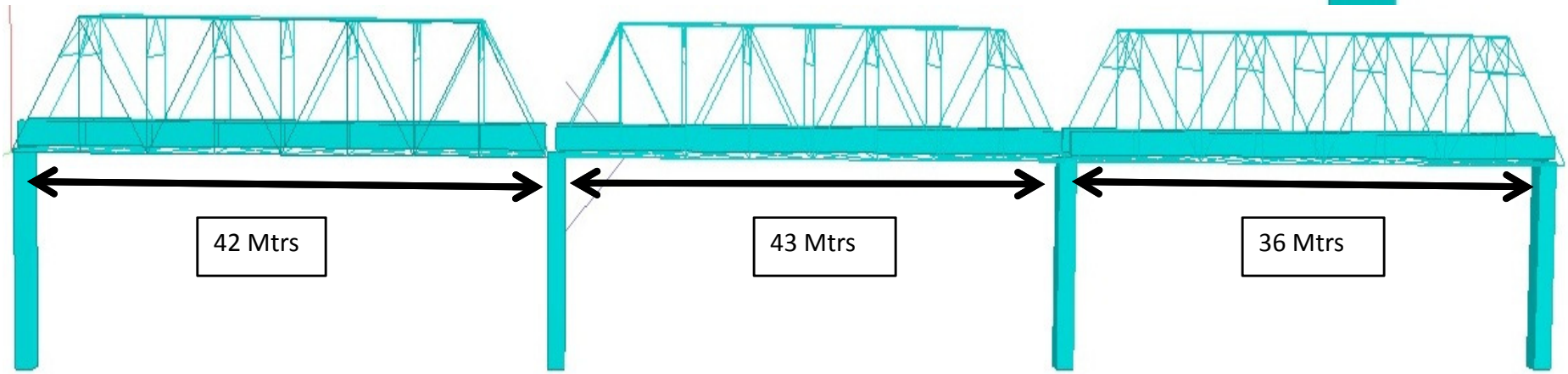
Railway Crossing (Obligatory Span)

Wadala Bridge Obligatory Span





Sectional Elevation



Challenges in Operation

- Availability and training of the work force – no prior experience in India
- Security concerns of Home Ministry – unbearable cost & requirement of additional space
- Station size and expectations of passengers
- Restricted approach to guideway beams
- Requirement of elevators and platform screen doors and their maintenance

Success?

- Real success can be determined only after the entire stretch of 20 kms is completed
- Technically sound system
- Excellent acceptability by public
- Per capita security cost is prohibitive and can make it unviable
- Per capita O&M cost is also high and is therefore a concern

THANK YOU

Life cycle cost analysis of mass rapid transit modes

STUDY BY

Institute of Urban Transport India

Status of Monorail

- While Monorail is a common sight in amusement parks around the world, its use for public transport is rather limited e.g. Mumbai , Chongqing, Kuala Lumpur & Las Vegas, Seattle, and Sydney.
- In India, Kozhikode and Delhi have the DPR ready. Trivandrum, Bangalore and Chennai have monorails under consideration.
- Monorail looks futuristic. It is best suited to congested areas because it does not require a deck like the Metro Rail and LRT.
- Hence, it does not block air and light underneath.

Tokyo monorail

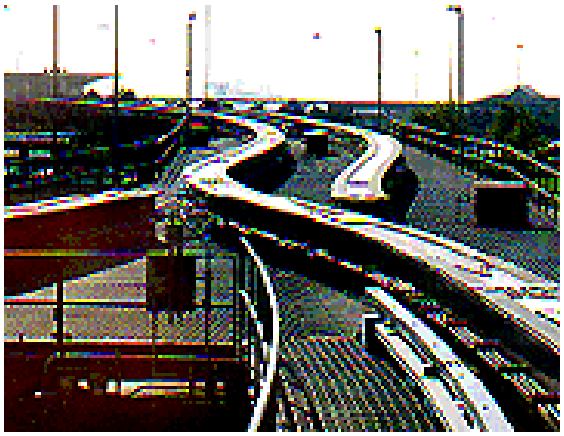
Seattle monorail

Sydney monorail

Issues with Monorail

- Three main reservations are:
  - Switching mechanism
  - Emergency detraining
  - High cost compared to Metro rail and Light Rail
- Proponents of Monorail make light of the first two issues and feel that solutions are available
- High cost perhaps is true, but a ‘life cycle cost’ analysis is needed for a proper comparison

Switching



Footpath for emergency

Choice of mode

- Choice of mode should not be based on initial cost only
- Ongoing operation, maintenance, repair and replacement cost should be taken into account
- For example the life of a bus is 10 years while that of Light Rail Vehicle is 30 years
- Capacity of a bus is 80 persons and that of a Light Rail Vehicle 250
- This gives an overall advantage to LRT by a factor of 9 apart from energy and environment benefits

Life Cycle Cost analysis

- IUT has assessed the life cycle cost of 6 alternative modes of PT e.g., Metro Rail, Monorail, LRT (Elevated), LRT (At grade), BRT and city bus service.
- This presentation compares the life cycle cost of these alternative modes of MRT
- The results of this analysis are presented

Features of MRT Modes

- **Metro rail: I**ntra-city mode that may be underground or elevated, but seldom at-grade. It requires flat curves (About 300 m) and moderate gradient (3%)
- **Commuter rail** serves suburbs and is primarily at-grade. It also requires flat curves (About 300 m) and low gradient (1-2%)
- **Light rail** may be at-grade or elevated. It essentially operates at-grade mixed with road traffic, may have road level crossings, alignment may have sharp bends (25m), steep gradients (6%) and signaling may not be provided.
- **BRT: A**t-grade in physically separated lanes in the middle of the road.
- **Monorail** is rubber tyred which is essentially elevated is less intrusive than other elevated modes, may have sharp curves (70m) and steep gradients (6%).
- **HSST** is a mag lev system, **Linear Metro** cuts down the tunnel size from 5.8 m to 4.0 m, automated guideway transit **(AGT)** and automated people mover **(APM)** are rubber tyred guided systems. Several similar modes have been developed in Europe and the USA as well.

Features of MRT Modes

Mode	Used as	Grade separation Needed or not	Curves Negotiability	Gradient Negotiability
METRO RAIL	Intra-city	Grade separated	300m	3%
COMMUTER RAIL	Suburban	At-grade	300m	1-2%
LIGHT RAIL	Intra-city	At-grade or Grade separated	25m	3%
BUS RAPID	Intra-city	At-grade generally	Road bends	3%
MONORAIL	Intra-city	Grade separated	70m	6%

- BRT, LRT and Monorail can go round sharp road bends and hence reduce the need for property acquisition.
- Monorail can in addition negotiate steep gradients hence reduce the need for long ramps.
- Between these 3 modes, Monorail is elevated while BRT and LRT are at grade modes.

Basis for Cost Assumptions for LCC analysis

S no.	MODE	CAPEX	OPEX
1	Metro rail	Delhi Metro Phase III	Delhi Metro rail
2	Monorail	DPR assumptions of Kozhikode and some interpolations	Delhi Metro Rail cost discounted by 25%
3	LRT at-grade	DPR for a 45 km stretch in Delhi.	Delhi Metro Rail cost discounted by 25%
4	LRT elevated	DPR for a 45 km stretch in Delhi.	Delhi Metro Rail cost discounted by 25%
5	BRT	Delhi, Ahmedabad and Rajkot	Data compiled from CIRT journals,
6	Bus services	infrastructure development cost of DTC for the CWG 2010	Data compiled from CIRT journals,

CAPEX and OPEX of modes

S no.	Mode	Capex Rs cr. per Route km (2011-12)	Opex Rs. Crore per Route km per annum	SOURCE
1	Metro rail (elevated)	182.05	8.8 (2016-17)	CAPEX DMRC, Hyderabad and Kochi O&M time series of DMRC.
2	Monorail (elevated)	214.27	7.2 (2016-17)	CAPEX Kozhikode, Delhi and Mumbai O&M first year of Kozhikode
3	Light rail (elevated)	159.25	6.05 (2016-17)	CAPEX Delhi LRT escalated to 12-13 O&M based on Elevated Monorail
4	Light rail (At grade)	107.36	6.5 (2016-17)	CAPEX Delhi LRT escalated to 12-13 O&M based on Monorail
5	BRT (At grade)	27.38 (Incl. bus)	14.9 (2014-15)	CAPEX Ahmedabad, Rajkot O&M DTC, BEST, BMTC, MTC + OCC
6	BUS (At grade)	17.67 (Incl. bus)	16.3 (2014-15)	CAPEX as per WGUT for 12th FYP O&M Cost for DTC, BEST, BMTC, MTC

Financial Assumptions

- Various financial assumptions for both development and O&M stage are elaborated below:
  - Taxes and duties at prevalent level
  - Escalation at 5%
  - 10% discount rate
  - For rail-based systems the debt equity ratio adopted is 70:30 and debt repayment period has been assumed to be 15 years.
  - The ratio chosen for bus-based systems is 70:30 but the debt repayment period has been assumed to be 10 years.
  - Depreciation has been charged at different rates for different components of the systems at a uniform rate across the life-cycle of the urban transport systems

LCC in the hypothetical case

LCC per seat (in INR Lakh) at NPV for the assumed lifespan of 30 years for a hypothetical case of a 20 km corridor with a phpdt of 15000

Mode	Number of Seats	LCC (NPV in INR Crore)	LCC per seat (in INR Lakh)
Metro Rail	25,300	7,792.49	30.80
Monorail	27,264	7,676.58	28.16
LRT (Elevated)	28,072	6,539.18	23.29
LRT (At Grade)	30,008	4,578.65	15.26
BRT	29,600	5603.06	18.93
Buses	33,040	5,727.82	17.34

LRT (At Grade) has the least LCC of Rs 15.26 lakh.
The LCC of both bus (Rs 17.34 lakhs) and BRT (Rs 18.93 lakhs) is higher.
Monorail and elevated LRT are cheaper than Metro rail

Moderating the hypothetical case

- The findings from the hypothetical case need to be moderated because;
- Bus with a capacity of 80 persons operating at 1 minute headway can carry a maximum of 4,800 phpdt and not 15,000 phpdt as assumed in the hypothetical case
- Metro rail is a very high capacity mode >15000 phpdt
- BRT capacity in most cases may be <15000 phpdt
- Elevated LRT could be >15000 phpdt
- Hence LCC has been calculated at different phpdt e.g.
- demand or usage level

LCC per seat in INR Lakhs

PHPDT	Metro Rail	Monorail	LRT (Elevated)	LRT (At Grade)	BRT	City Bus
3000	91.56	75.26	79.98	41.03	25.49	17.93
5000	64.12	52.88	53.66	28.59	22.13	17.89
7000	50.41	41.88	41.51	23.58	20.91	17.59
10000	40.17	34.62	31.09	18.77	19.79	17.41
12000	35.29	30.98	27.58	17.06	19.37	17.33
15000	30.80	28.16	23.29	15.26	18.93	17.34
20000	25.22	24.97	19.95	13.57	18.58	17.25
25000	21.59	23.06	17.64	12.51	18.27	17.26
30000	19.77	21.74	16.10	11.81	18.14	17.21
35000	18.04	20.85	14.96	11.35	17.98	17.20
40000	17.09	20.19	14.15	11.01	17.93	17.18
45000	16.31	19.69	13.52	10.73	17.84	17.19
50000	15.48	19.28	13.02	10.49	17.80	17.20

Life cycle cost comparison

- LRT (At grade) < BRT at 10000 phpdt
- LRT (At grade) < City bus at 12000 phpdt
- LRT (At grade) and LRT (Elevated) less costly than Metro/LRT/Monorail at all phpdt levels
- Monorail < Metro rail up to 20000 phpdt
-

Conclusion

- Metro rail is high capacity mode and would be uneconomic if used for corridors with low future demand. Perhaps only a few cities in India will need Metro rail.
- Most Indian cities are urban sprawls and medium capacity modes i.e. BRT, LRT and Monorail should be adequate.
- BRT is low initial cost but high in life cycle cost when compared to LRT. The choice between BRT and LRT for a specific location should be based on a proper ‘alternates analysis’ taking various factors into account including externalities i.e. energy and pollution aspects.

Thank You

Moderating the hypothetical case

- The hypothetical case has been analysed further to bring it closer to reality in two steps;
  - The LCC of various modes has been calculated at different phpdt levels i.e. demand or usage levels
  - The impact of variation in carrying capacity of each mode
  - The limiting capacity of each mode depends on the number of coaches or buses and the frequency of service

Impact of Capacity Limitations

System	No. of Coaches in the Train	Train Set Capacity	Maximum PHPDT	LCC per seat (in INR Lakh)
Metro Rail	4	1100	26,400	21.30
	6	1650	39,600	17.03
	8	2200	52,800	15.07
Mono Rail	3	384	9,216	36.38
	6	768	18,432	25.80
	9	1,152	27,648	22.28
Light Rail elevated	2	484	11,616	33.01
	4	968	23,232	19.10
Light Rail At-grade	2	484	11,616	19.90
	4	968	23,232	13.23
BRTS	1	80	8,000	26.65
	2	160	16,000	24.99
Ordinary Buses	1	80	4,800	17.99

Headway for Rail Based Systems has been assumed at 2.5 minutes, whereas for BRTS it has been assumed at 0.6 minutes and for Ordinary Buses at 1 minute.

LCC for Monorail and LRT fall substantially in comparison to Metro rail, BRTS and Bus Service

Findings with Capacity Limitations

- Headway for Rail Based Systems has been assumed at 2.5 minutes, whereas for BRTS it has been assumed at 0.6 minutes and for Ordinary Buses at 1 minute.
- LCC per seat (in INR Lakh) at NPV for the assumed lifespan of 30 years
- It is noted that with the increasing mode capacity and hence PHPDT, LCC for Monorail and LRT fall substantially in comparison to Metro rail, BRTS and Bus Services

INNOVIA Monorail 300 system

Workshop on Monorail at Mumbai

Ministry of Urban Development

Sushil K. Jaitly
Head – Systems / India

Transportation Systems
Bombardier Transportation

March 22, 2014

BOMBARDIER
the evolution of mobility

Agenda

1. Introduction to Bombardier
2. *INNOVIA* Monorail 300 system
3. Case study: *INNOVIA* Monorail 300 system for São Paulo

Bombardier
OVERVIEW

- World's only manufacturer of both planes and trains
- Worldwide workforce of 76,400[1] people
- Headquartered in Montréal, Canada
- Shares traded on the Toronto Stock Exchange (BBD)
- Listed on the Dow Jones Sustainability World and North America indexes
- Fiscal year ended December 31, 2013: posted revenues of $18.2 billion USD

[1] as at December 31, 2013 (includes 200 employees at our corporate office in Canada)

Bombardier Transportation: products and services

THE BROADEST PORTFOLIO IN THE RAIL INDUSTRY

Rail Vehicles

- Light rail vehicles
- Metros
- Commuter trains
- Regional trains
- Intercity trains
- High speed trains
- Locomotives

Transportation Systems

- Driverless Systems: Monorails, Metros, People Movers
- Light rail systems
- Metro Systems
- Intercity Systems
- E-mobility Solutions
- Operations and Maintenance

Services

- Fleet Management
- Asset Life Management
- Material Solutions
- Component re-engineering and overhaul

Rail Control Solutions

- Integrated control systems
- Automatic train protection and operation
- Interlocking systems
- Wayside equipment
- Services

Propulsion & Controls

- Traction converters
- Auxiliary converters
- Traction drives
- Control and communication

Bogies

- Portfolio to match entire range of rail vehicles
- Full scope of service over the lifetime of a bogie

BOMBARDIER
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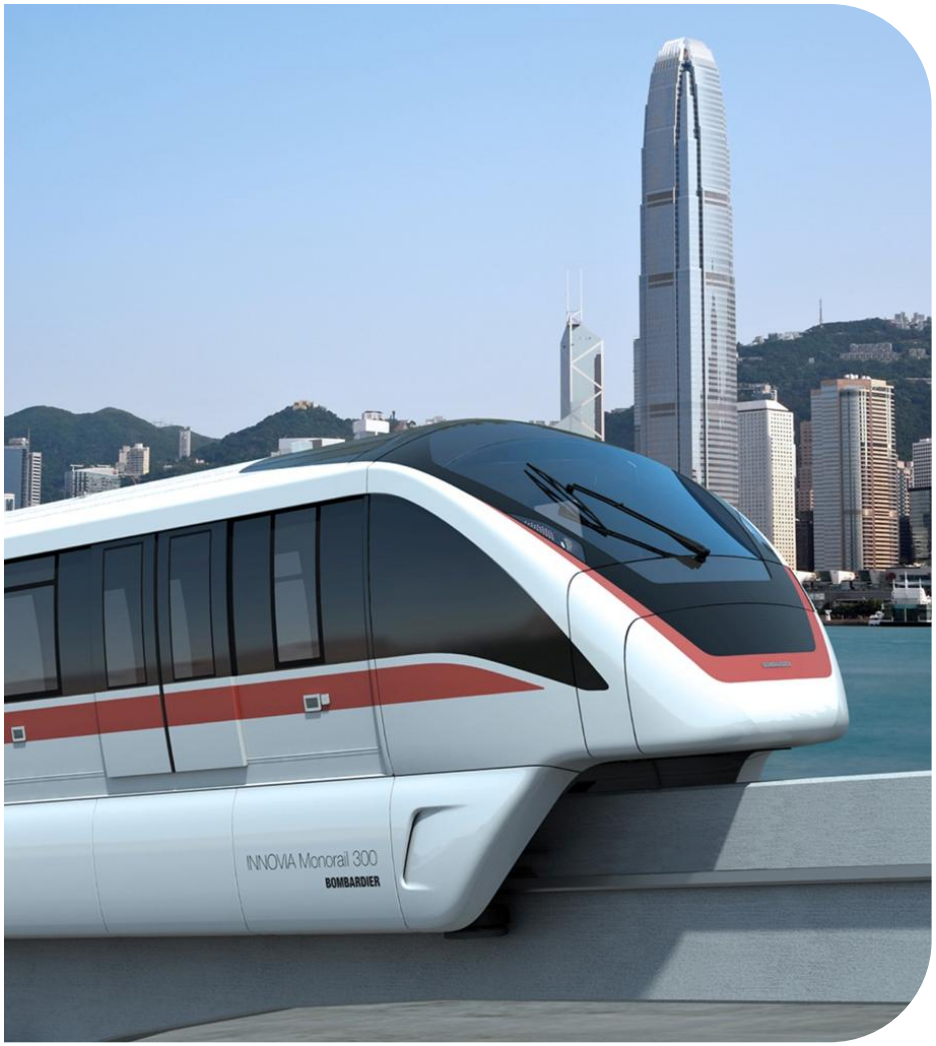
Game changing urban transportation solution

NEW GENERATION INNOVIA MONORAIL 300 SYSTEM

The *INNOVIA* Monorail 300 system incorporates the design and operational features required for rigorous urban line-haul service

- Fully automated and driverless mass transit solution
- Futuristic aerodynamic design
- Speeds up to 80 km/h
- Minimised headways for highest frequency of service
- Energy efficient technologies
- High passenger capacity
- Superb comfort and ride quality



BOMBARDIER
the evolution of mobility

Optimised system for mass transit applications

TECHNICAL OVERVIEW

Train configuration	2- to 8- car trains
Car empty weight	14,000 kg
Maximum gradient	6 %
Minimum horizontal curve radius	46 m
Maximum speed	80 km/h
Power distribution	750 Vdc
Propulsion system	Permanent Magnet Motor
Design capacity	
▪ 2-car trains	9,680 pphpd[1]
▪ 4-car trains	20,400 pphpd
▪ 8-car trains	41,840 pphpd

BOMBARDIER
the evolution of mobility

Capacity comparison

INNOVIA MONORAIL 300 VS. OTHER TRANSIT SOLUTIONS

			Capacity at 6 passenger / m^2		
TECHNOLOGY	DESCRIPTION	NUMBER OF CARS	VEHICLE CAPACITY	120 SECOND HEADWAY	90 SECOND HEADWAY
Heavy metro	Smaller size (Rc+M+M x 2)	6	1,016	30,500	40,600
	Medium size (Rc+M+M x 2)	6	1,508	45,200	60,300
	Large size (Rc+M+M x 2)	6	1,736	52,100	69,400
Monorail	7-car train	7	1,002	30,080	40,000
Tramway	30 metre	1	270	8,100	10,800
	2 coupled 30 metres	2			21,600
	40 metre	1	380	11,400	15,200
	2 coupled 40 metres	2			30,400
Standard bus	With 2 axles	1	85	2,550	3,400
	Articulated	1	121	3,650	4,840
	Bi-articulated	1	173	5,200	6,920
Bus in segregated line	Type milenio Bogota	1	160	22,400	30,000

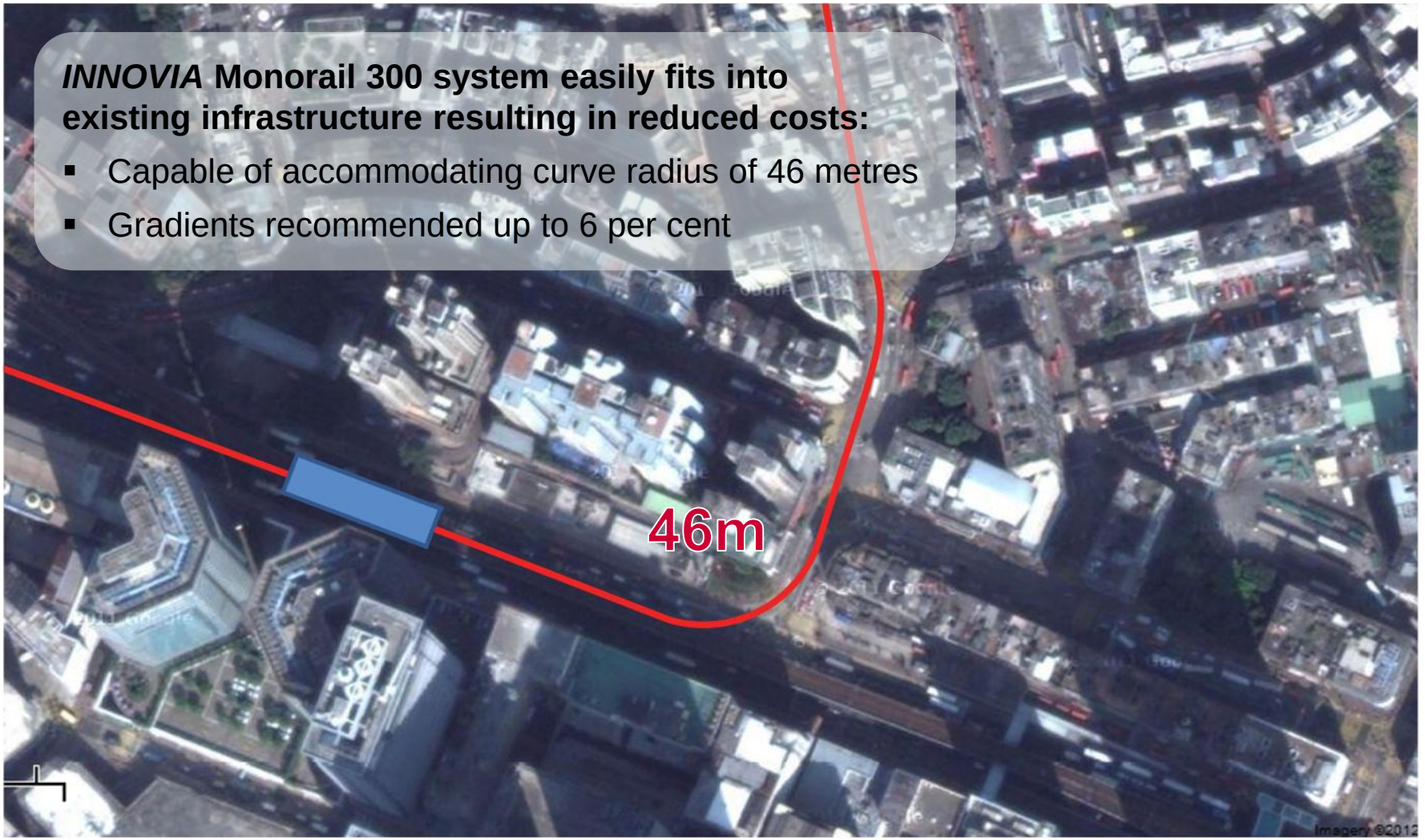
Seamless integration and route flexibility

URBAN FIT

- Slender guideways are easily integrated into different environments
- Low profile sleek vehicles
- Infrastructure requires minimal land expropriation
- Flexible route alignment
- Sharp curve radii and steep grades
- Designed for seamless integration with buildings and structures
- Unobtrusive stations
- Quiet vehicle operation

Outstanding urban integration

ALIGNMENT CAPABILITIES



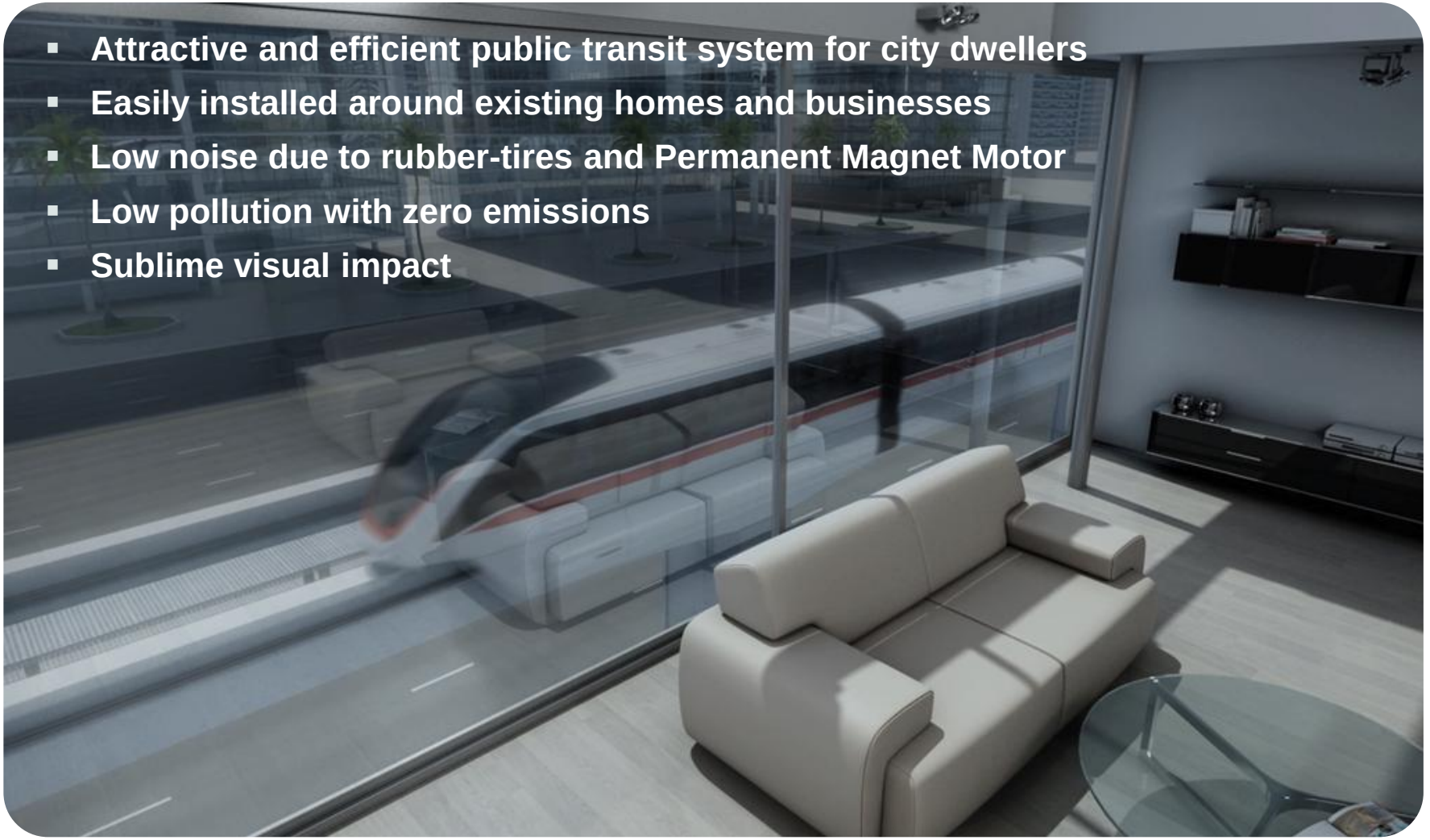
***INNOVIA* Monorail 300 system easily fits into existing infrastructure resulting in reduced costs:**

- Capable of accommodating curve radius of 46 metres
- Gradients recommended up to 6 per cent

BOMBARDIER
the evolution of mobility

A good neighbour

PEOPLE AND CITY LIVING



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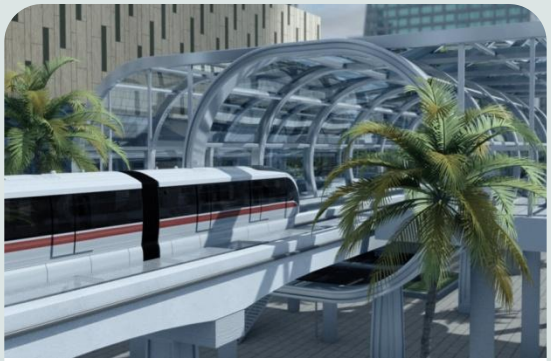
Flexible alignment with minimum visual impact

GUIDEBEAM DESIGN AND CONSTRUCTION



Concrete structures provide elegant strength and durability as well as:

- **Fast and efficient construction**
- **Affordability**
- **Fire-resistance**
- **Low maintenance**
- **Full compliance to all norms and standards**

Exclusive guidebeams ensure:

- **Dedicated right-of-way unrestricted operation**
- **Accidents with surface traffic are impossible**
- **Derailment virtually impossible**

Unobtrusive evacuation walkway, always recommended for safe egress, allow for:

- **Passenger safety**
- **Easy access for system maintenance**
- **No need for active intervention in an emergency**

Cost effective and easy installation

FAST IMPLEMENTATION

- Infrastructure developed to minimise the cost and disruption of civil construction
- Pre-cast lightweight guideway structures built off-site allow rapid assembly on site
- Low land intake / low expropriation costs reduce delays and allow for quick progress
- Elevated guideway eliminates the need for expensive and time-consuming tunnelling
- Easy implementation into different environments (suitable for both greenfield and brownfield)

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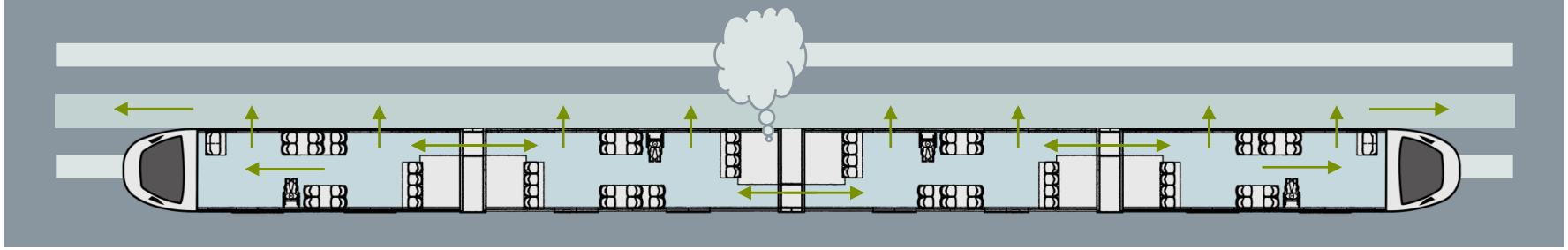
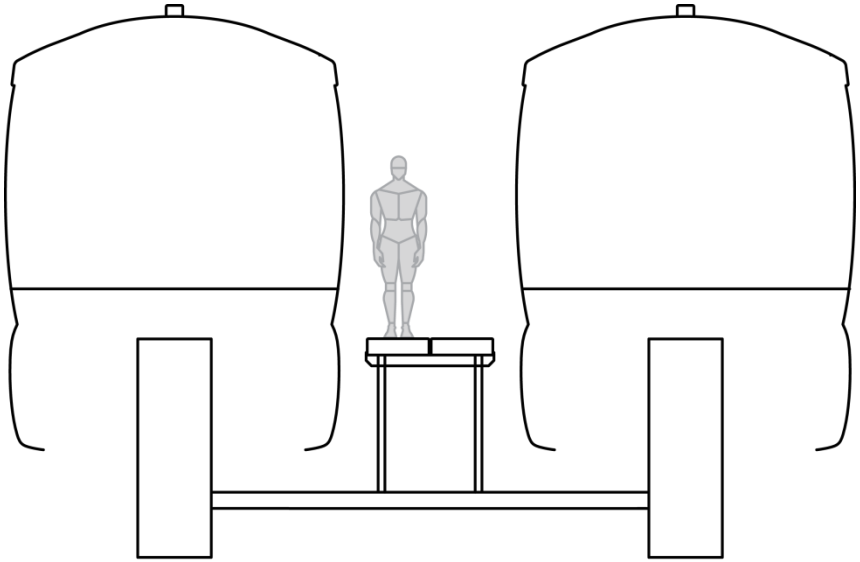
the evolution of mobility

Enhanced safety with uncompromised aesthetics

EVACUATION WALKWAY

Immediate, rapid passenger initiated evacuation from a hazardous situation





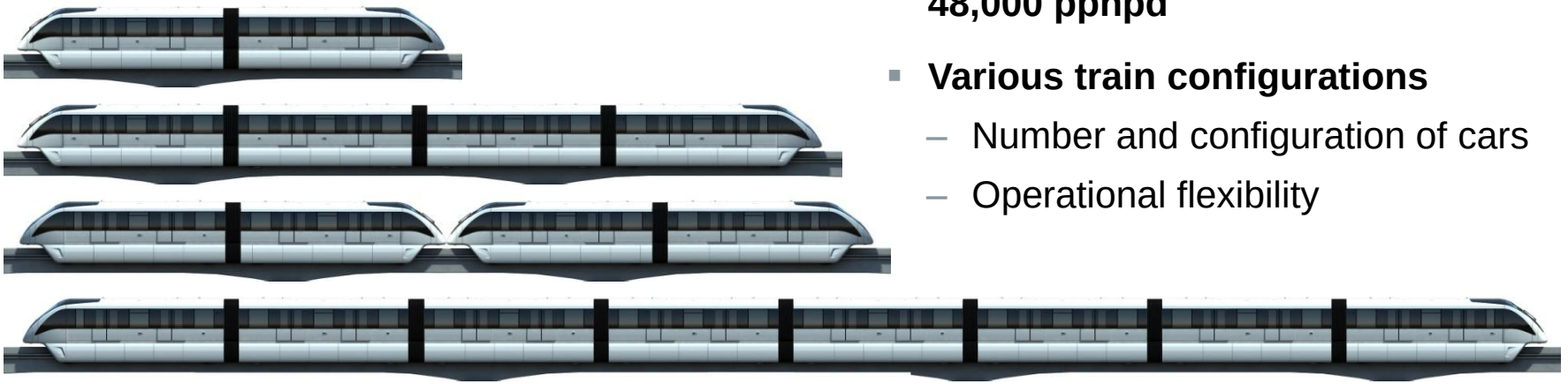
BOMBARDIER
the evolution of mobility

High flexibility and customisation

TAILOR-MADE VEHICLES

- **Customisable exterior design**
- **Flexible interior arrangements**
  - Wide choice of colors and materials
  - Configurable seating
  - Spacious interiors and gangway
- **Customisable static and dynamic signage**

- **Solutions from 2,000 to 48,000 pphpd**
- **Various train configurations**
  - Number and configuration of cars
  - Operational flexibility



BOMBARDIER
the evolution of mobility

Fully automated driverless operation

CITYFLO 650 TECHNOLOGY

- **Proven technology**
- **Reduces cost of operation**
- **Reduces system maintenance costs**
- **Minimises energy consumption**
- **Allows for very short headways, which enable:**
  - Maximum train speed
  - Minimum train lengths
  - Minimum platform length and civil station costs
  - Optimum fleet size
  - Minimum wait times (higher frequency of service)
  - High ridership levels

BOMBARDIER
the evolution of mobility

Low environmental impact

ENERGY EFFICIENCY

System energy usage optimized through:

- **Aerodynamic, lightweight aluminium vehicles**
- **High percentage of recyclable materials**
- **LED lighting**
- **Automatic train control**
- **Efficient permanent magnet motor propulsion technology**
- **Improved vehicle thermal insulation system**
- **Regenerative braking**
- **Intelligent power management system**
- **Minimal consumption of construction materials**
- ***EnerGstor* wayside energy storage system**

BOMBARDIER
the evolution of mobility

Fast and smooth switches

SYSTEM OPERATION

- **Beam replacement or multi-position pivot switches**
  - Beam replacement switches are used on the mainline
  - Multi-position pivot switches are used in storage yard areas
- **No restriction of system capacity or operating speed**

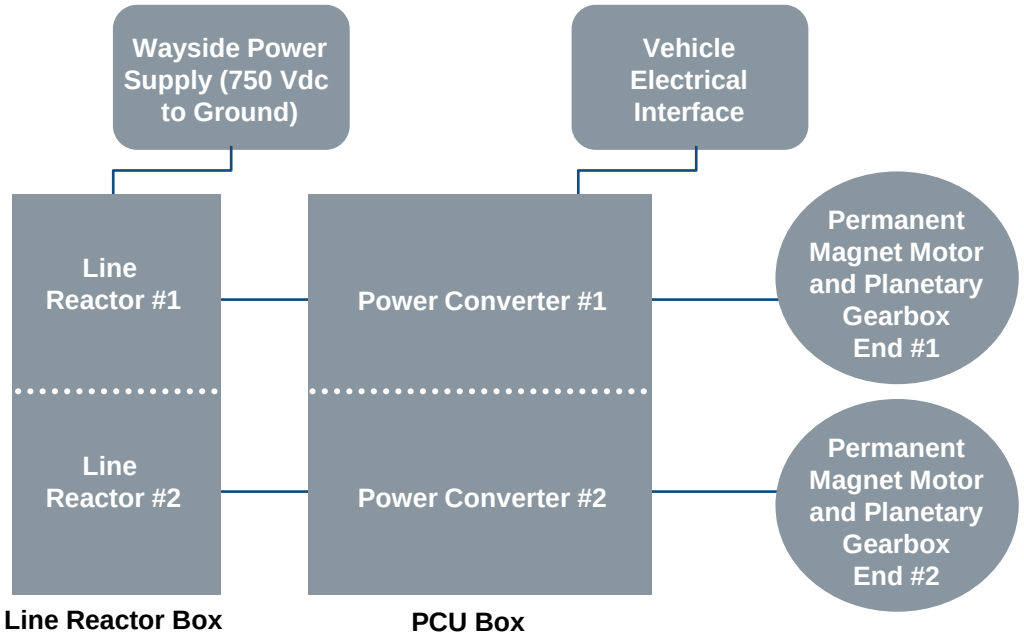
High speed beam replacement turn out switch

Multi-position pivot switch

Driven by innovation and ingenuity

PROPULSION TECHNOLOGY

- **Permanent magnet motor (PMM) designed for *INNOVIA* Monorail 300 system**
- **Rotor creating its own flux by incorporating magnets**
- **Propulsion system maximizing regenerative dynamic braking to minimize use of friction brake**



- **Speeds up to 80 km/h**
- **High capacity transit**
- **Low noise**

BOMBARDIER
the evolution of mobility

An eco-friendly solution

WAYSIDE ENERGY STORAGE

Based on modular supercapacitor technology for wayside, the new *EnerGstor* solution provides both economic and environmental benefits.

- **Simple interface**
- **No house power connection required**
- **No communications connection required**
- **Only connections are to traction power +ve, -ve and ground**

Bombardier's test track in Kingston, Canada

PROVIDING A REALISTIC TEST ENVIRONMENT

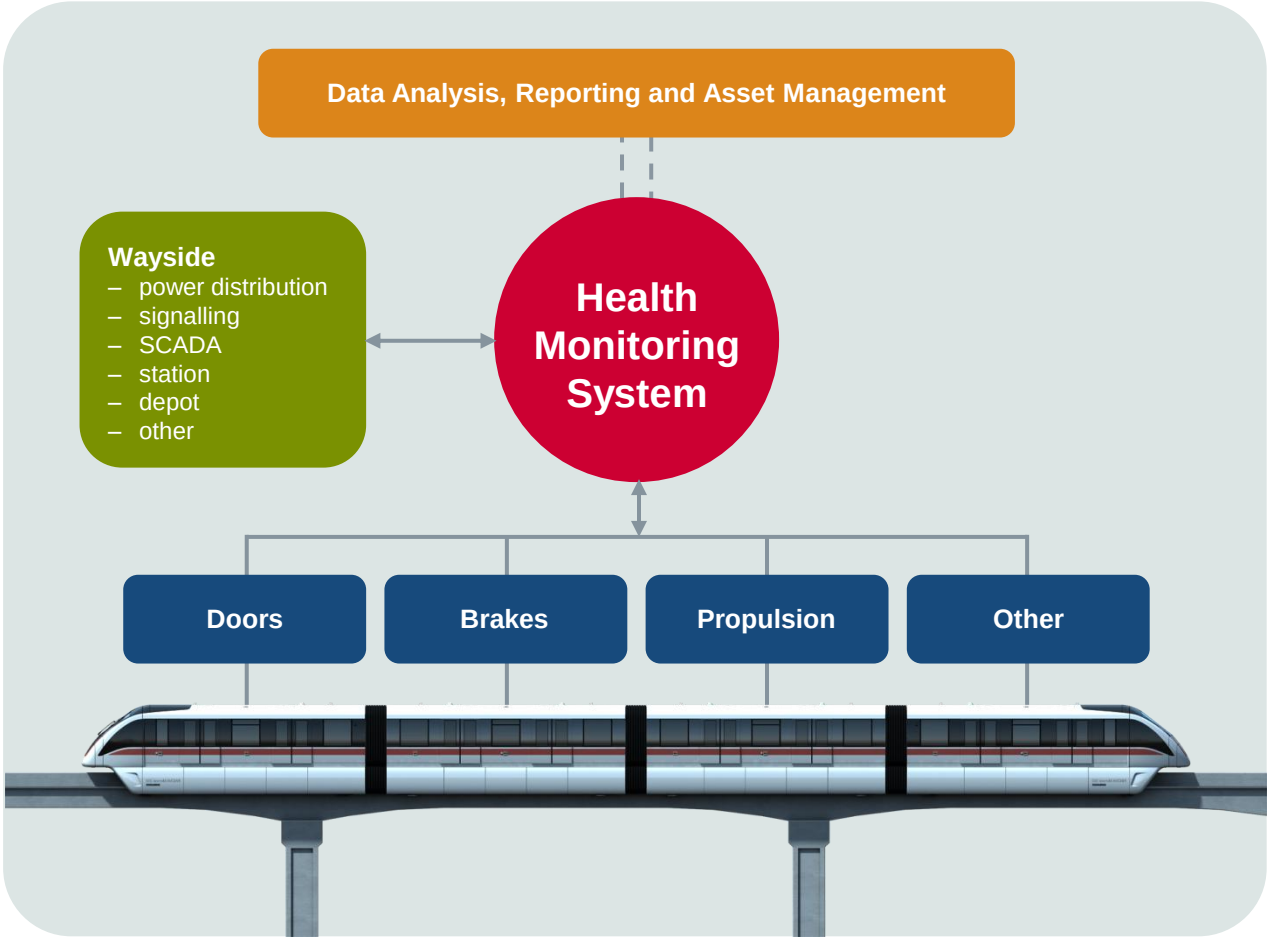
- **Testing and commissioning transit systems since 1978**
- **Four test tracks for different transit technologies (monorail, metro, and LRV)**
- **Speeds up to 100 km/h**
- **Monorail test track installed with 46m radius curve (tightest in the monorail segment) and an 'S' bend for realistic test environment**

Bringing together people, processes and technology

DYNAMIC MAINTENANCE

New developments in embedded diagnostic systems for vehicle subsystems and wayside systems

- **Collect and analyse data**
- **Data trending and visualisation**
- **Deep visibility into performance**
- **Fast fault finding and resolution**



BOMBARDIER
the evolution of mobility

Predictive maintenance for increased system health

OPERATION AND MAINTENANCE

Increase availability

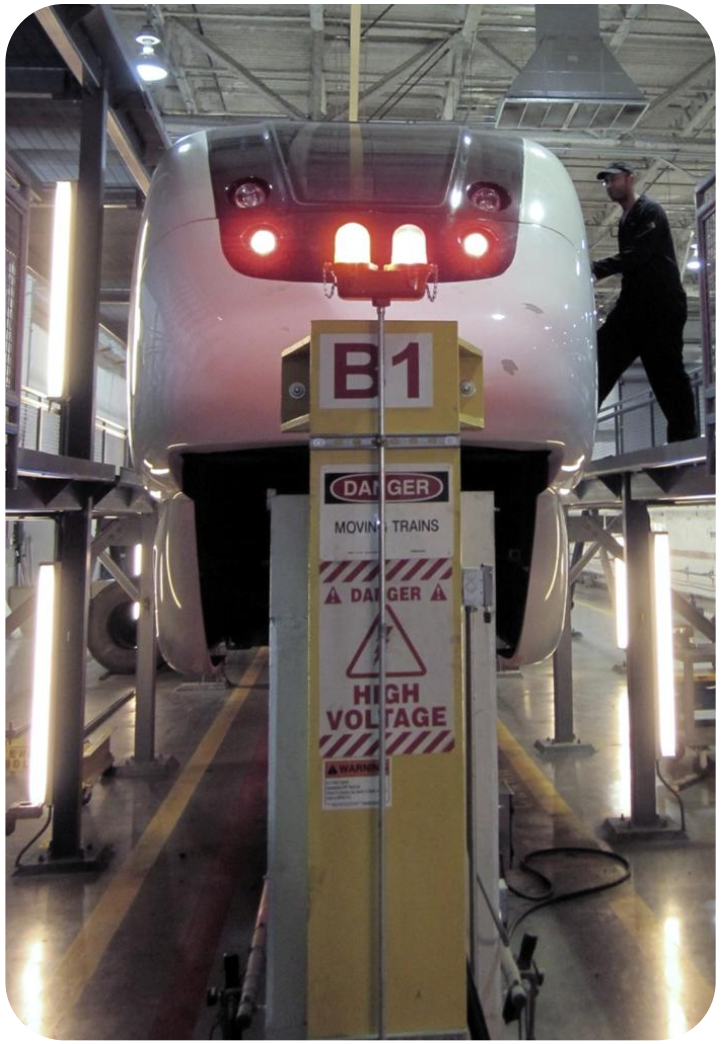
- **Minimize service affecting failures**
- **Track failure trends and mitigate**

Improve customer service

- **Perform maintenance optimally**
  - Extends the operating life of the system
  - Extends life of equipment

Reduce the total cost of ownership

- **Extends maintenance intervals**
- **Potential elimination of daily/monthly tasks**
- **Automated vehicle inspections**
- **Reduce planned maintenance activities**
- **Reduce spares holdings**



BOMBARDIER
the evolution of mobility

Summary of benefits

INNOVIA MONORAIL 300 SYSTEM

Technology	▪ Sleek and attractive vehicles ▪ Slender contemporary guidebeams have a subtle presence ▪ Unique emergency walkway allows for safe passenger egress ▪ Modern solution to transportation needs
Operation	▪ Driverless system enhances overall efficiency ▪ Frequent, safe and reliable service ▪ High service capacity ▪ Cost effective transit solution
Passenger	▪ Modern visual appeal ▪ Spacious vehicle interior ▪ Easy access for passengers ▪ Comfortable rides
Environment	▪ Low visual impact ▪ Low noise ▪ Zero emissions ▪ Energy saving equipment

Twenty years of urban mobility evolution

REFERENCE PROJECTS

São Paulo, Brazil
INNOVIA Monorail 300 System
2015

Riyadh, Saudi Arabia
INNOVIA Monorail 300 System
2016

Las Vegas, USA
INNOVIA Monorail 200 System
2004

Jacksonville, USA
INNOVIA Monorail 100 System
1998

Newark, USA
INNOVIA Monorail 100 System
1996

Tampa, USA
INNOVIA Monorail 100 System
1991

BOMBARDIER
the evolution of mobility

Agenda

1 Introduction to Bombardier

2 *INNOVIA* Monorail 300 system

3 Case study: *INNOVIA* Monorail 300 system for São Paulo

INNOVIA Monorail 300 system in São Paulo, Brazil

PROJECT OVERVIEW

- From Vila Prudente to Cidade Tiradentes urbanization – extension of the São Paulo Metro Line 2
- Revenue service begins in 2015
- 24 km dual-beam alignment
- 17 stations
- 378 cars (54 seven-car trains)
- Designed to carry 40,000 pphpd[1]
- 6% maximum grade
- *CITYFLO* 650 automatic train control

[1] Fleet expansion required to realize full system ridership capacity of 48,000 pphpd.

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Progress of INNOVIA Monorail 300 system in São Paulo

FIRST 7-CAR TRAIN IN TESTING

- **Construction of first car completed in July 2013**
- **First 7-car train completed in September 2013**
- **Dynamic testing of first 7-car train in São Paulo started in January 2014 (route from depot via guidebeam to station)**

BOMBARDIER
the evolution of mobility

Infrastructure construction works in São Paulo, Brazil

NO DISRUPTION OF TRAFFIC

- **Pre-cast structures built off-site for rapid assembly**
- **Minimal impact on city traffic during the construction**

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INNOVIA Monorail 300 system

ACHIEVEMENTS AND NEXT STEPS

- **7-car *INNOVIA* Monorail 300 train completed first test track run in Kingston in November 2013 reaching speeds up to 61 km/h**
- **7-car *INNOVIA* Monorail 300 train carried first riders at milestone event in São Paulo in January 2014 (between depot and Oratorio Station)**
- **In Kingston, test train will complete tests at varying speeds and loads before being delivered to São Paulo**
- **In São Paulo, by the time of the World Cup 2014 it is anticipated the first section of the Monorail system will be open to passengers for some trial services between the Vila Prudente to Oratorio stations**

BOMBARDIER
the evolution of mobility

BOMBARDIER

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www.transportation.bombardier.com
www.theclimateisrightfortrains.com

www.twitter.com/BombardierRail
www.youtube.com/bombardierrail

Scomi

A Global Technology Enterprise

URBAN TRANSIT SOLUTIONS

MONORAIL

Trust is the platform…
on which we demonstrate our
commitment to the stakeholders.

- Global Technology Enterprise

Scomi

Listed on the Malaysian Stock Exchange

Energy Services

Transport Solutions

Presence in 26 countries with over 3000 employees

TRANSPORT SOLUTIONS

Scomi Engineering Bhd

(Listed on the Malaysian Stock Exchange)

- **Monorail / Rail**
- **Buses / Coaches**
- **Special Purpose Vehicles**

Scomi

Engineering, Technology & Innovation Center

North KL Facility:

Location: Rawang, Malaysia
Factory covered area: 150,000 sq/ft
Operational: August 2009

Manufacturing Capacity:

2 lines: Monorail & Conventional Rail
1 Monorail vehicle per line per week
Test track enters facility to form a covered 4 car train test area

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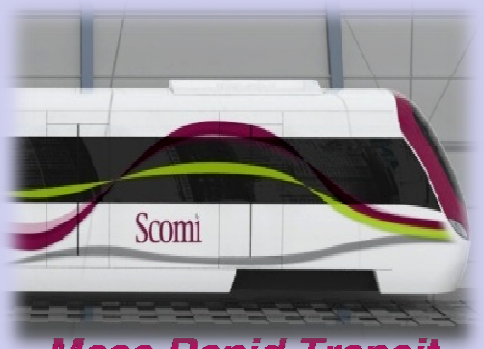
Scomi's Urban Transit Systems Evolution

Gen 2.0 - SUTRA

Gen 2.1 – Mumbai 4 car-train



Mass Rapid Transit (MRT)

2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
KLMS Commissioned				SUTRA Launch			Inauguration of 1st 4-car train				Commercial Operations of Mumbai Monorail

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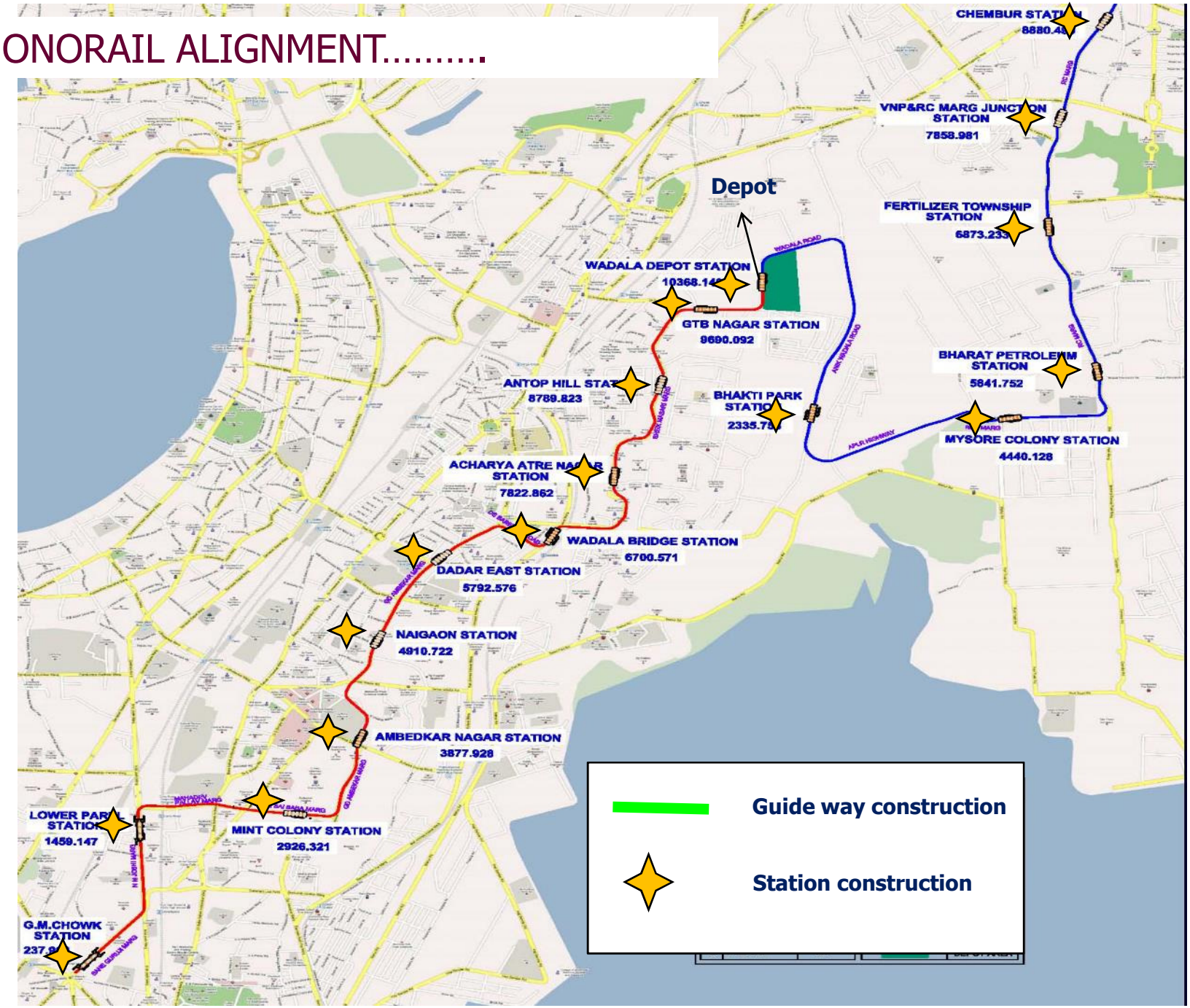
Mumbai Monorail

1ST in India…Mumbai's Pride

Scomi

- MONORAIL ALIGNMENT…….



Fact Sheet : Mumbai Monorail Project

Client	Mumbai Metropolitan Region Development Authority
Project Cost	Rs 2,460 crore (USD 420 Million)
Project Type	Design-Build-Integrate-Commission-Operations & Maintenance
Awarded To	Larsen & Toubro and Scomi Engg Bhd Consortium
Alignment	19.68 km with 17 stations Phase 1 8.92 Km from Wadala to Chembur (7 stations) Phase 2 10.76 Km from Wadala to Jacob Circle (10 stations)
Rolling Stock	15 trains
Commercial Operations Phase-1	2nd February 2014
Projected Commercial Operation Phase-2	2014/2015

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Fact Sheet : Operations & Maintenance

Contract Duration	3 years
Staff Strength	Over 250 staff
Rolling Stock	5 trains in operations 4 trains under testing & commissioning
Operations	Current 66 trips / day 7am to 3pm Headway : 15 mins Future (full alignment in operation) 19 Hours operations Headway : 4.5 minutes

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Mumbai Monorail Facilities




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Wadala Depot – Administration Building & Station

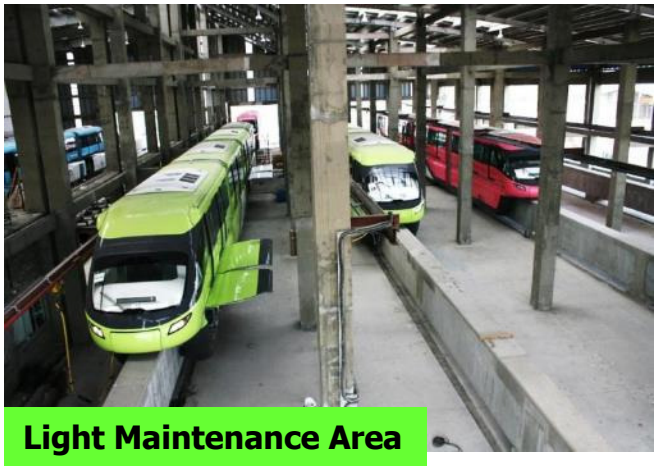
Scomi

- Depot – North Elevation

Scomi

Depot : Rolling Stock Maintenance

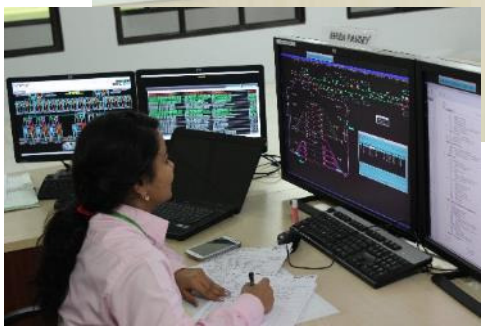
Heavy Maintenance Area



Light Maintenance Area

Scomi

- Operations Control Centre



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Station : Typical Layout

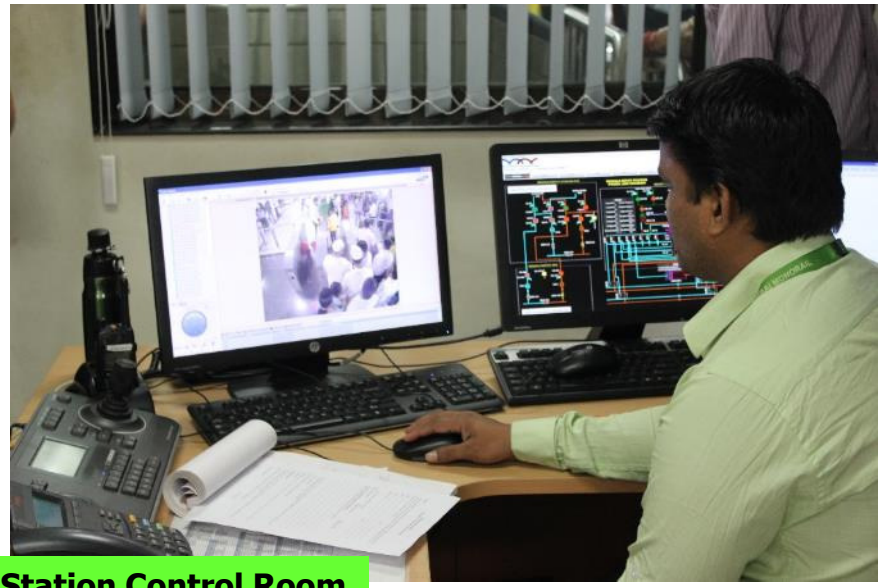
Station from Ground

Platform Level

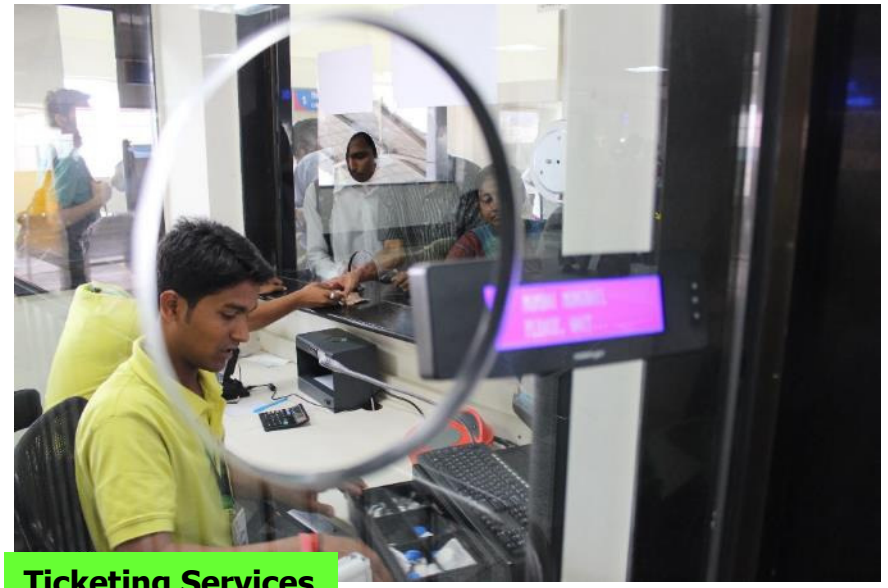
Concourse Level

Track Level

Station Operations



Station Control Room



Ticketing Services

Crowd Management at Platform

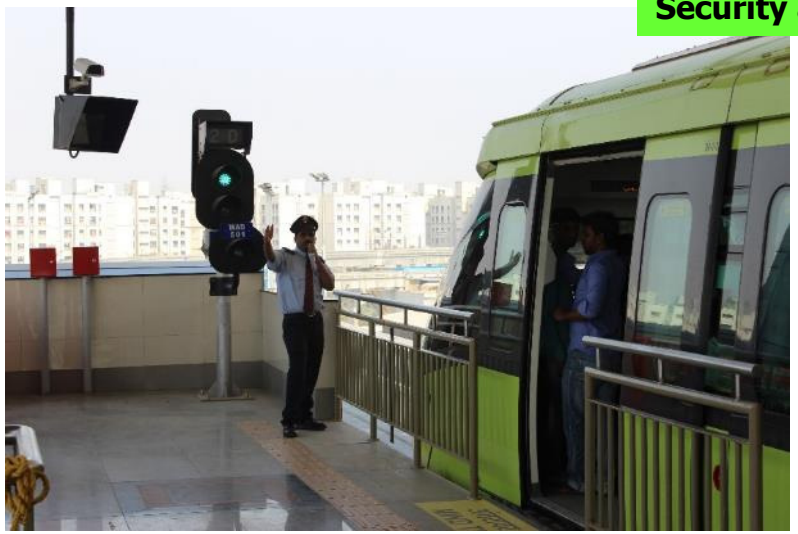
Crowd Management at Concourse

Scomi

Station Operations – Passenger Security

Security at Concourse

Security at Platform



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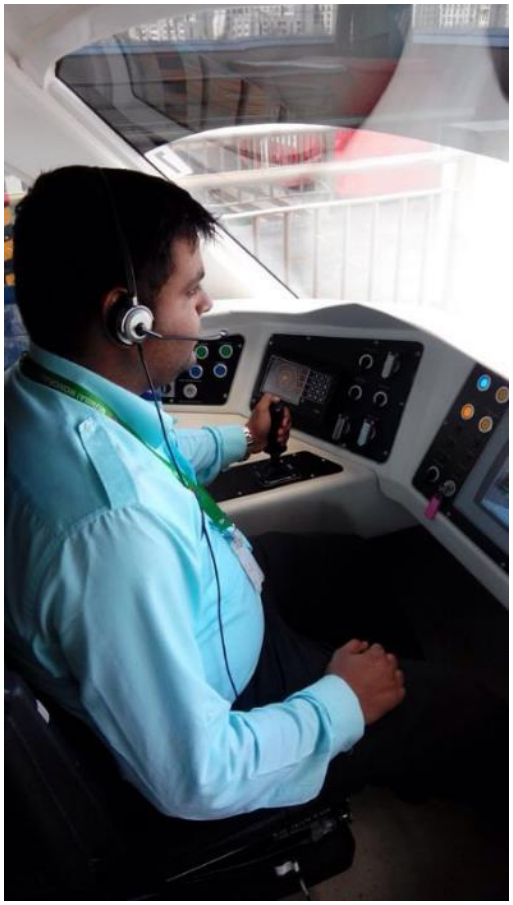
Train Operations

Breathalyser Test

Operations Equipment



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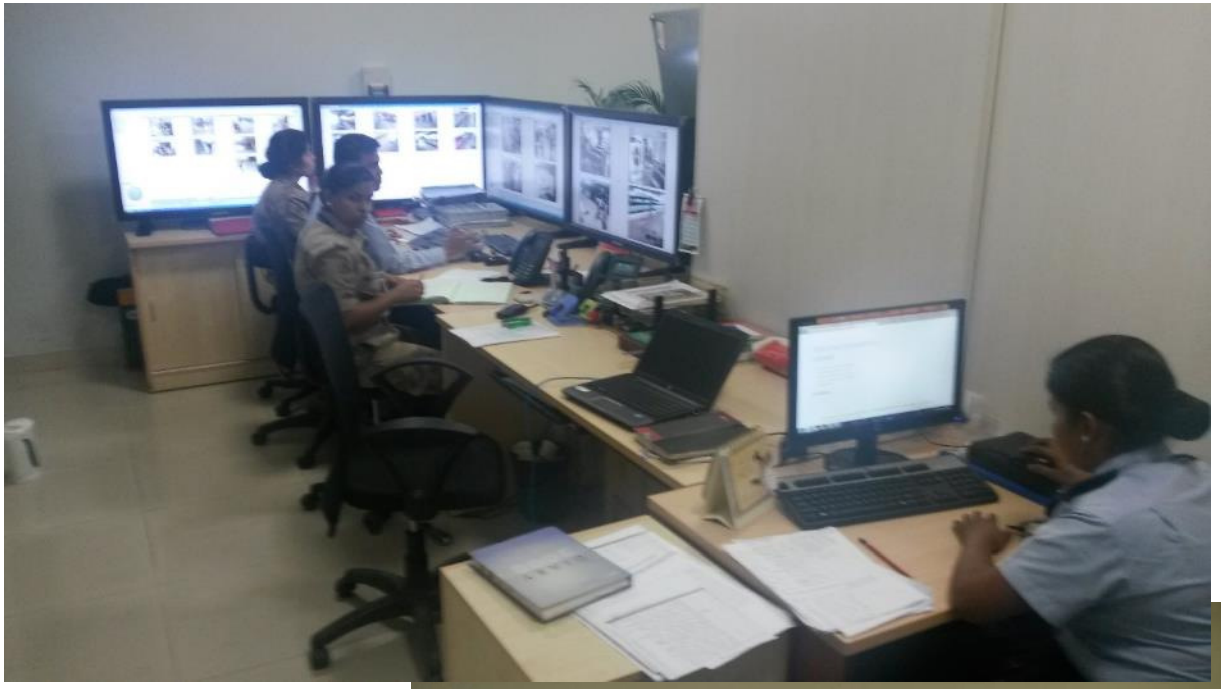
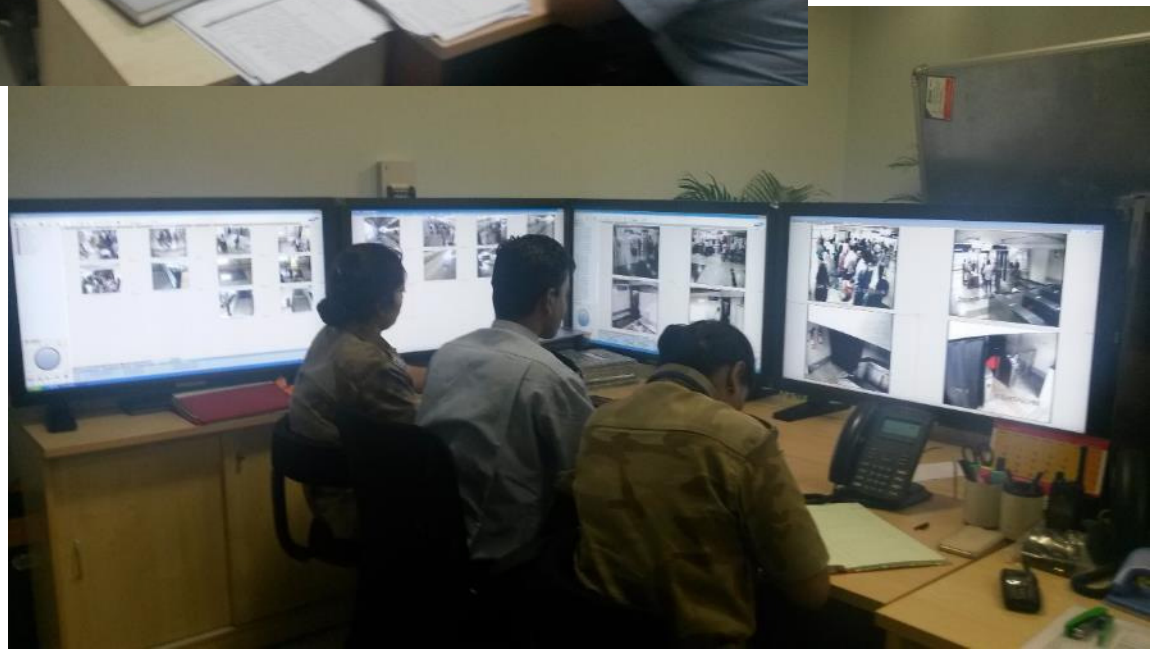
- Security Control Centre





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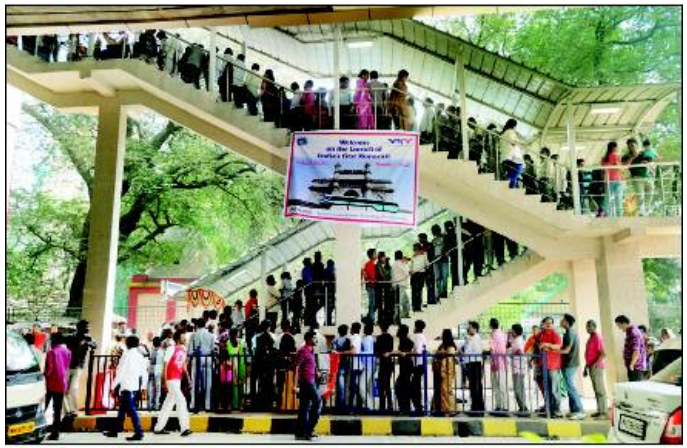
Phase 1 : Inaugurated by Chief Minister of Maharashtra - *1st Feb 2014*

Phase 1 : 1st Day of Operations - *2nd Feb 2014*



20,000 commuters on 1st day (4 trains & 8 hours operation)

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Challenges Faced




Scomi

Challenges on all Monorail Projects

Utilities

Existing vegetation

Land acquisition

Traffic diversion

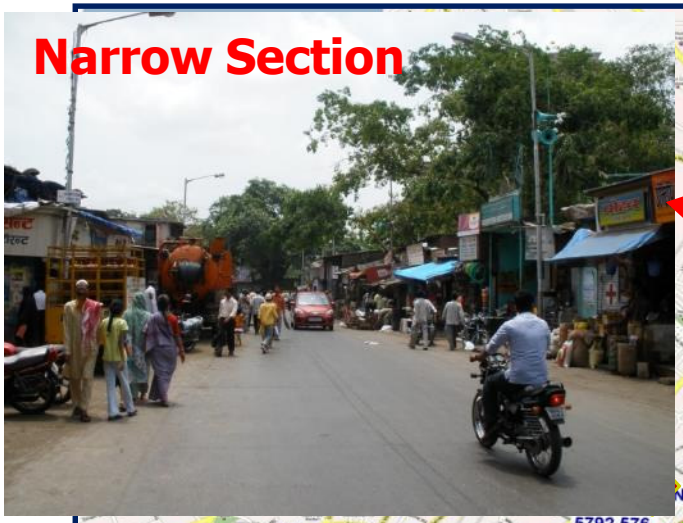
Explaining Monorail

	ITEM	MAXIMUM TOLERANCE	LOCATION AND WHEN TO MEASURE	MEASURING POSITIONS
11	DISTANCE BETWEEN GUIDEWAY CENTER LINES	e ≤ 0~+25mm	i) ON THE PIER : – BEFORE STITCHING CONCRETE	B + e; BEAM END; B = DESIGN DISTANCE BETWEEN GUIDEWAY CENTER LINES; MEASURE AT CENTER OF TOP SURFACE AT BEAM ENDS.
12	UNEVENNESS BETWEEN ADJACENT BEAMS	δ ≤ 5mm	i) ON THE PIER : – BEFORE STITCHING CONCRETE	167.5 167.5 100 800 1200; δ1 δ2 100 100 δ = δ2 − δ1; MEASURE AT 100mm FROM ENDS OF BEAM
13	UNEVENNESS BETWEEN FINGER PLATES	δ ≤ 2mm	i) ON THE PIER : – AFTER STITCHING CONCRETE	167.5 167.5 100 800; δ FINGER PLATE
14	UNEVENNESS BETWEEN BEAM/ FINGER PLATES	δ ≤ 2mm	i) ON THE PIER : – AFTER STITCHING CONCRETE	167.5 167.5 100 800; δ FINGER PLATE

Civil Partner Learning Curve

Scomi

CHALLENGES in Phase – 2: Wadala to GMC



Scomi

- Construction over railway tracks

Wadala Railway Crossing

Curry Road Railway Crossing

Scomi


Future of monorail in India




Scomi

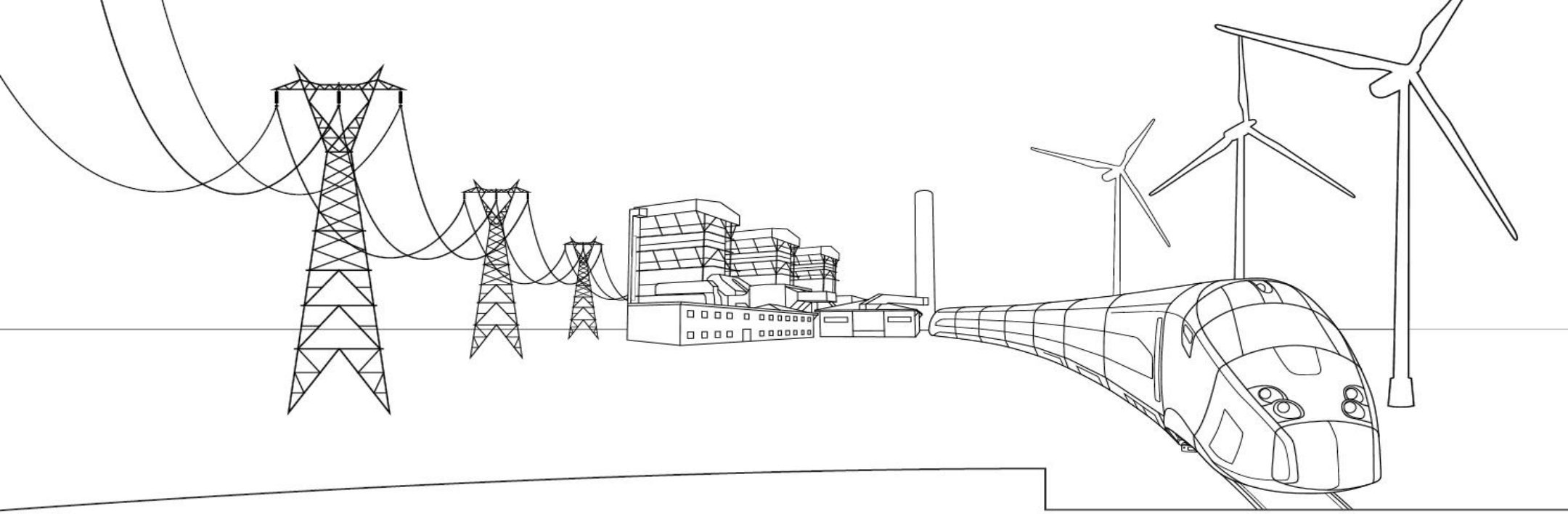
Opportunities for Growth in India

- **Integration into Urban Transit Solution master plans**
- **Viable option as a linking feeder service**
- **Suitable for densely populated areas** (small footprint, high manoueverability)
- **Scomi's global focus :**
  - Creating new technical skill among the locals
  - Creating new talent streams
  - Option to build monorail manufacturing facility in India based on demand

Scomi

Thank You

Scomi



Light Metro & Monorail Workshop

AXONIS - an integrated turnkey metro solution

Mangal Dev, Director Business Development

MMRDA, Mumbai

22 March 2014

ALSTOM

Shaping the future

AGENDA

Alstom & VSL

Alstom

- Alstom Transport
- Alstom Metro Expertise

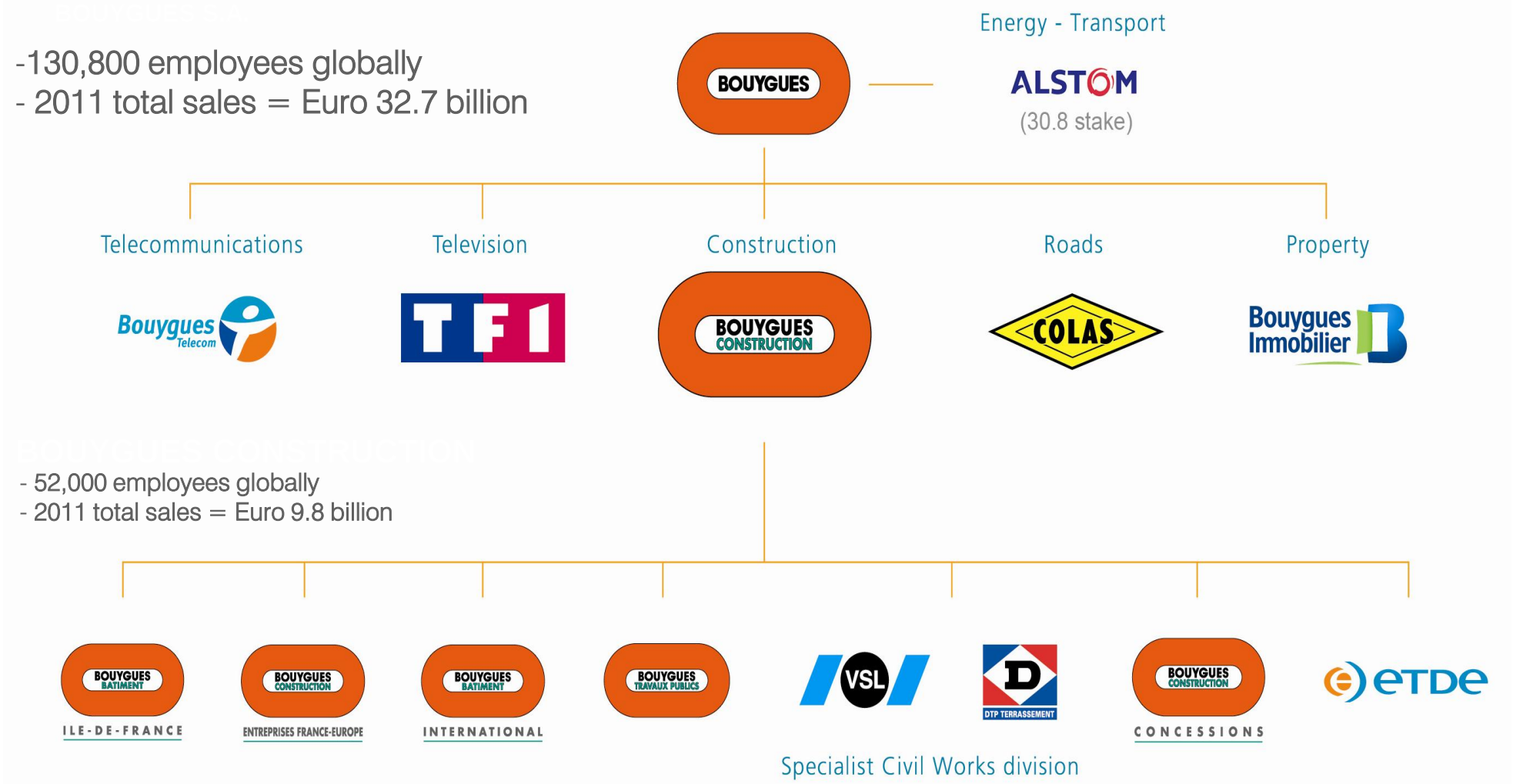
VSL

- VSL Worldwide Presence
- VSL Core Competencies

AXONIS

- Customer Benefits
- Inside AXONIS

Alstom & VSL within Bouygues Group



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AXONIS

- Customer Benefits
- Inside AXONIS

With Alstom, designing fluidity becomes a reality

A unique integrated approach in the market





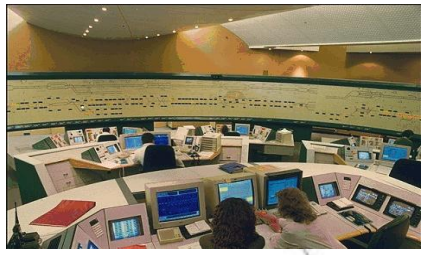
- Rolling Stock & Components
- Signalling
- Services
- Infrastructure & Systems

- N° 1 in urban transport (tramways, metros)
- N° 2 in very high speed
- N° 2 in signalling
- N° 2 in maintenance

Alstom: A reference in Metro Solutions

- Conventional or Driverless operation,
- Steel wheels or rubber tires, large or small Capacity
  - **1951: First rubber-tired metro**
  - **1999: First steel-wheeled Driverless Heavy Rail Transit (HRT) Turnkey system, and still the leader…**
  - **2008: First Driverless Metro with slope up to 12%**
  - **1/4** of the metro cars sold worldwide were produced by ALSTOM

Metro Transport Global Solutions



Signaling and Control Systems

Depot and Maintenance Facilities

Catenary / 3rd rail

Track Works

Testing and Commissioning

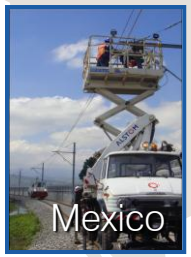
Power Supply

System Engineering and Project Management

Station Equipment

ALSTOM

Alstom Turnkey worldwide references



Stockhlom Arlanda express

Channel Tunnel Rail Link

Reims

Lausanne

Orléans

Milano

Bordeaux

Athens Suburban

Barcelona

Firenze

Athens

Murcia

Istanbul

HSL Spain

Algiers

Oran

Cairo

Constantine

Dubai

Seoul - Pusan

Incheon Metro/Suburban

Mexico

Panama

Caracas

Taipei

Singapore

Sao Paulo

Metro project

Past

On-going

ALSTOM

AGENDA

Alstom & VSL

Alstom

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AXONIS

- Customer Benefits
- Inside AXONIS

VSL WORLDWIDE PRESENCE

320 M€ Sales 2011 3,700 Employees

R & D Center

32 Registered Patents in use

(R&D: 3 M€ in year 2010)

Licenses

Technical Center

2 Technical Center

(Switzerland & Singapore)

1 PT Academic (Bangkok)

Plants

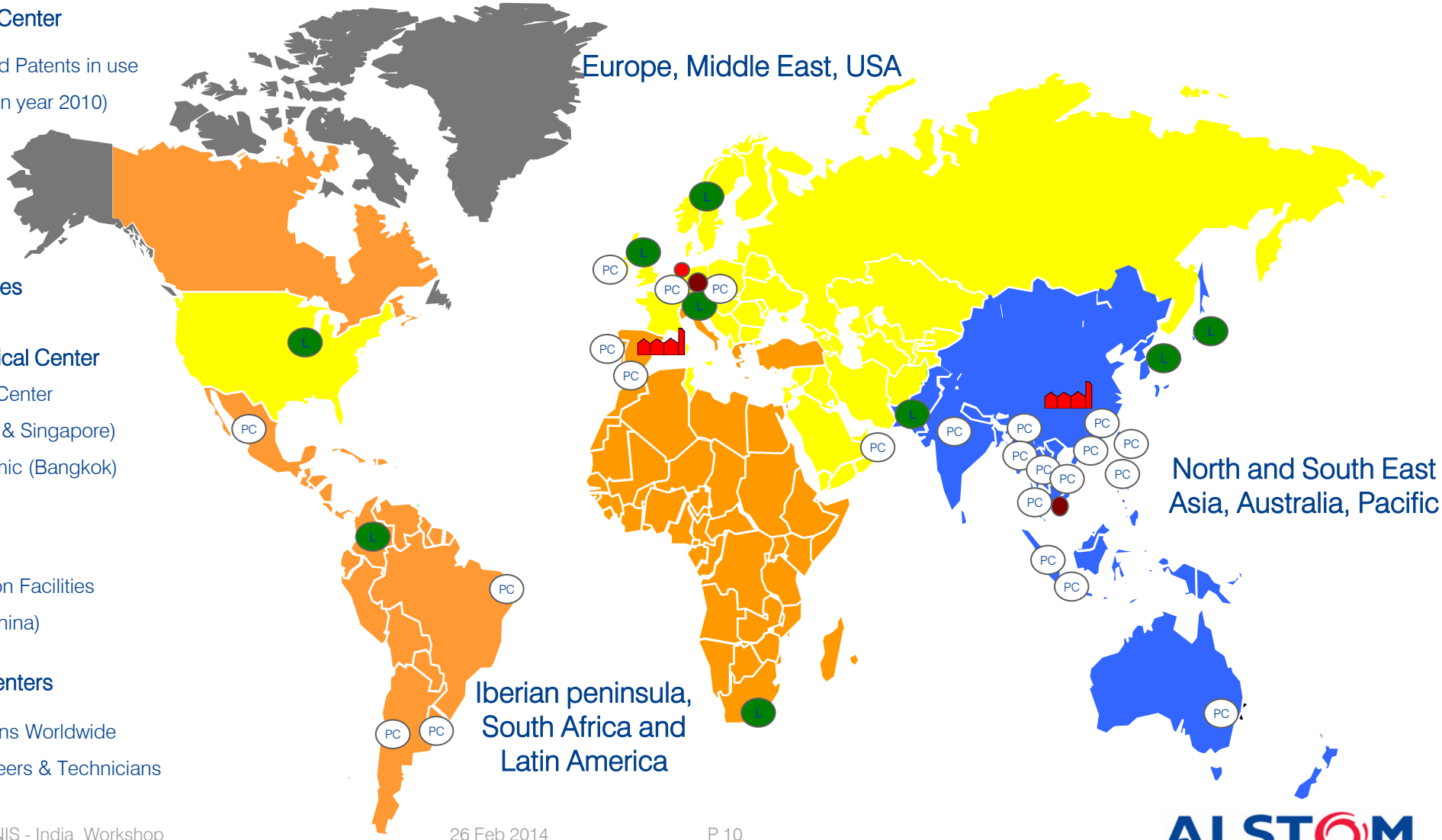
2 Production Facilities

(Spain & China)

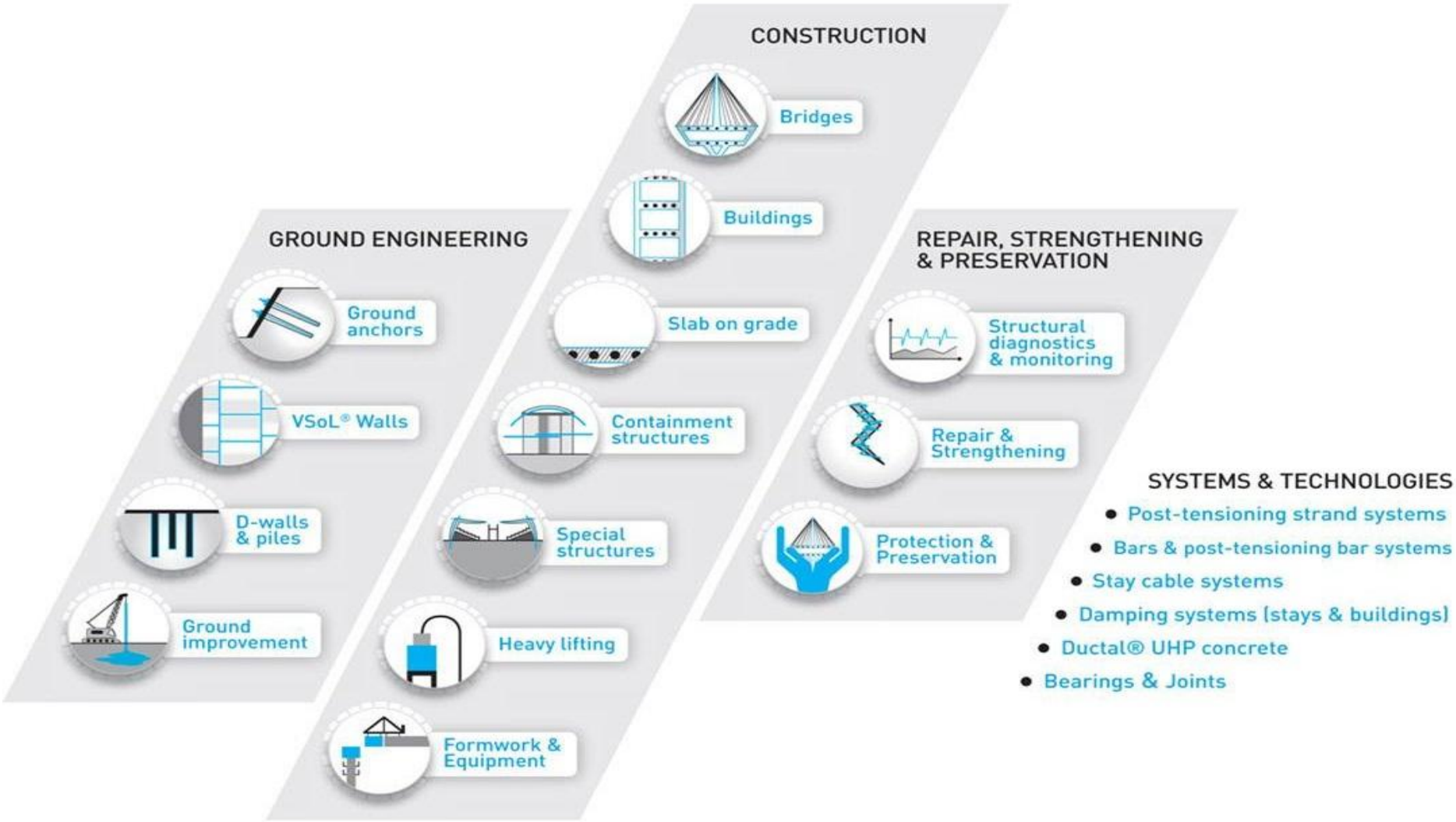
Profit Centers

50 Locations Worldwide

900 Engineers & Technicians



VSL Core Competencies



VSL – Current Metro Projects

KV MRT Kuala Lumpur

- Over 41km of viaduct under construction
- 10 Overhead Gantries in operation
- More than 150 specialist staff and labour

VSL – Past Metro Projects

- Over 150,000 precast elements erected in the last 20 years, primarily within the last 10 years.

- Over 6,000,000 square metres of precast bridge deck erected in last 20 years, primarily within the last 10 years.

Dubai LRT

Gautrain - SA

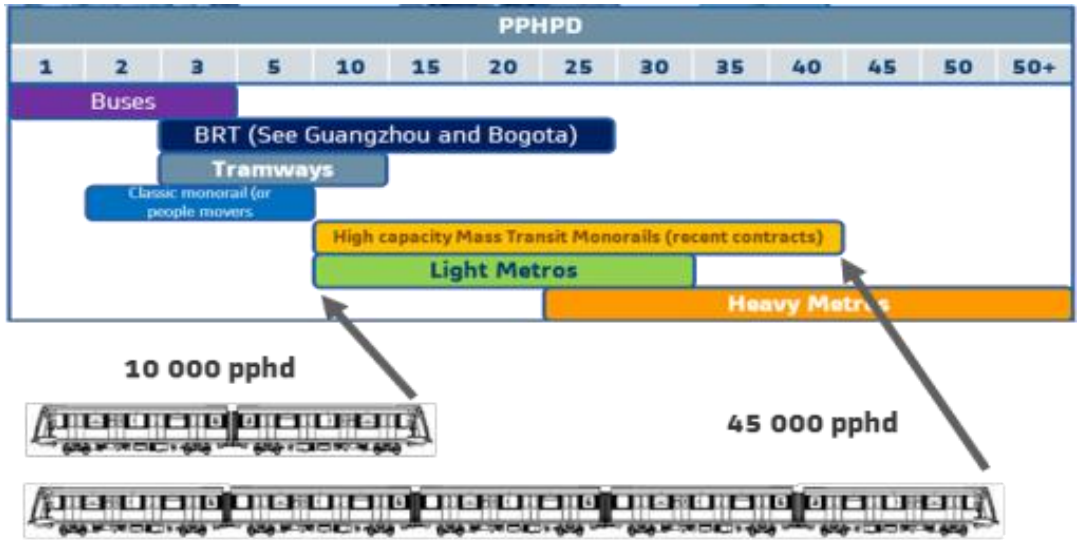
AXONIS

TRANSPORT | ALSTOM

Introduction

AXONIS is a **driveless metro system** to meet the specific transport needs of fast-growing and densely-populated cities that are seeking **quick construction**, **easy urban insertion** and **improved life-cycle cost**.

Axonis Concept Drivers



- Fully Integrated design (CW/E&M)
  - Accelerate design & construction
- Standardisation & Modularisation
  - Reduce costs
- Turnkey delivery of a
  - non-proprietary metro system
    - with a peak-hour link capacity between10,000 and 45,000 passengers and
    - able to operate at grade and/or on elevated guideways and/or in tunnels.

AXONIS CUSTOMER BENEFITS

TRANSPORT | ALSTOM

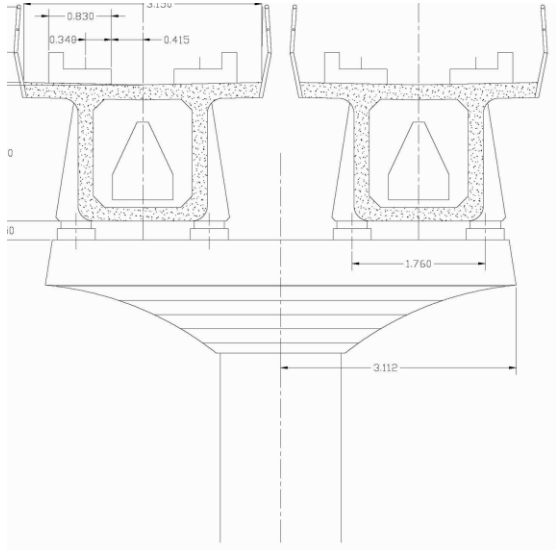
5 basic benefits

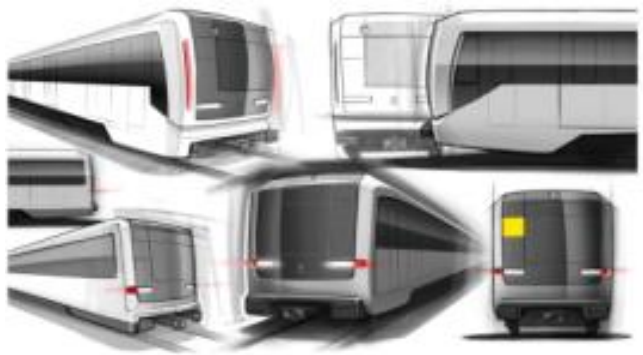
- ✓ **Elegant** & **Easy to insert** in Cities
- ✓ **Fast** to design, build, integrate
- ✓ **Economical** to acquire and operate
- ✓ **Non-proprietary**
- ✓ **Safe** & **Secure**

Elegant & Easy to insert in your city

AXONIS is designed for easy integration into the city, providing effective mass-transit mobility.

- Capacity of **10,000** to **45,000** passengers per hour per direction
- 2-car to 5-car trains
- Ability to operate on **45-m** radius curves and **6%** grade
- System can be deployed at grade on elevated guideways or in tunnel
- Light and narrow viaducts: less than **7 meters** in width (frontal emergency evacuation system)
- Minimized visual impact through the use of 3rd rail
- In-house Design & Styling expertise allowing the personalization of the train to enhance the City branding





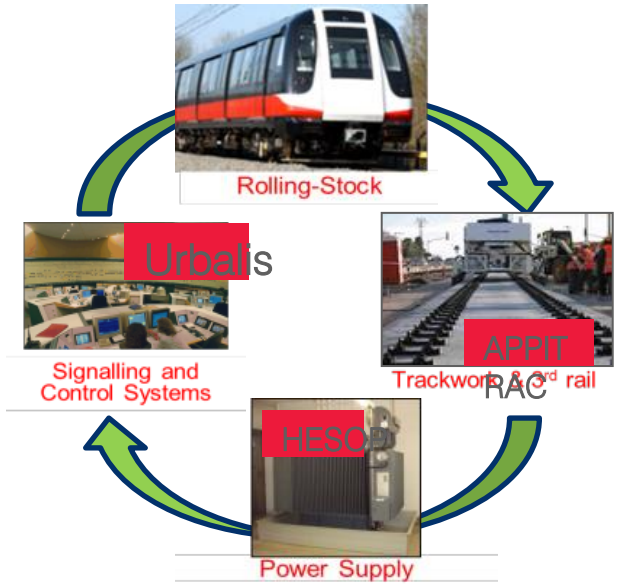
Fast to design, build, integrate

Construction time considerably reduced when compared to traditional methods

3 to 4 years from

Notice To Proceed to Start of Revenue Operation.

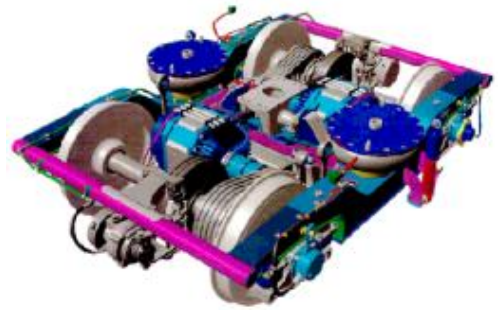
- Standard Driverless Operation mode
- Fully integrated System: track, power supply, signalling, PSD and trains
- Modular viaduct: precast modules for easy transportation and swift erection
- Alstom's APPITRACK fast track-laying technology

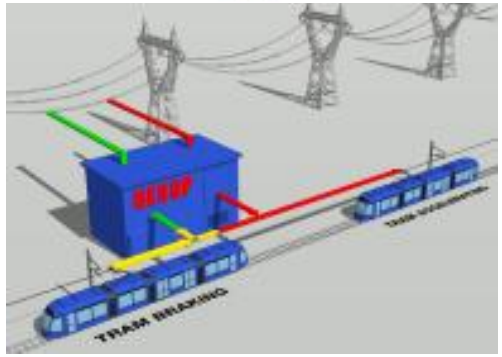


Economical to acquire and to operate

AXONIS lowers CAPEX and OPEX , through a system approach that provides high performances at optimum costs.

- **standardisation** reduces development costs
- narrower structures &shorter stations that reduce the system **footprint**
- vehicle architecture which optimises the **depot and maintenance footprint**
- **driverless operation** that lowers operation costs
- steel wheels that lowers maintenance costs and reduce energy consumption
- **100%** motorisation
- **30-40%** Lower traction energy consumption thanks to HESOP sub-station, motorisation and Eco-driving

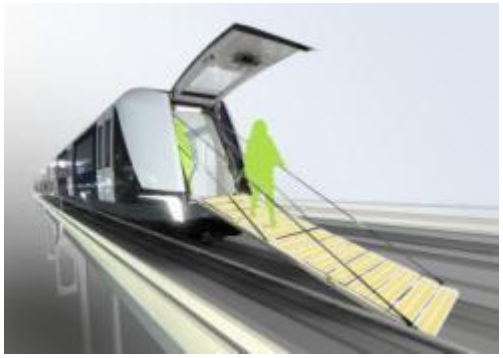




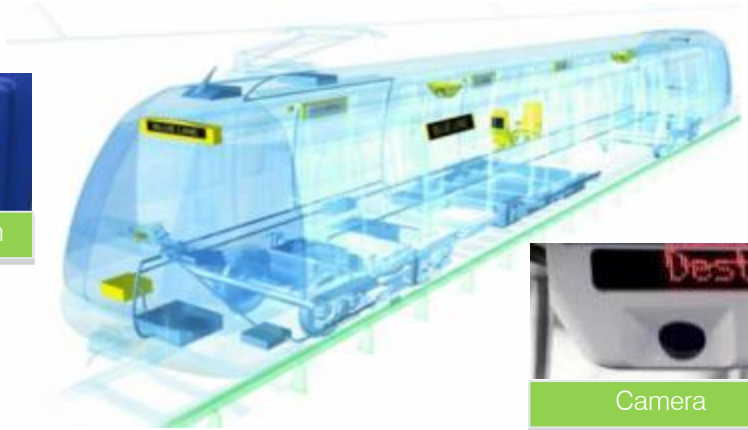
Safe and Secure

AXONIS fully benefits from **Alstom's metro integration expertise** acquired worldwide, **over** 50 years.

- URBALIS Signalling system, chosen for more than 50 metro lines worldwide (URBALIS CBTC Driverless: 11 metro lines)
- Convenient front-end emergency exit door
- Possibility to use sleeper-less trackforms for easier passengers evacuation
- Platform Screen Doors in station for complete passengers safety
- Stations and vehicles equipped with video surveillance to improve passengers security



Intercom



Camera

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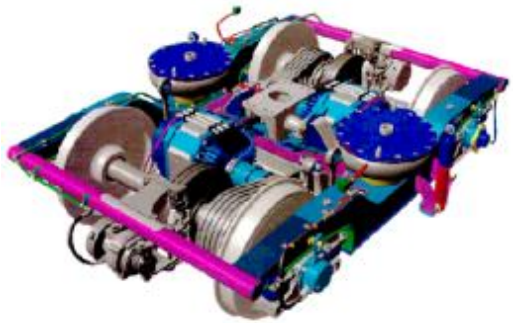
Open system

Since the early 80's, many types of light & driverless transport systems have entered revenue service

Nowadays, modern systems must be open systems



- Train/Track interface must be sustainable. Those interfaces cannot be modified along the transport system's life.
- AXONIS uses a standard track system with standard gauge of 1,435 mm (UIC) and floor height of 1,150 mm above top of rail providing customer freedom, for easy line extension or rolling stock fleet increase.

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INSIDE THE AXONIS SYSTEM Technical Focus

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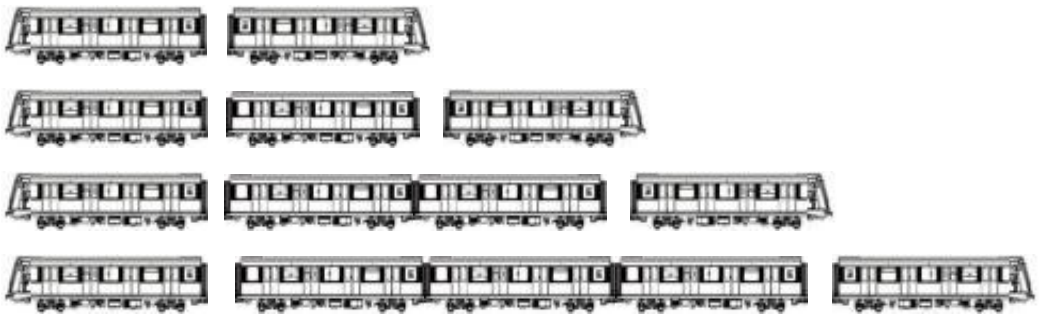
AXONIS: Flexible Train Configuration - Smart Metropolis

2 to 5 cars, steel wheels, 100% motorized



- Easier Transport capacity evolution
- Improved commercial speed
- Energy saving, full electrical braking
- Reduced maintenance costs
- 6% ramp, including recovery mode
- Reduced development and integration

- Driverless
- Steel wheels gauge 1435 standard
- 750 V_{DC} traction
- Car 2,71 * 18m
- 100% motorised
- Aluminium car body

- Severe environment (Brazil, India, MENA)
- Frontal or lateral evacuation
- Capacity about 200 pas/car at 6 pas/m^2
- 3 door 1,5m large per car
- slope 6%, curve 45 m

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Rolling Stock and System Capacity

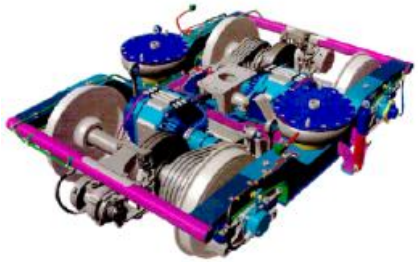
	Intermediate car	End car
seats	32	25
Total AW2 (4p/m²)	146	141
Total AW3 (6p/m²)	203	200

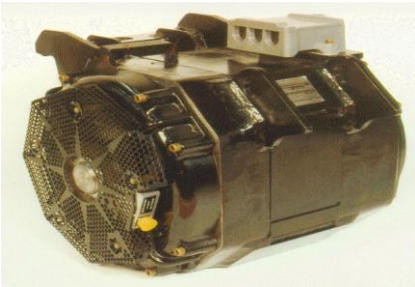
TRAIN CONFIG	2 cars	3 cars	4 cars	5 cars
Seats	50	82	114	146
AW2 @ 4pass/m²	282	427	572	717
ratio seat/stand	18%	19%	20%	20%
AW3 @ 6 pass/m²	400	603	806	1009
Train lenght	36m	54m	72m	90m

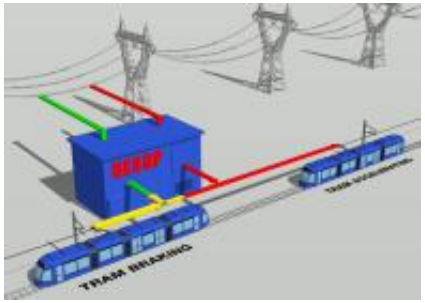
trains/headway	120	110	100	90	85	80	75	70	65
2 Cars	12 000	13 091	14 400	16 000	16 941	18 000	19 200	20 571	22 154
3 Cars	18 090	19 735	21 708	24 120	25 539	27 135	28 944	31 011	33 397
4 Cars	24 180	26 378	29 016	32 240	34 136	36 270	38 688	41 451	44 640
5 Cars	30 270	33 022	36 324	40 360	42 734	45 405	48 432	51 891	55 883

AXONIS: system optimisation transversal functions 1/2

- Traction energy saving & reduced maintenance:
  - up to 40%
- Steel wheels vs. rubber tires:
  - Lower energy consumption due to lower running resistance
  - improved by 20/25 %
- 100% motorized axles improve electrical braking by 15% *
- The reversible HESOP substation allows regenerating the excess kinetic energy not used on the dc network to the ac grid increasing energy savings by 18% on average







* UITP report 1997

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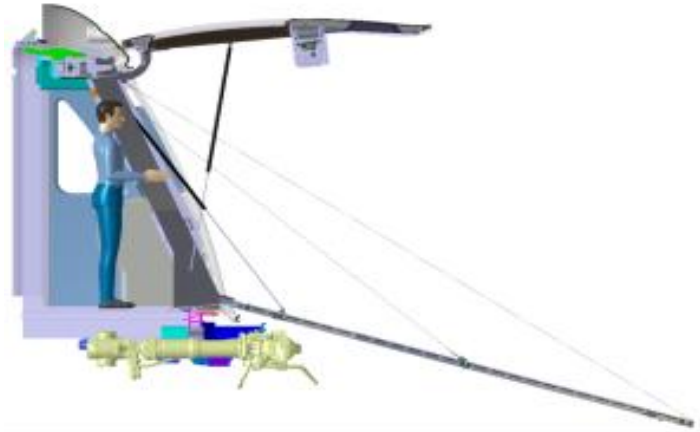
AXONIS : system optimisation transversal function 2/2

- Footprint and CW optimization
- Driverless: no driving cabin
- Trains equipped with frontal doors
- Track built using APPITRACK direct fixation method
- Providing wide, **safe & free walkway**
- Savings:
  - Viaduct width saving 1,2m to 1,8 m (20-25%)
  - Tunnels diameter reduction 0,7m to 1,2 m



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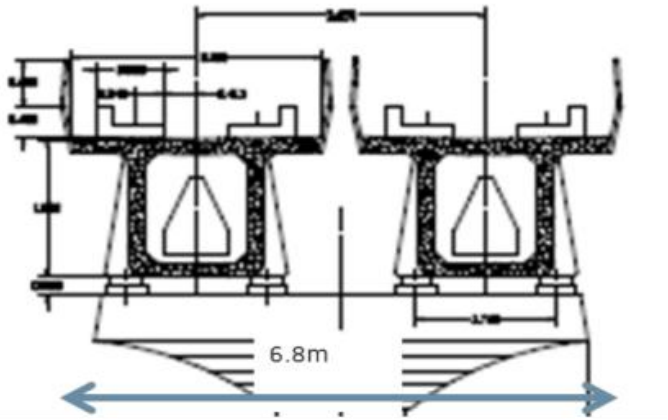
Viaduct and associated infrastructure

Faster construction and reduced footprint through

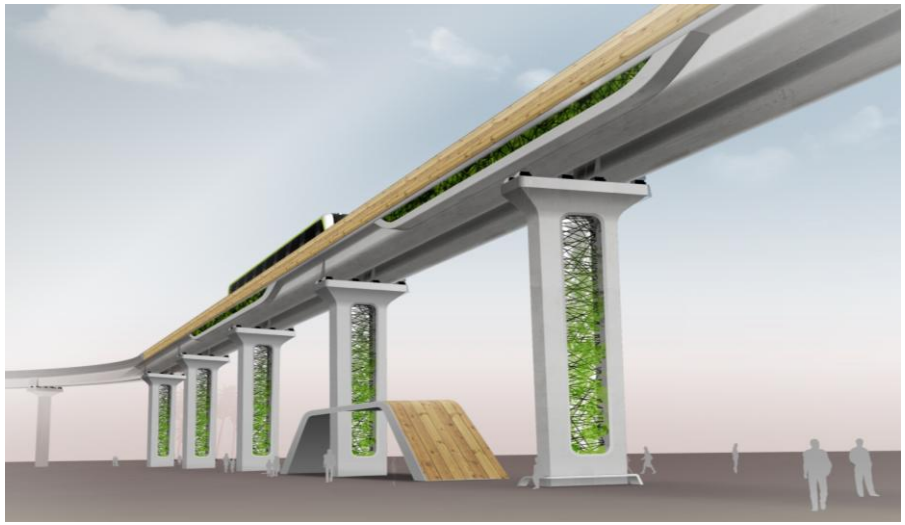
- Modular and standard elevated guideway: one **30-meter** long beam per day
- Designed for local pre-casting with **local civil works partner**
- Modules easily **transportable** into the city on road vehicles
- Standard-gauge track built with the service proven **APPITRACK** track-laying technology

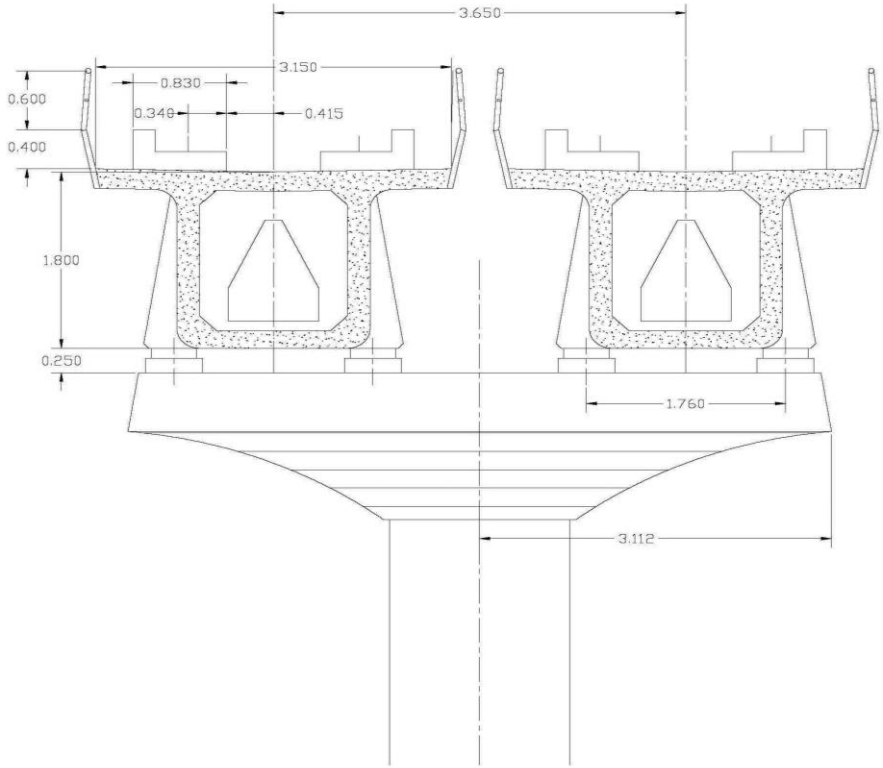


Viaduct and associated infrastructure

Simple but flexible design

- Typical 30m spans when the radius of the alignment is less than 200m
- Standard details for curves with small radius down to 45m radius. Possibility for portal piers.
- Maximum gradient of 6%

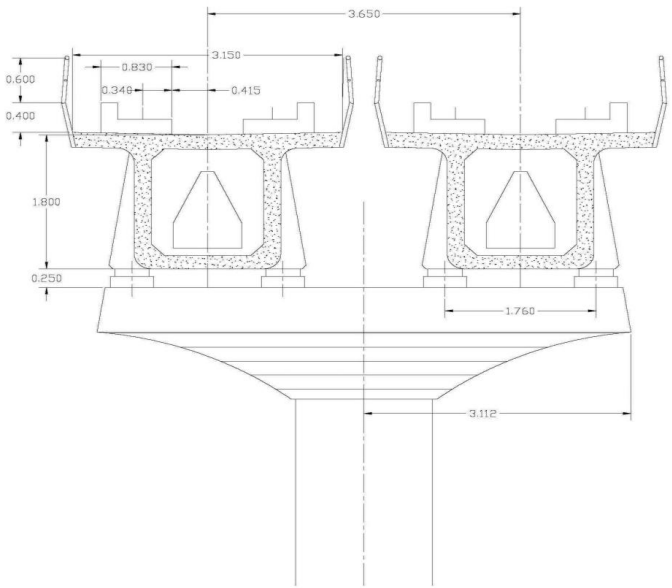




Viaduct and associated infrastructure

Small footprint

- Pier dimensions of 1.6m x 1.6m
- Viaduct only 6.8m wide with gap for light
- Possibility for central or lateral stations



Viaduct and associated infrastructure

Advantages

- Option of full span or segmental erection - 8m sections
- Erection by crane or by launching gantry
- Efficient design to reduce box beam weight - 120t per beam
- Standard long span solutions

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Viaduct and associated infrastructure

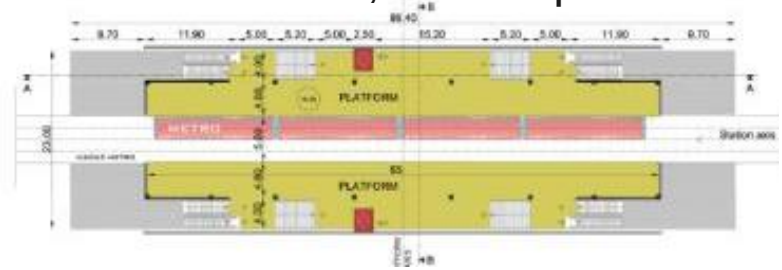
Maintenance

- Superstructure is made from durable, high strength low permeability concrete, pre-stressed to eliminate flexural cracking
- Superstructure is precast in factory like conditions with better quality control which limits undetected defects that may need to be addressed through maintenance
- Concrete structures do not require painting throughout their service life
- Fatigue stresses in the superstructure from repeated train loading are less critical for concrete structures compared with steel structures.

Summary Conclusions
AXONIS: A quick-to-build, easy-to-own light metro system

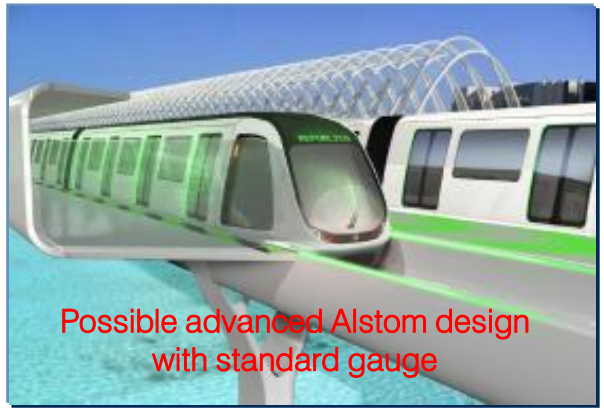
- Smaller footprint
  - Smaller station
  - Smaller trace in the city

85m for 40,000 at 6p/m²



Viaduct < 7 m

- Flexible and safe use
  - Compatible with viaduct, at grade, and tunnel operation
  - Frontal or lateral passengers evacuation
- Open system
  - For line extension
  - For capacity extension
- OPEX reduced
  - Energy consumption
  - Maintenance



- Fully proven system performances
  - **6%** Slope, **45-m** curve, capacity, availability of **99.7%**

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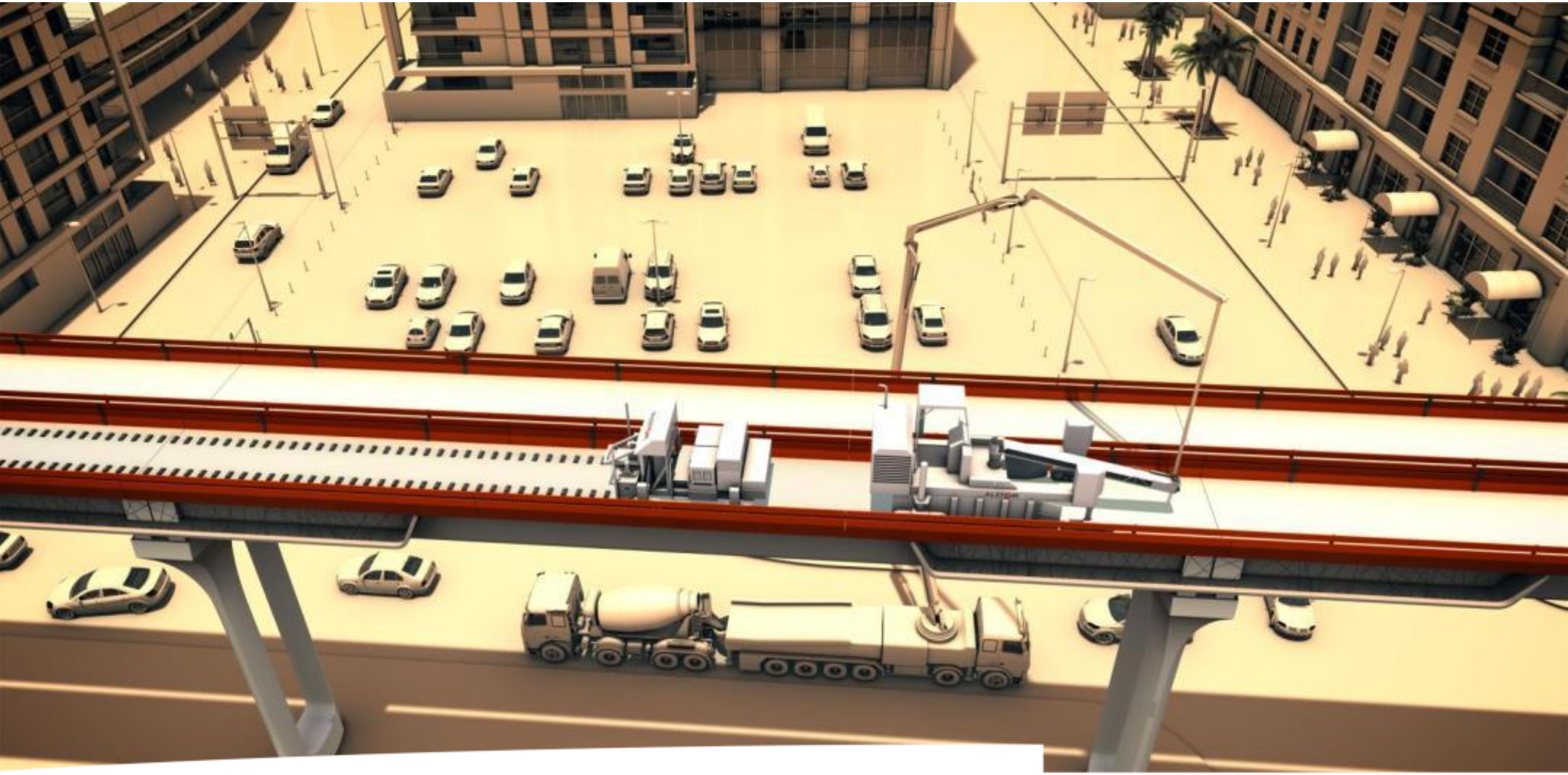

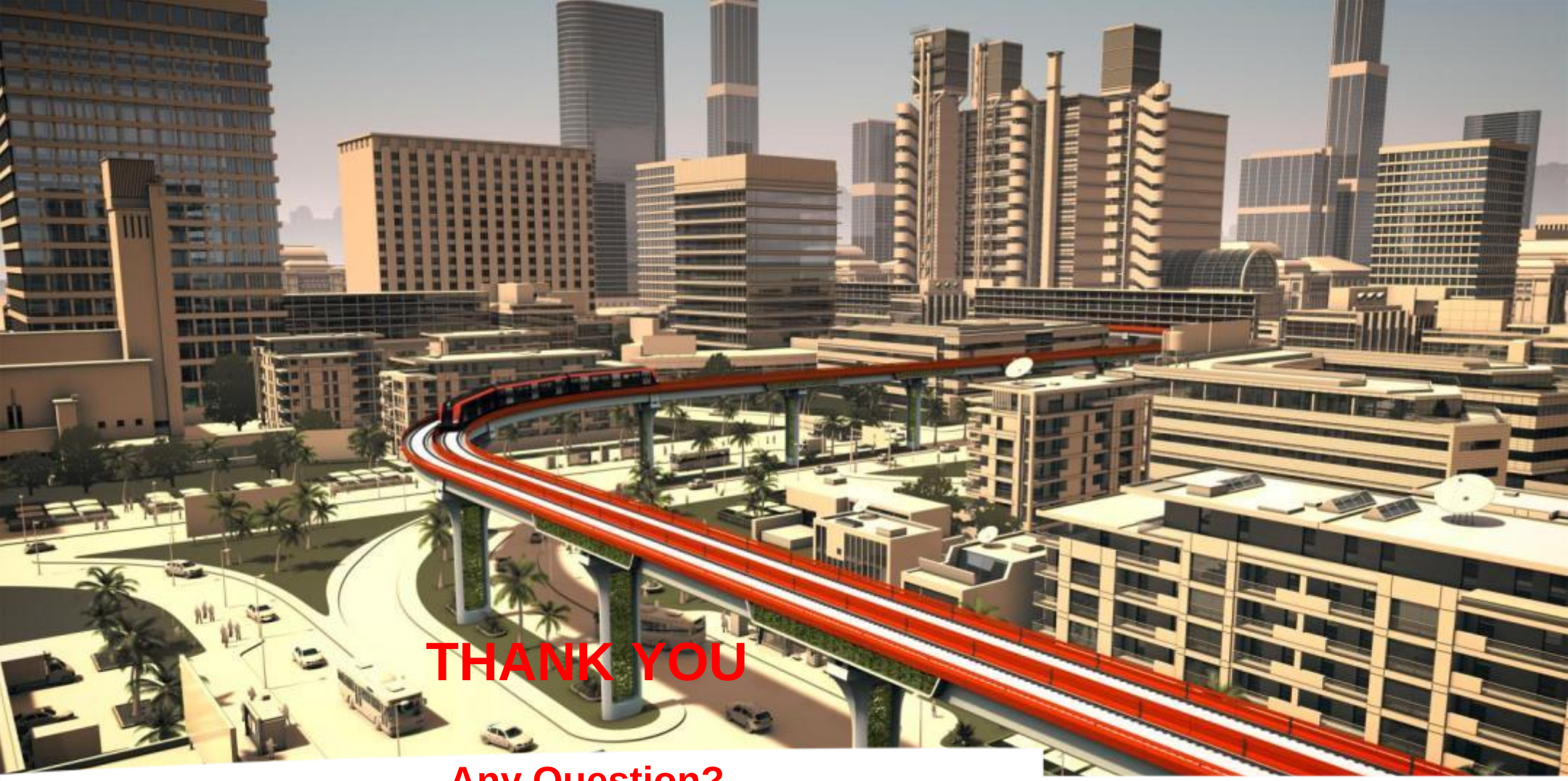

Any Question?

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