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Automation in urban public transportation

February 2016

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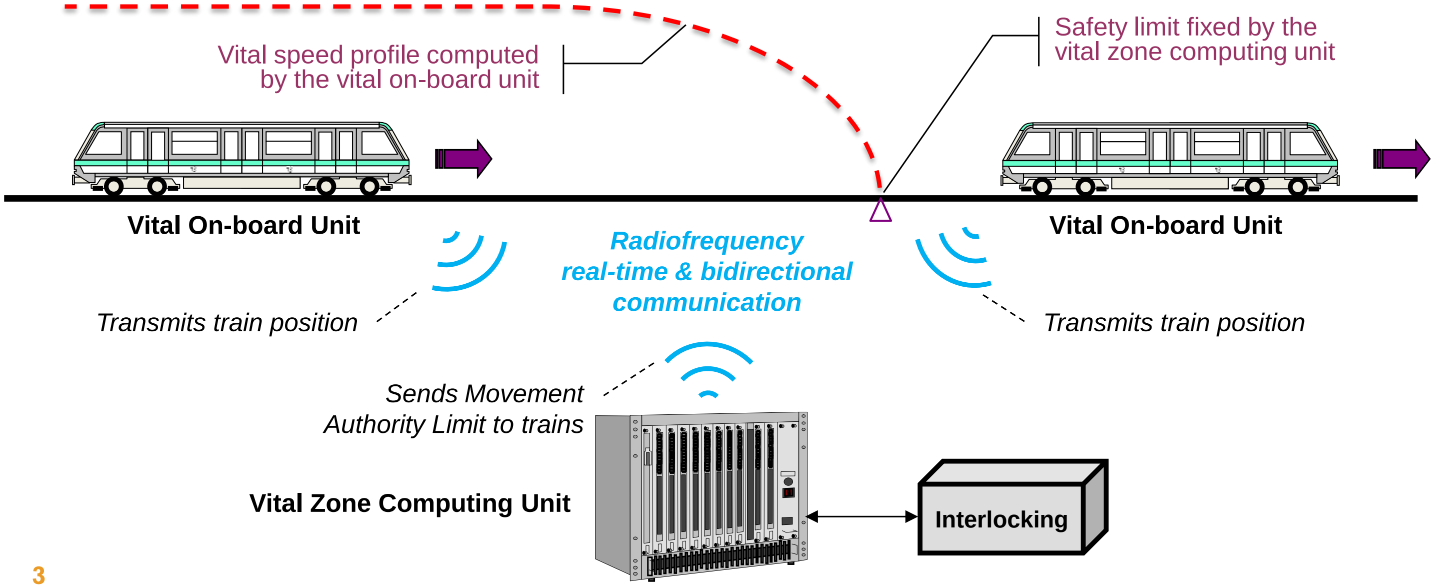
WHAT IS CBTC ?

Communication Based Train Control Systems

The new market standard for signaling systems

- Most often using radio frequencies for train to track communication



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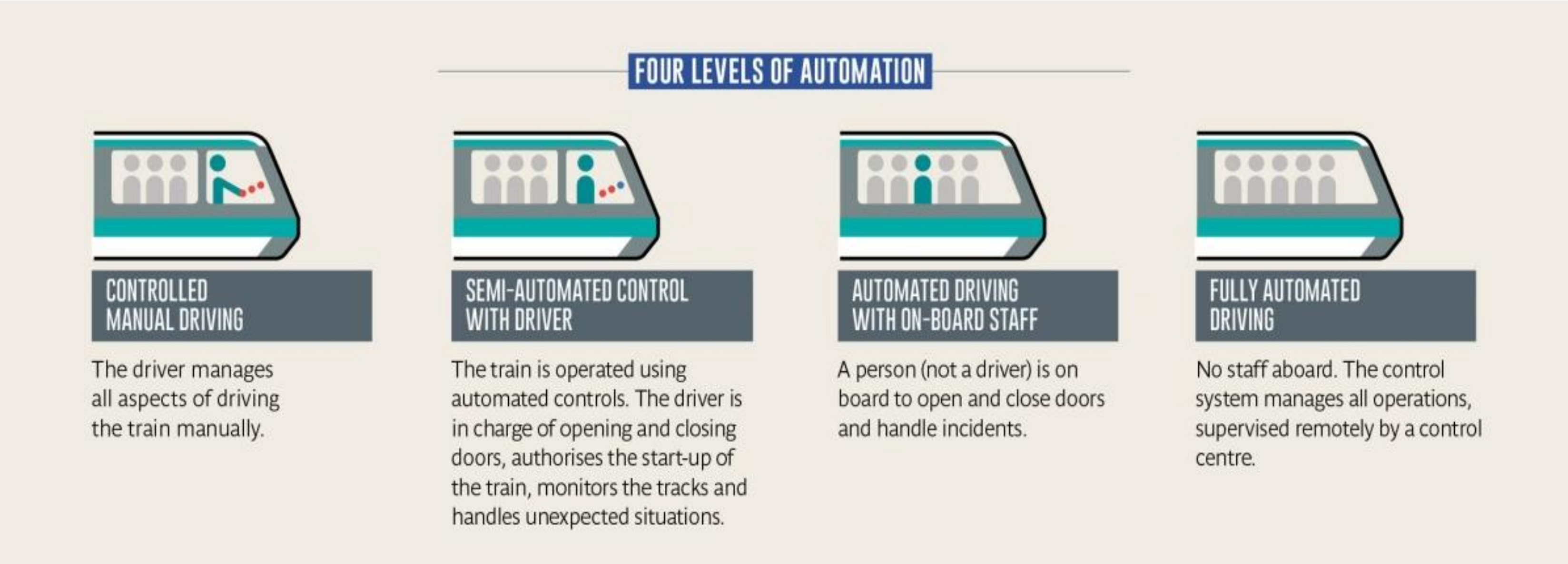
AUTOMATION
RATP’s ACHIEVEMENTS

Levels of automation



GOA1 | GOA2 | GOA3 | GOA4

RATP's first times

Automated metro is the result of a long story of innovation that began in the 50's.

1981: World first GOA4 lines (Japan)

1952

Ⓜ Network

1st ATO exp.

1967

1st OCC

1970's

90% of metro network is GOA2

1989

Line Ⓐ

World 1st First safety critical computerized system

1998

Line 14

World 1st GOA4 large capacity metro

2012

Line 1

World 1st automation of an existing line without major traffic disruptions

2015

Lines 3 5 9

1st new generation GOA2 lines, with CAB-Signal (5,9)

Line 14
1998

The first fully-automated large capacity metro

2 ACHIEVEMENTS

Line 14 construction

In 1987, RATP proposes a solution to relieve traffic on the RER A. Construction starts in 1992, first tests of the automated system begin in 1995 and the line opens in 1998.

SYSTEM VISION

A whole system to re-think :

- organization (maintenance and operation),
- Passenger service (stations, staff presence),
- And technical systems with new safety challenges

Large capacity auto. metro

Line 14 automated system prefigures modern CBTC *(Communication Based Train Control)*

TECHNICAL CHALLENGES

- Infrastructure designed for performance : Distance between stations, tracks (straight profile, chain profile)
- Safety criteria allocated on every system component
- Board/tracks data transmission via Magnetic Loops (ATP/ATO : Automatic train protection and automatic train operation)
- **Capitalizing on SACEM achievements** : encoded processor, industrialization of B method
- Innovations : Video surveillance by radio

Innovation lies above all in the operational management model.

Line 1
2012

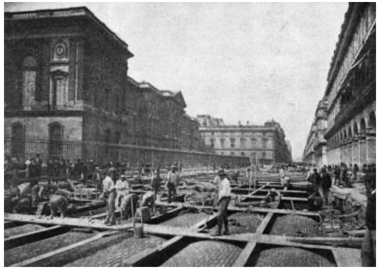
World first automation of an existing line without major traffic disruptions

Line 1 automation

Built in 1900, Line 1 is the oldest, fastest and most crowded line of the Paris metro network. It is heavy loaded during rush hours and also off-peak hours, weekends & holiday periods. In 2003, RATP launches an automation feasibility study.

Double challenge

Automation of **a 100-year old line without major traffic disruption**



A 100-YEAR OLD LINE

Old infrastructures and specific configuration, implying

- Renewal of all the signalling equipment
- Infrastructure adaptation (Energy, tracks, platforms)
- Curved stations management

NO TRAFFFIC INTERRUPTION

Automatizing a line without traffic disruption implies strong **operational constraints** :

- Work shifts of 3 hours per night
- Maintenance works “as usual”
- Mixed mode operation (trains with and without drivers)

Lines 3, 5, 9
2015

GOA2 new generation

New generation GOA2

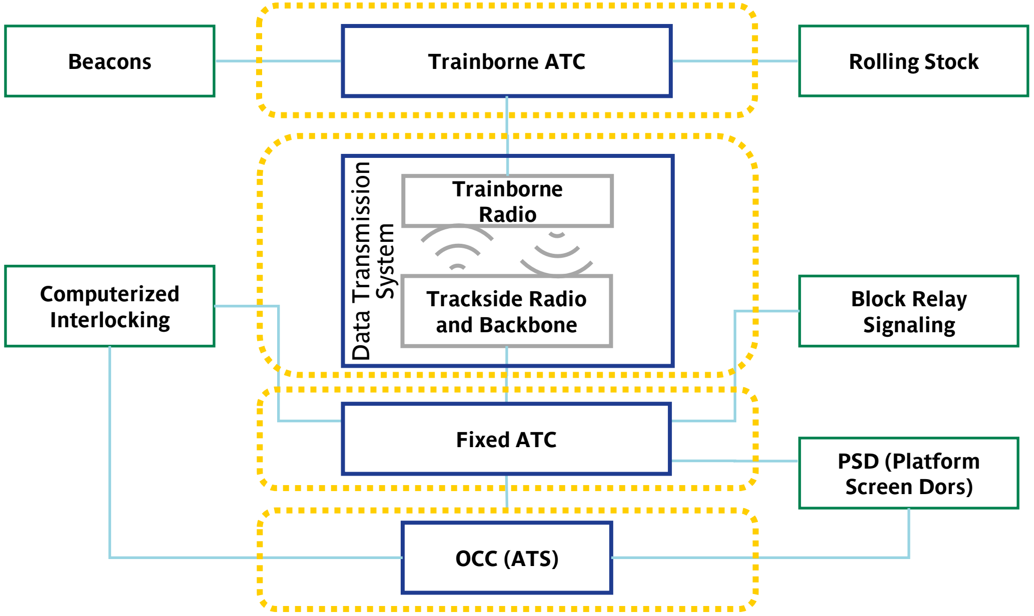
OCTYS principles….

MAIN FEATURES

- transmission via free propagation radio @ 5.9 GHz
- System architecture compatible with international standards (IEC62-290 & Modurban)
- Software safety demonstration by
  - B Method or
  - **Formal proof –** innovation

INTERCHANGEABILITY

4 Separate contract shares for GOA2 CBTC



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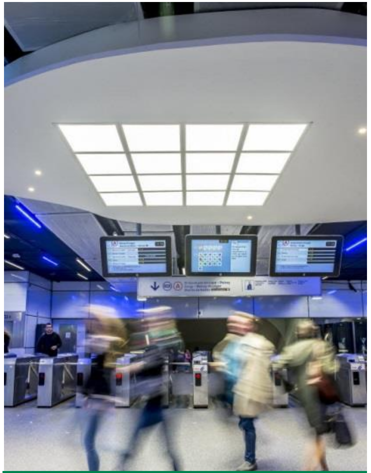
ADVANTAGES OF
THE AUTOMATED METRO

4 kinds of improvement

Automated system has many benefits.

Better Safety
(GoA2, GoA3, GoA4)



Better socio-economic performance (GoA4)

Better functional performance
(GoA2, GOA3, GoA4)

Better environmental performance

Better safety

0 accidents

No accident on automated line in Paris.

WARNING : The maintaining of drivers’ competences, which are needed during rare automated system breakdowns, is a major challenge.

Losing the barriers between the responsibility of the automatic pilot and the driver can prove to be disastrous.

HUMAN FACTOR

Compared error rates

- Human operator: 10-3/h
  (10-4/h if well trained)
- Automated system : <10-9/h

CONTINUOUS CONTROL

Signal passed at danger or overspeed are

- anticipated
- controlled
- And leads to emergency stopping of the train

TRACK/PLATFORM INTERFACE

Platform screen doors prevent technical incidents and accidents

Better OPEX

ADDITIONAL COSTS

- Maintenance of new functions and equipment

DIRECT SAVINGS

- Less staff to operate
- Less maintenance on trains (less traction / braking commutations for instance)
- Energy savings

OTHER SAVINGS

- Increased ridership
- Better service : less delay-related economic losses
- No more passenger accidents

Return on investment within 15 years (line 1)

3 ADVANTAGES of Automated metro

Functional performance

CAPACITY

- Reduces headway
  Line 1 and 14 can reach a headway of ***85 seconds***
- No more driver cabin (GoA4) : better train capacity

ADAPTABILITY

- Possibility to add more trains instantaneously
  Example : end of a music show
- Reduced marginal cost of operation (enables to increase the service off peak for instance)

+ 30% capacity

For Paris line 1 when converted to GoA4.

Headway of 100s all day long on line 1 during heavy maintenance work on line A during summer

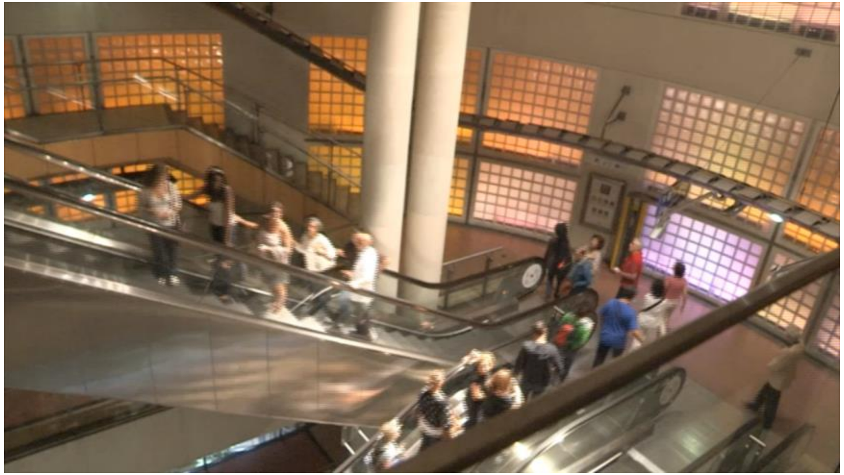
RELIABILITY

- Coasting and dwelling times are precisely controlled

RESILIENCE

- After an incident, back to normal within minutes

98% satisfied passengers



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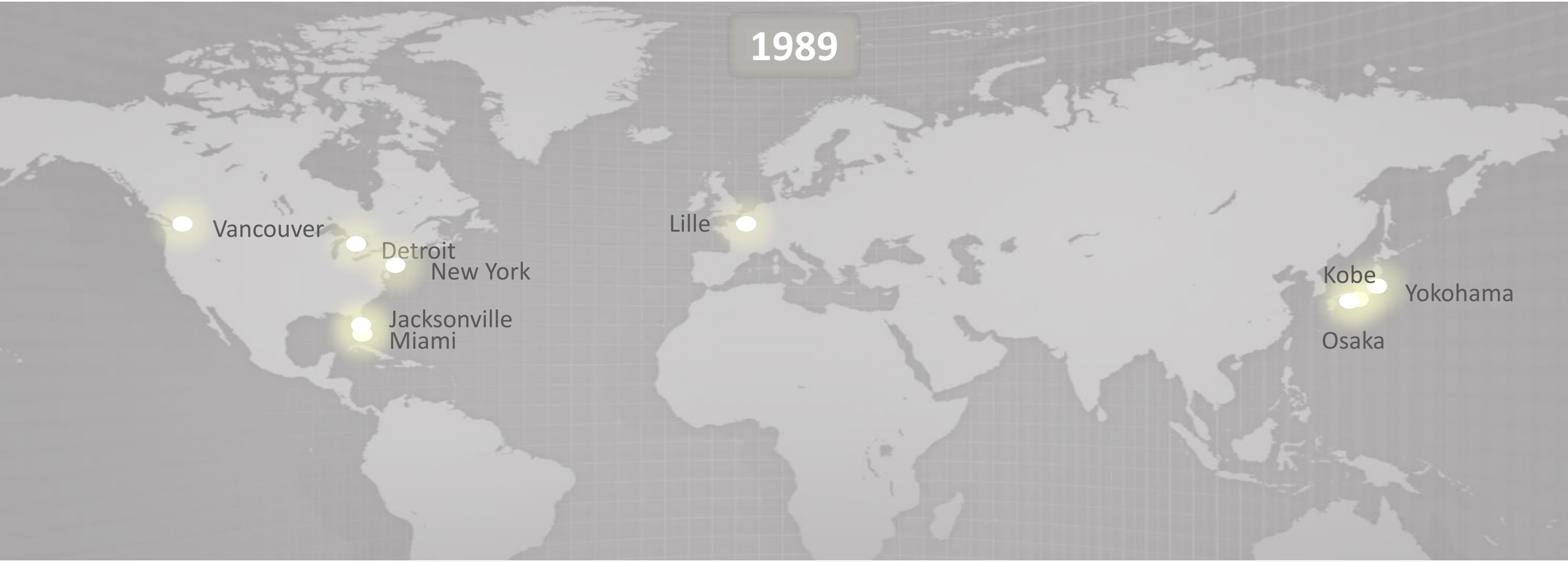
TRENDS AND EVOLUTION OF AUTOMATIION IN THE WORLD

UITP data from Observatory of automated metro

PIONEERS ERA: 1980-90

99 km



PIONEERS ERA: 1980-90

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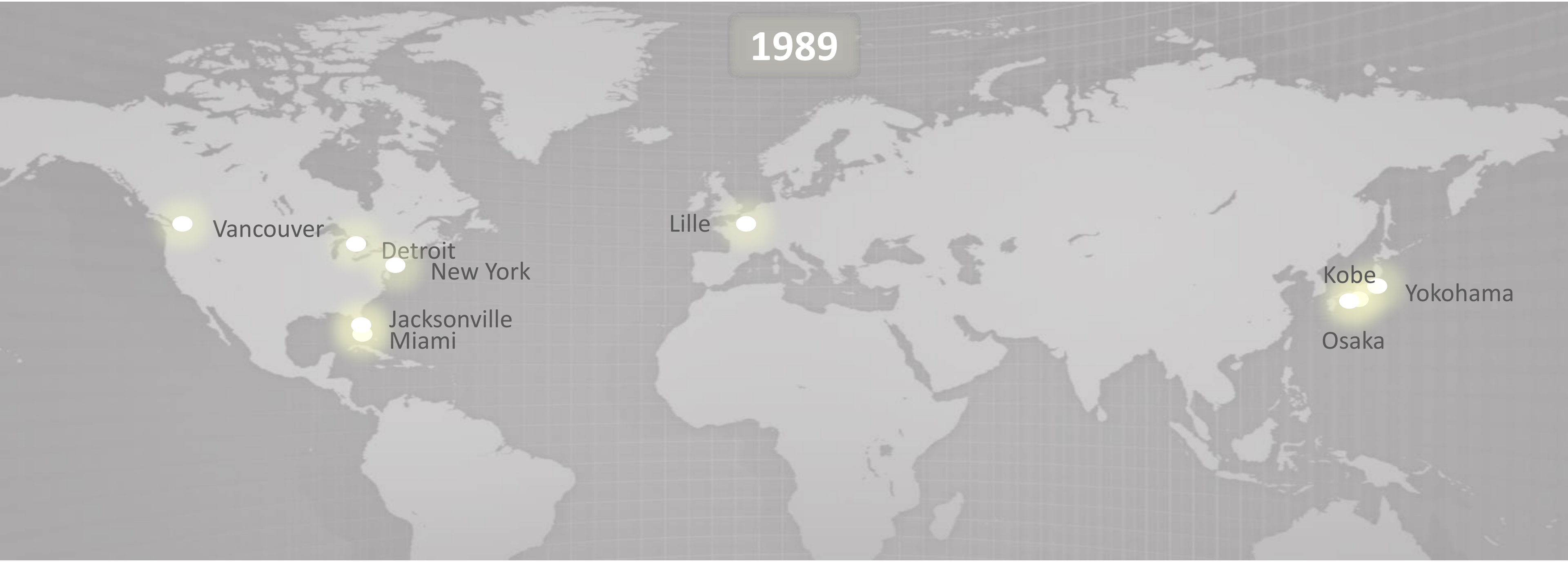
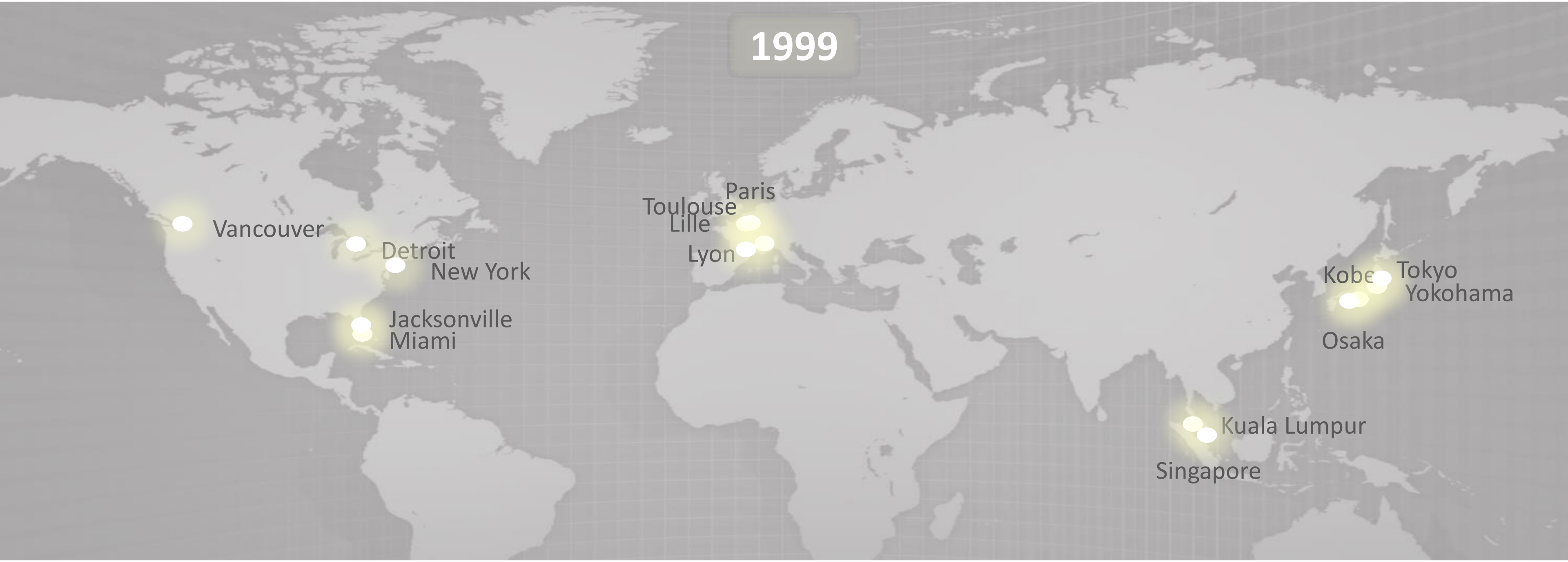


EARLY ADOPTERS: 1990-2000

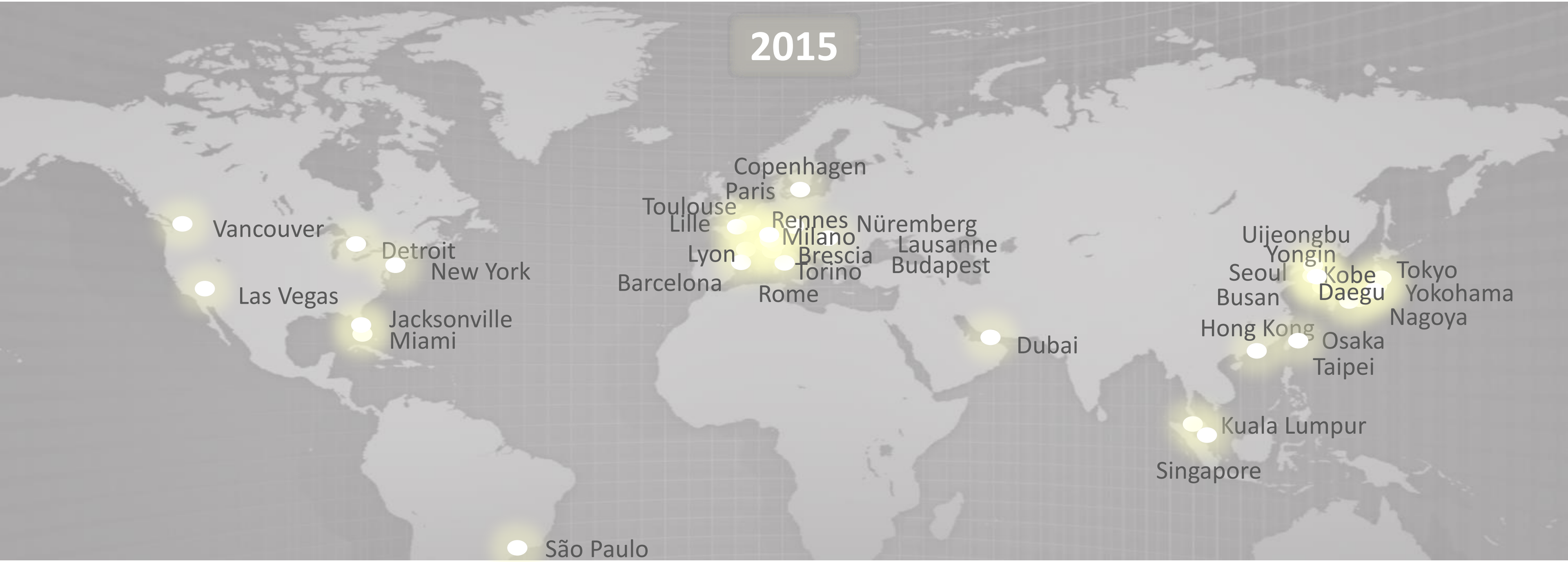
213 km



A PROVEN REALITY: 2000-2010

A PROVEN REALITY: 2010-TODAY

737 km



EXPONENTIAL GROWTH! 2014-2025

AUTOMATION TODAY

737 km

54 lines

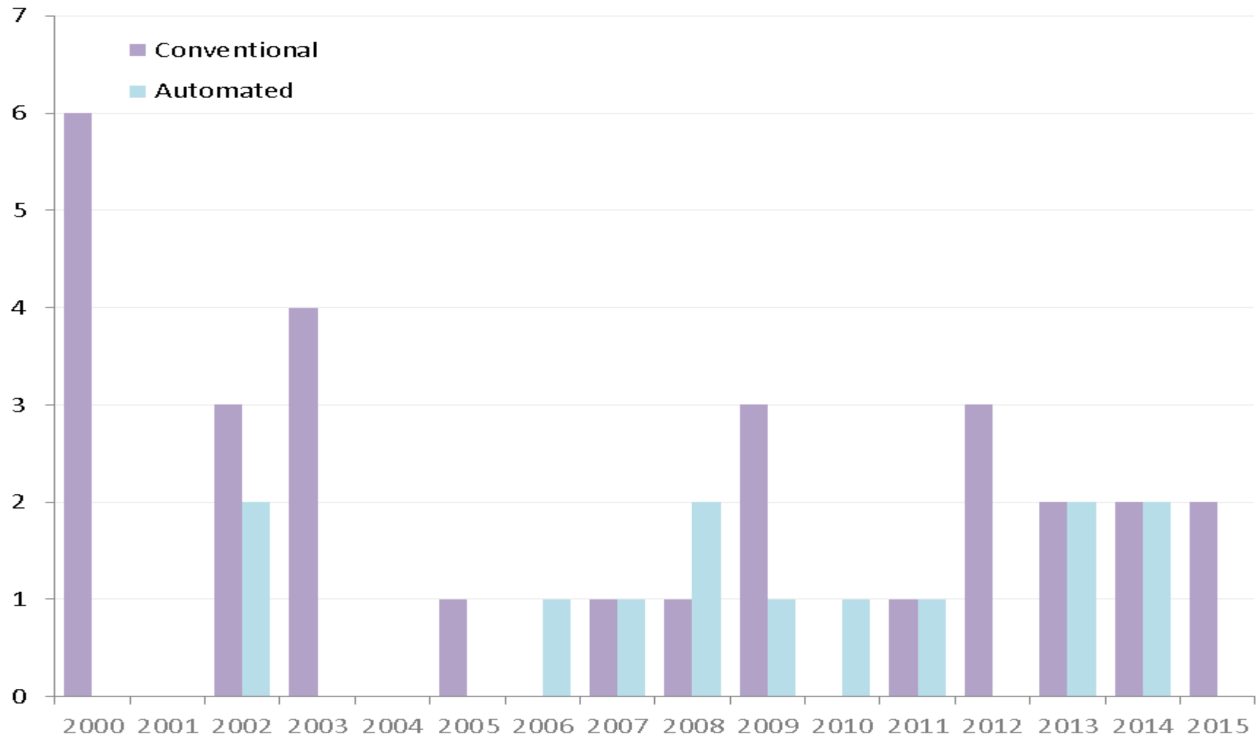
UTO today

785 st.

36 cities

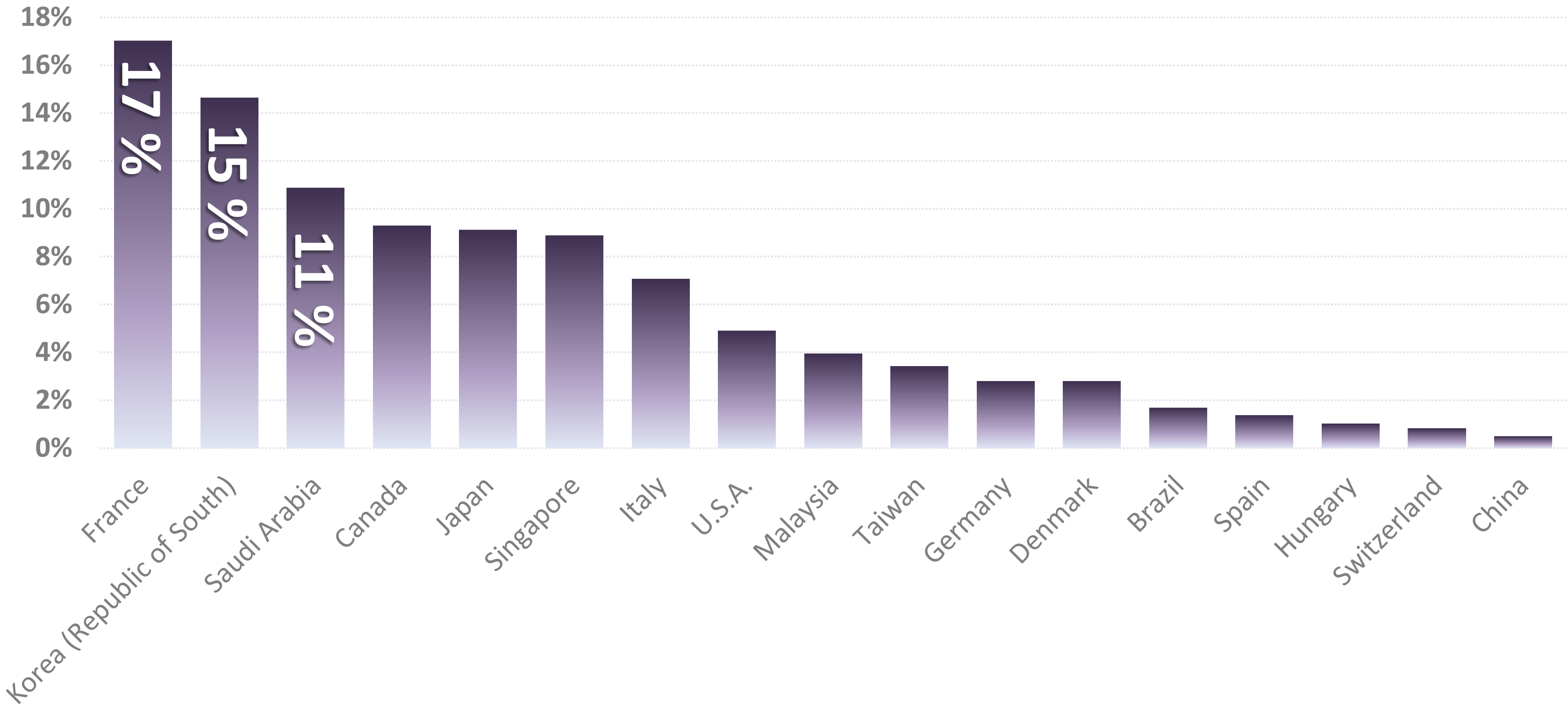
AUTOMATION TODAY

Europa New Conventional Lines vs UTO Lines



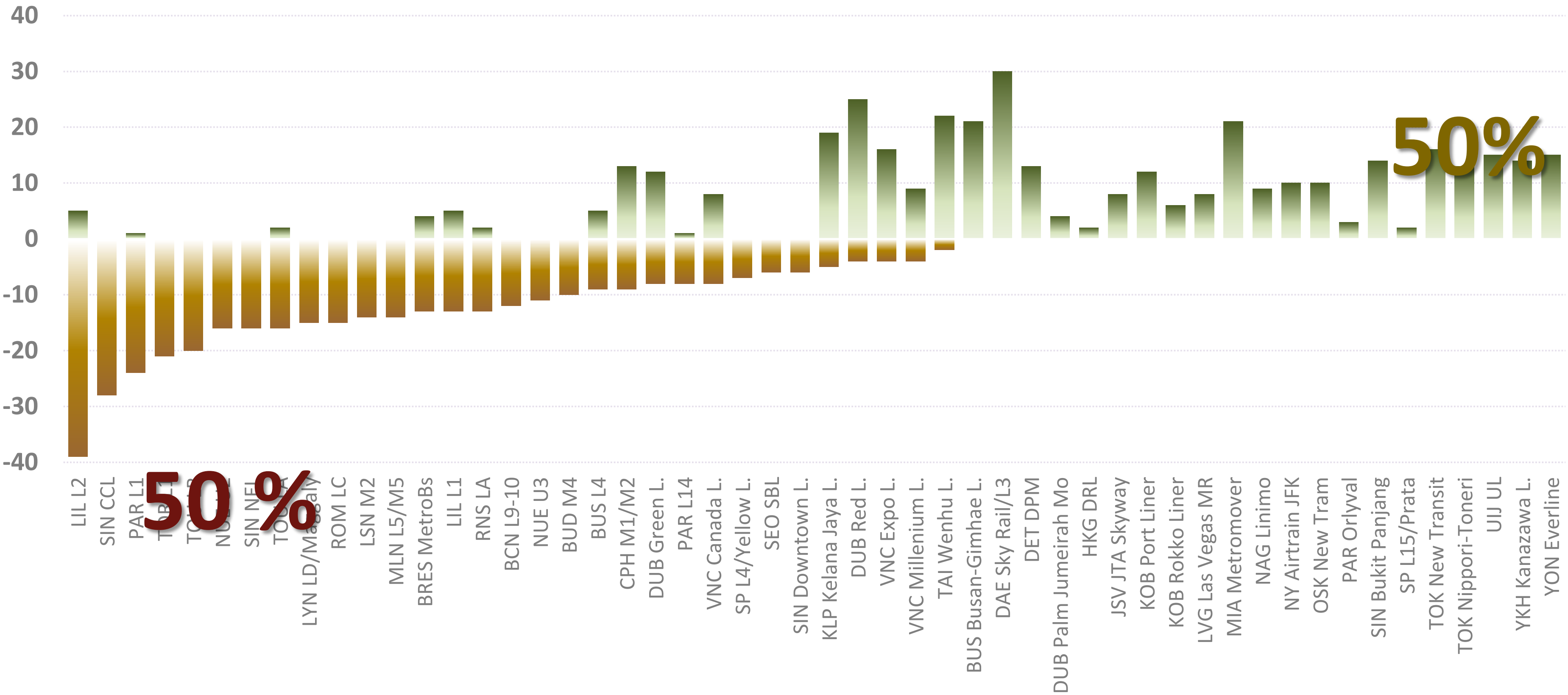
AUTOMATION TODAY

UTO % of km per Country



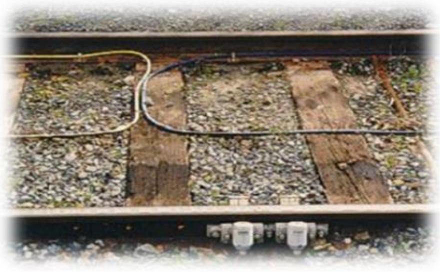
AUTOMATION TODAY

Constructive models: underground vs elevated (# stations)



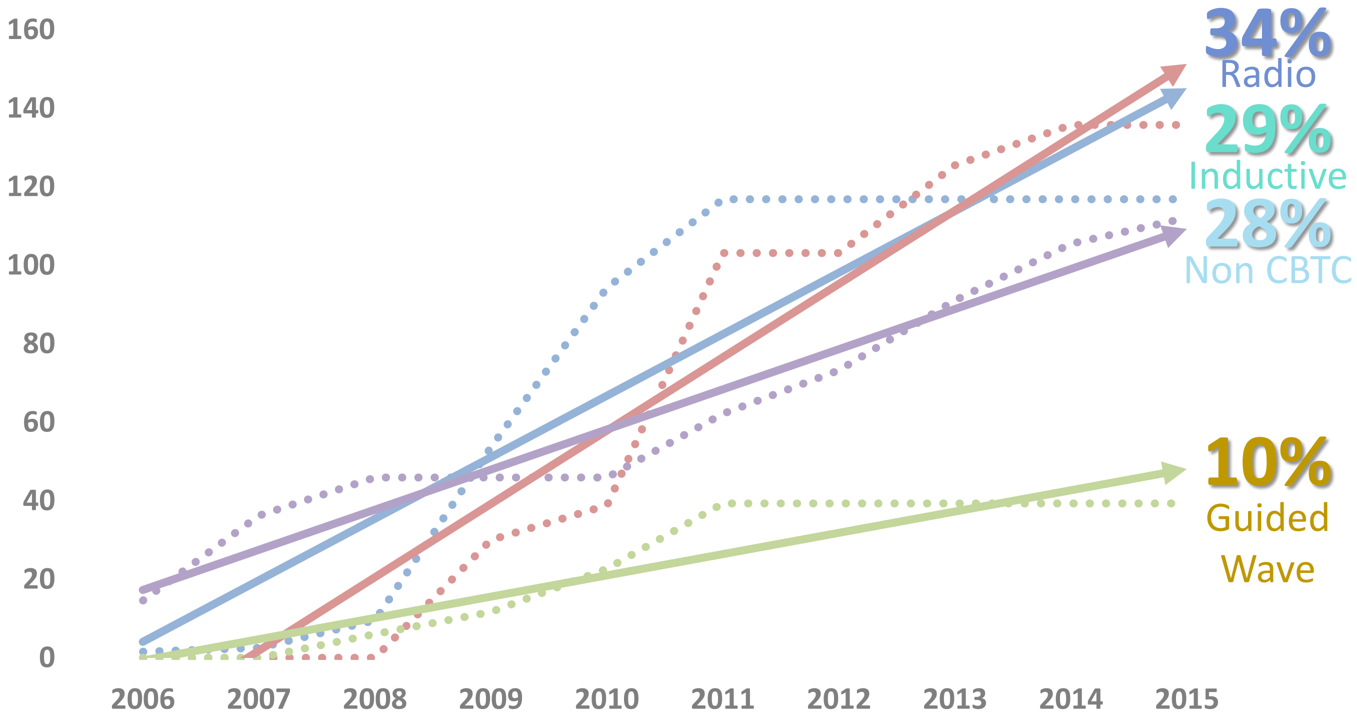
TRENDS & EVOLUTION

◉ Signaling Solutions: Share of Inductive loops – Radio - µWave



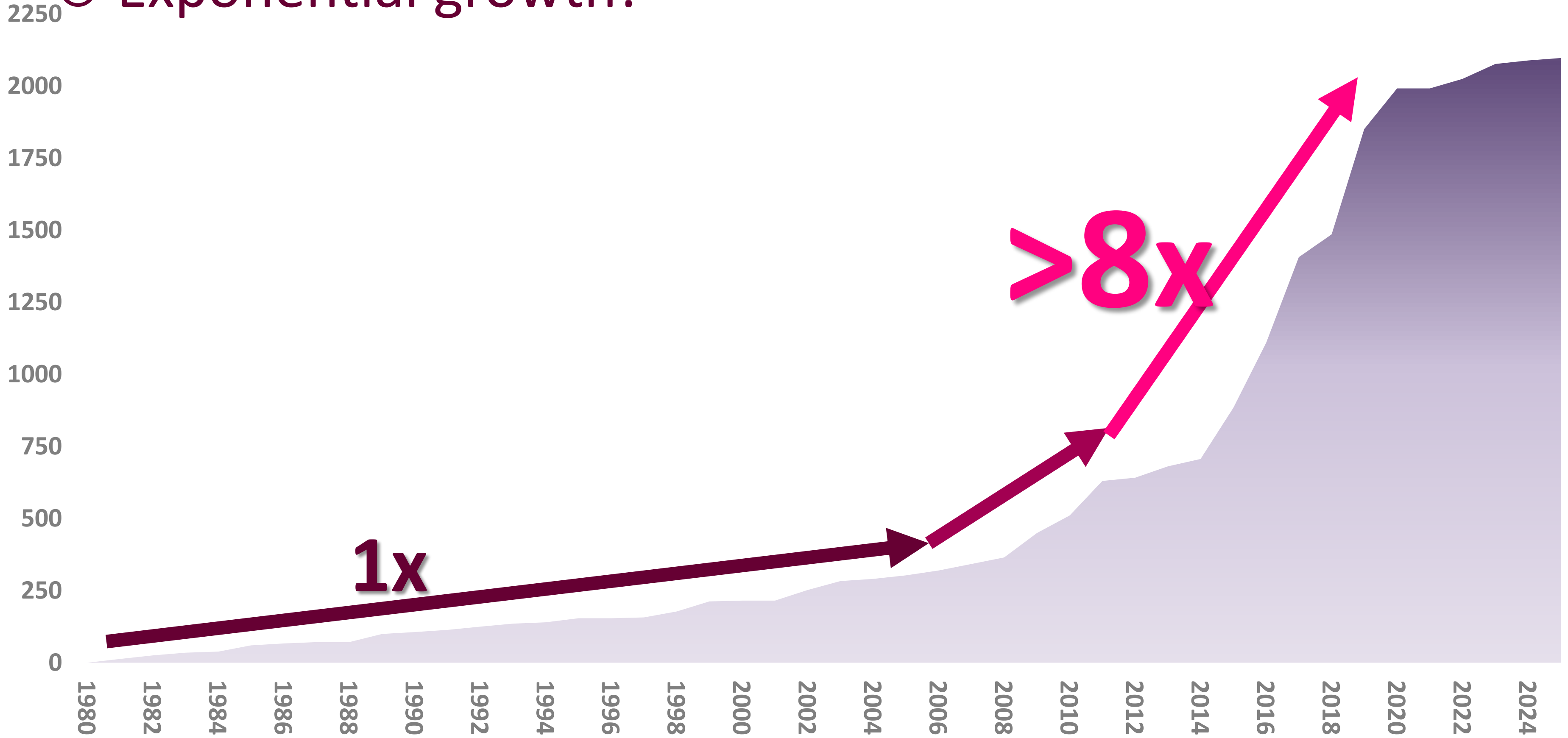
Inductive Loop

RF free propagation



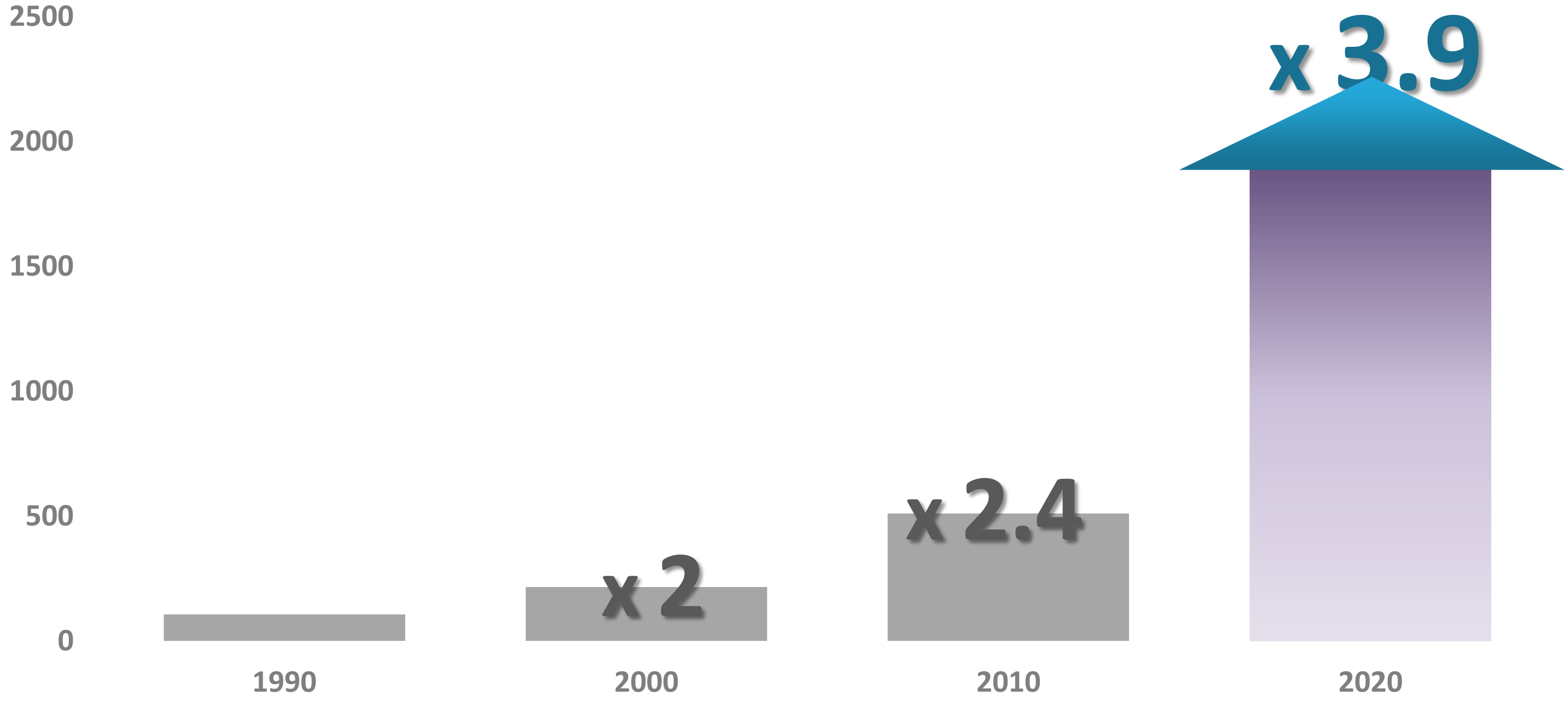
FUTURE: GROWTH

- Exponential growth!



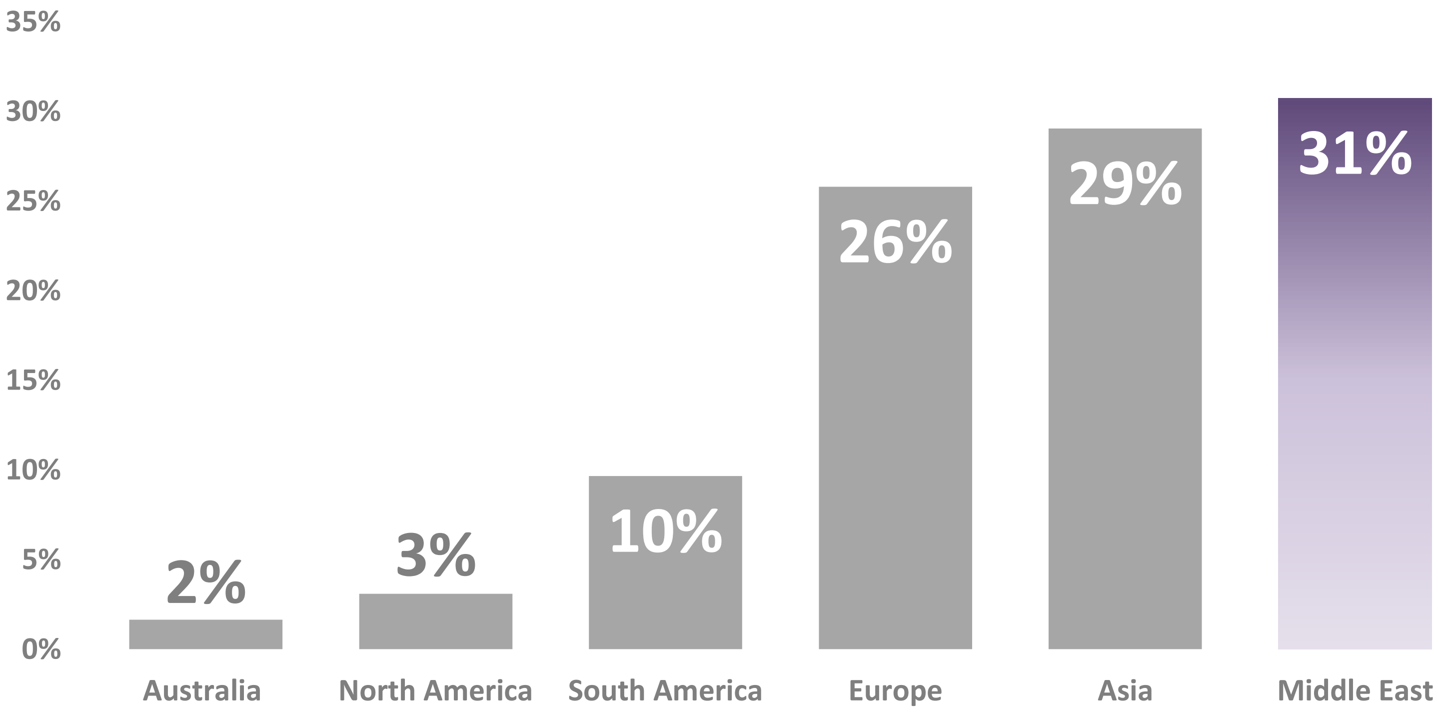
FUTURE: GROWTH

- Exponential growth! relative to previous decade



FUTURE: GROWTH

- Worldwide growth distribution *(% of new km’s 2015-25)*



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THE USE OF RADIO FREQUENCIES FOR SIGNALLING SYSTEMS

CBTC

Main criteria for radio frequency selection:

- Propagation (either in tunnels and in open air)
- Resilience (robustness to perturbations)
- Bandwidth (hundreds of kb/s required for CBTC)

Common applications:

- Wifi based 2.4 GHz (or 5.1-5.8 GHz)
  - Open band (ISM) but more and more saturated with commercial Wifi, Bluetooth and Zigbee applications
- Wifi based 5.9 GHz
  - Not (yet) saturated band but subject to local licensing
- LTE based frequencies (4G/5G)
  - Dependency to radio-communication operators

CBTC

Several EU countries already use radio communication systems in the 5,9GHz range :

- SNCF for freight trains : 5,915 GHz to 5,935 GHz
- RATP for Paris subway : 5,915 GHz to 5,935 GHz
- SYTRAL for Lyon subway : 5,915 GHz to 5,935 GHz
- Copenhagen : 5,925 GHz to 5,975 GHz
- Helsinki : 5,925 GHz to 5,960 GHz
- Malaga : 5,915 GHz to 5,935 GHz
- Lille : 5,915 GHz to 5,935 GHz

All on a limited duration licensing scheme

- depending on the local regulation authority

The threat :

Intelligent Transport Systems (ITS)

ITS include telematics and all types of ommunications in vehicles, between vehicles (e.g. car-to-car), and between vehicles and fixed locations (e.g. car-to-infrastructure)

- Already owning the 5.875-5.905 GHz band (decision ECC(08)01)
- With an option toward 5.905-5.925 GHz for future functionalities (confirmed in December 2012)

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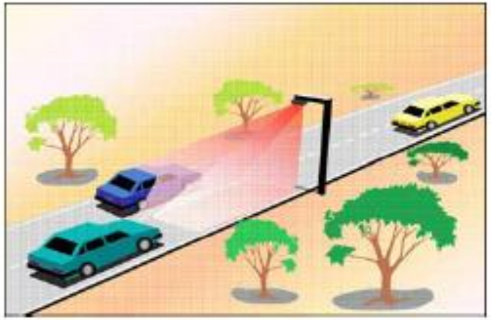
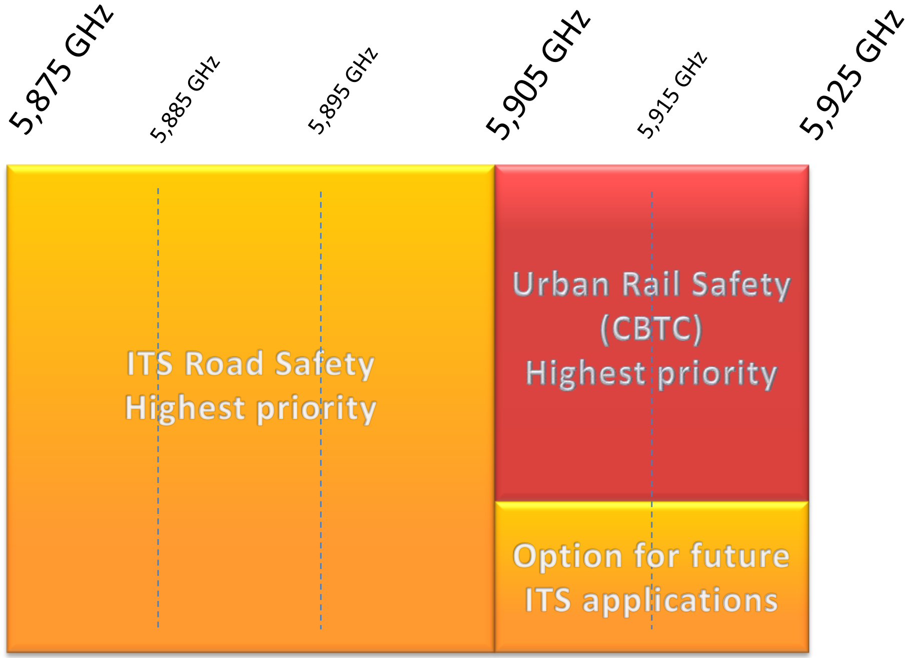


Conflicting bandwidth allocation



Position paper & Spectrum Users Group of UITP

23 November 2015

The automation of existing urban rail lines and the development of fully unattended metro operation (no staff on board) are booming and represent tomorrow's challenges in this sector. Millions of passengers use urban public transport every day (in Europe, 31,6 million daily passengers in 45 cities only for metro), and the European Union's modal shift objective means more people using public transport.

Metro automation is a …

- proven
- scalable
- adaptable

… solution that meets the needs of diverse mobility scenarios