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MEDIA BACKGROUNDER

METRO AUTOMATION FACTS, FIGURES AND TRENDS

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A global bid for automation: UITP Observatory of Automated Metros confirms sustained growth rates for the coming years

What is metro automation?

In metro systems, automation refers to the process by which responsibility for operation management of the trains is transferred from the driver to the train control system.

There are various degrees of automation (or Grades of Automation, GoA); these are defined according to which basic functions of train operation are responsibility of staff, and which are the responsibility of the system itself. For example, a Grade of Automation 0 would correspond to on-sight operation, like a tram running on street traffic. Grade of Automation 4 would refer to a system in which vehicles are run fully automatically without any operating staff onboard.

Grade of Automation	Type of train operation	Setting train in motion	Stopping train	Door closure	Operation in event of Disruption
GoA 1	ATP with driver	Driver	Driver	Driver	Driver
GoA 2	ATP and ATO with driver	Automatic	Automatic	Driver	Driver
GoA 3	Driverless	Automatic	Automatic	Train attendant	Train attendant
GoA 4	UTO	Automatic	Automatic	Automatic	Automatic

ATP - Automatic Train Protection ATO - Automatic Train Operation

In this document, the term **automated metros** is used for ***Grade of Automation 4*** systems, where there is **no driver in the front cabin of the train, nor accompanying staff** assigned to a specific train. This can also be referred to as ***Unattended Train Operation***, or **UTO**

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What makes automation possible?

Technical progress has made train control systems capable of supervising, operating and controlling the entire operational process. The key elements for this are:

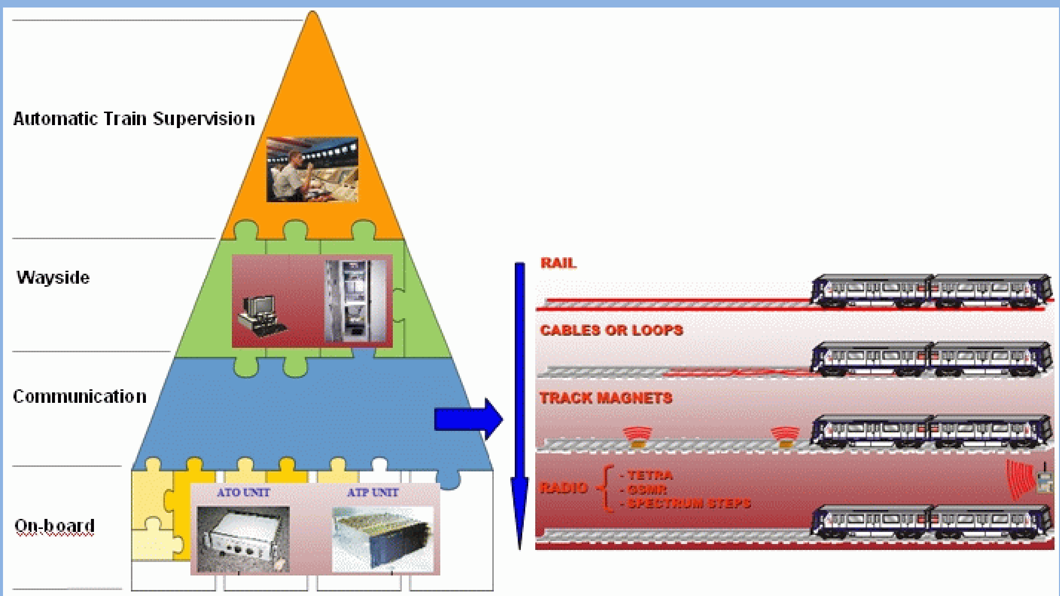
- **Automatic Train Protection (ATP)** is the system and all equipment responsible for basic safety; it avoids collisions, red signal overrunning and exceeding speed limits by applying brakes automatically. A line equipped with ATP corresponds (at least) to a GoA1.

- **Automatic Train Operation (ATO)** insures partial or complete automatic train piloting and driverless functionalities. The ATO system performs all the functions of the driver, except for door closing. The driver only needs to close the doors, and if the way is clear, the train will automatically proceed to the next station. This corresponds to a GoA2. Many newer systems are completely computer controlled; most systems still elect to maintain a driver, or a train attendant of some kind, to mitigate risks associated with failures or emergencies. This corresponds to a GoA3.

- **Automatic Train Control (ATC)** performs automatically normal signaller operations such as route setting and train regulation. The ATO and the ATC systems work together to maintain a train within a defined tolerance of its timetable. The combined system will marginally adjust operating parameters such as the ratio of power to coast when moving and station dwell time, in order to bring the train back to the timetable slot defined for it. There is no driver, and no staff assigned to accompany the train, corresponding to a GoA4.

At **Grade of Automation 4**, ATC systems work within an overall signalling system with interlocking, automatic train supervision, track vacancy detection and communication functions.

FOUR LEVELS FOR A FULL-SIZED AUTOMATED TRAIN CONTROL SYSTEM



→ **The Operation Control Centre (OCC)** supervises the overall train running and provides automatic train supervision (ATS) functions.

→ **The ATP, ATO and ATC functions are performed by on-board and wayside equipments which exchange data.**

Wayside level – providing automatic train protection (ATP), automatic train operation (ATO), electronic interlocking and track vacancy detection functions from the trackside

Train borne level – providing ATP, ATO and human-machine interface (HMI) functions on board the trains.

→ **Various types of communication between track and train.** Progress of Information and Communication Technology (ICT) means that traditional equipments such as induction loops or beacons are increasingly replaced by radio communication.

Why choosing metro automation?

Unattended Train Operation has many benefits and many beneficiaries: customers, operators, funding authorities and staff.

The implementation of UTO systems allow operators to optimise the running time of trains, increasing the average speed of the system, shortening headways up to 75 seconds, and reducing dwell time in stations (in optimal conditions) to 15 seconds.

Greater flexibility in operation

By taking the human factor out of the driving equation, operators gain flexibility and can make better use of assets. UTO systems offer a more tailored service coverage, reducing overcapacity supply at off-peak hours and enabling operators to inject trains in response to sudden surges in demand, for example in the case of big events.

Impressive safety records

UTO systems also offer safer operations by reducing the human-risk factor; well designed UTO systems have proven to be more reliable than conventional metros and hold an impressive safety record. Platform and track incidents aside, there has been only one operational incident in Osaka, at the end of the 80s, when a train did not stop at terminus and hit a bumper stop, provoking injuries in a few dozen passengers..

Increase in quality of service

Overall, passengers perceive an increased quality of service, thanks to the enhanced reliability of trains and shorter waiting times in platforms. The re-deployment of staff in stations also increases passenger's level of subjective safety and security.

Financial feasibility

For new lines, automation costs have a relatively low comparative weight within the overall budget. Main cost factors are mainly connected to the rolling stock, the signalling and control systems and platform and track protection systems:

- **Rolling stock**- An increase in commercial and average commercial speeds, reduced headways and the optimal distribution of reserve train sets along the lines translate in gains in the fleet. Thanks to higher reliability, it is possible to achieve more capacity with the same (or even reduced) fleet size; the technical reserve (spare vehicles) can also be downsized.
- **Signalling and control systems**- Full UTO represents a higher cost than traditional ATP systems. However, the current trend is to install CBTC systems on new lines – even with drivers (GoA2). The signalling technology being basically the same, the cost difference is marginal in the case of a new line.
- **Platform & track protection systems-** The need to replace the role of the driver in preventing platform and track incidents represents the highest civil engineering cost increase.

Metro also becomes affordable for smaller cities: when trains run more frequently, the system does not need to be "oversized" to cope with peak demand. Accordingly, civil structure works can be of smaller scale.

… even in the case of conversion

Line conversion poses a more complicated business case. It is necessary to factor in extra costs due to the technical difficulties connected to the modification of the existing signalling and control systems and the need to replace or retrofit existing rolling stock, as well as the increased cost and complexity of installing platform and track protection systems in older stations. To minimise its impact, conversion projects should be timed to the end of the life cycle of the existing equipments. For conventional lines that upgrade to UTO in parallel with the renewal of rolling stock or signalling equipment, it is estimated that the return on investment period is around 10 years. (The automatism costs being offset by gains in rolling stock fleet, this figure refers to the extra cost of retrofitting PSD into existing stations). For more details on conversion, see the dedicated section to Paris Line 1.

Operational cost factors: staff & energy gains

When factoring in operational costs, automated lines come clearly ahead of conventional lines; some studies indicate a halving in operational costs. Staff costs are greatly reduced thanks to the abolition of the drivers' function, even in cases of line conversion, when staff is likely to be retrained and deployed to other functions. Acceleration and deceleration patterns can be adjusted to reduce energy consumption and maximise energy recovery, thus significantly reducing energy costs. While maintenance costs are marginally increased due to the introduction of platform and track protection systems, the overall balance is positive thanks to the gains in personnel and energy costs.

Holistic efficiency and organisation opportunities

Implementing UTO (as a new system or retrofit of an older line) is a major milestone in the life of the operating company. The introduction of a more sophisticated computerised system and Operation Control Centre (OCC) should be an opportunity to review most operation processes and assess how they can be improved and "plugged in" to the system in order to extract maximum benefit from the data process capabilities installed, and also yield better performance at optimised costs. The main operation areas likely to be affected are: operation resource planning, staff training, rolling stock management, maintenance management, quality management.

Job profile change

The introduction of UTO requires some significant changes to the qualifications of staff. Routine driving work disappears and staff is no longer locked inside a cabin, but deployed along the line and in contact with customers. Front-line staff needs a customer-oriented profile and some technical knowledge to be able to reset defective equipments (e.g. escalators) or drive in case of failure. OCC staff requires demanding qualifications and skills to be able to perform emergency operation without the support of on-board staff.

In general terms, staff in a UTO line acquires a deeper knowledge of all the key systems, as well as a global overview on the functional interactions among them, allowing for professional growth. In automated lines, operational staff tasks also evolve towards maintenance. Two fields of activity totally separated in a traditional line merge, having a positive impact in the staff (who has a more diverse profile) and the line.

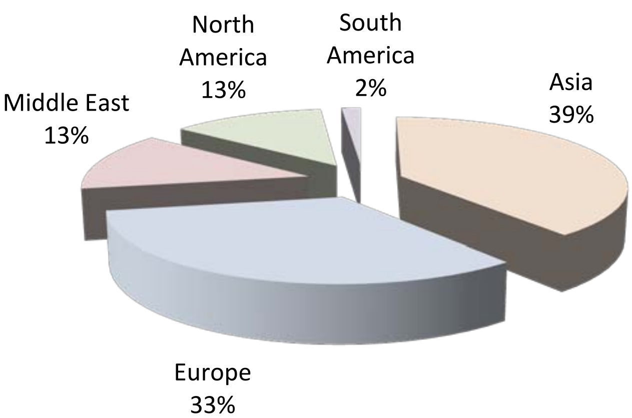
As a consequence, UTO raises the attractiveness of the job profiles, and of the operator company as an employer, contributing to staff motivation. In those systems where it is possible to compare with conventional lines, the indicators show that UTO line staff are more satisfied with their job and translate into reduced levels of absenteeism.

Automation landscape- Key facts, figures and trends

Unattended train automation is a widespread solution – 25 cities have opted for automated metros, in all 4 continents (fig. 1). The highest prevalence is in **Asia** and **Europe** (see fig. 2) but North America, and more recently **South America** and the **Middle East** are developing automated metro systems.

Figure 1: Cities with automated metro lines, as of 2011.

Figure 2: Geographic distribution of automated lines, as of 2011



Apples and pears…

the Atlas criteria

The indicated data correspond to:

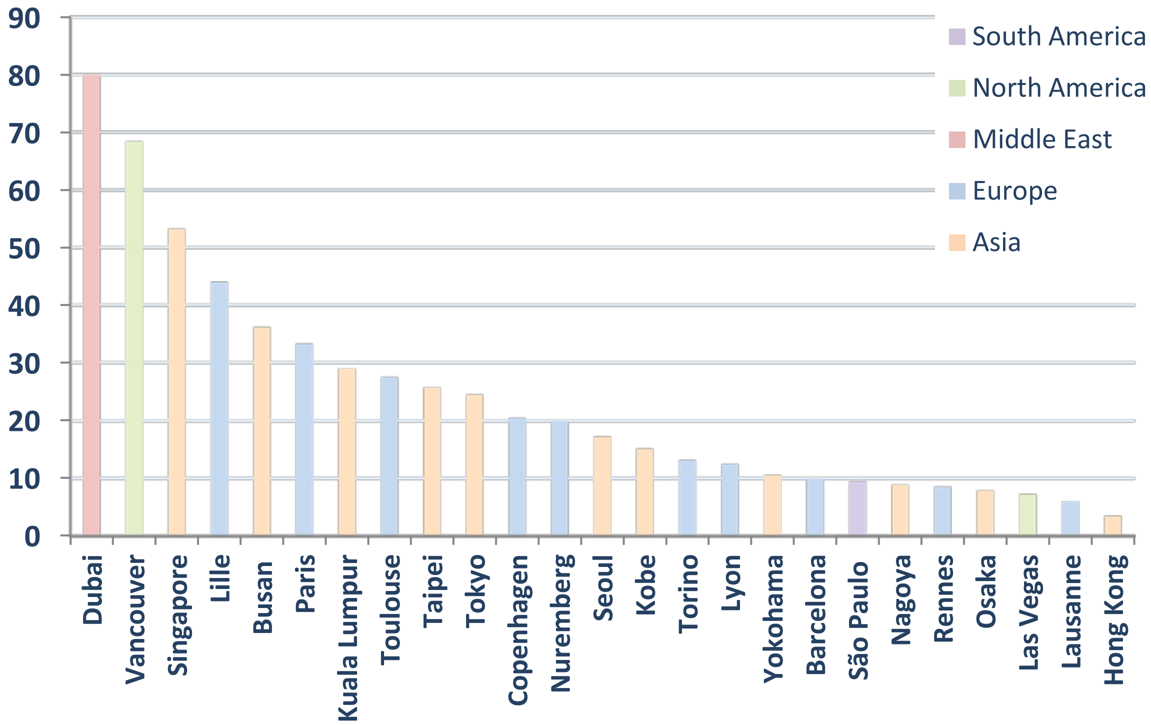
- **UTO -** Only metro lines without staff on board have been considered (GoA4 according to IEC 62267)
- **Public transport service -** Private lines have been discarded (airport services, people movers, etc.)
- **Train capacity –** Only trains with a minimum capacity of 100 passengers have been considered

Unattended train automation is a proven solution – UTO is associated to innovation, and the public belief is that it is a very recent development. However, the first UTO lines date from 1981. With **30 years** of operating experience, automated systems have proven their maturity and accumulated extensive operating experience.

Key figures – There are currently **588 km** of automated metro in operation, in **41 lines** that together serve **585 stations**. Some of the longest metro lines in the world are actually automated (see figure 4).

Of the 25 cities with automated metros, **13 have more than one automated line**: Barcelona, Busan, Copenhagen, Dubai, Kobe, Lille, Nuremberg, Paris, Singapore, Taipei, Tokyo, Toulouse and Vancouver.

Figure 3: Km of automated metro in 2011, by city



WORTH NOTING…

Some developments are not included in these figures (since they don't fully comply with the stated Atlas criteria), but deserve to be noted, as they point to a bid for automation in significant areas:

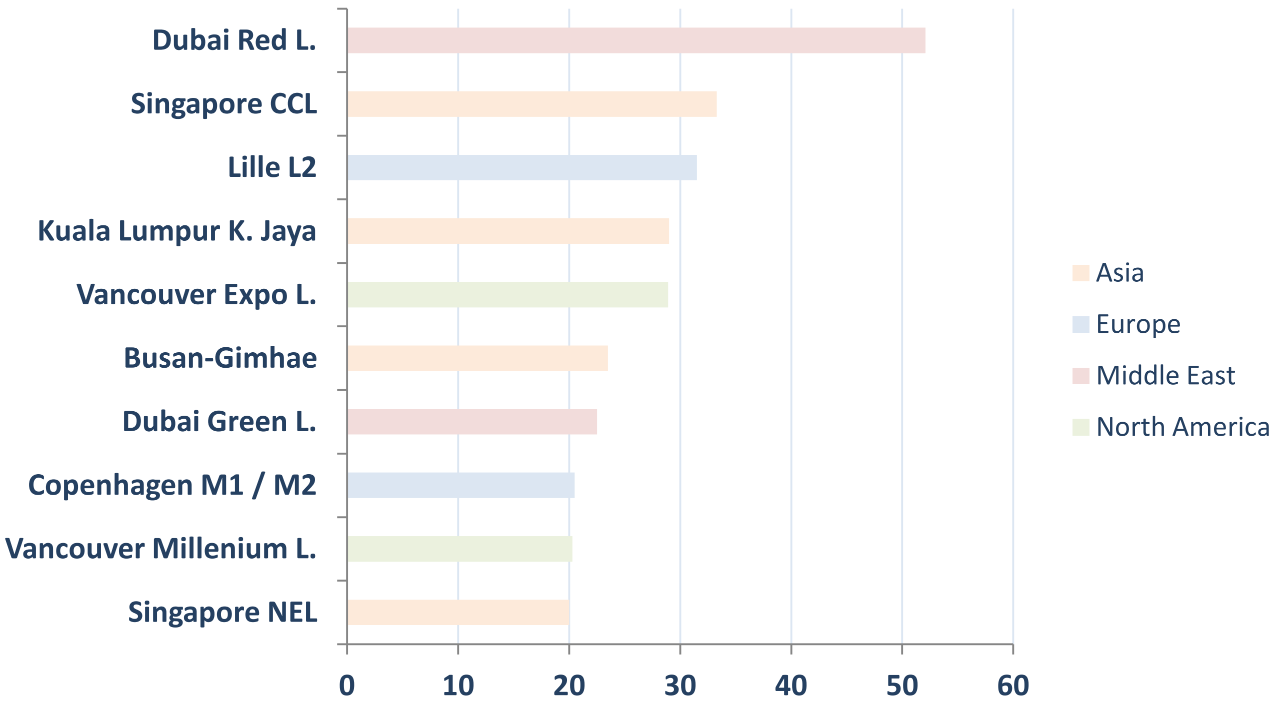
Shanghai Metro Line 10 (30 km), designed as UTO but at the moment operating in manual mode, signals to the Chinese interest for UTO.

Two further lines in Middle East confirm UTO as the preferred option in this region:

- **Makkah** (18 km), conceived as well as a UTO line, but not yet operating as such, represents a bid for UTO to solve one of the most critical mobility issues in this region.
- **Ryadh** (12 km) cannot be classified as a public transport system as it serves only a university campus. However, it is worth noting, due to its capacity and dimensions.

Taking these developments into account, total **UTO figures** reach **648 km** and **644 stations**.

Figure 4: The 10 longest automated lines in operation, 2011 (length in km)

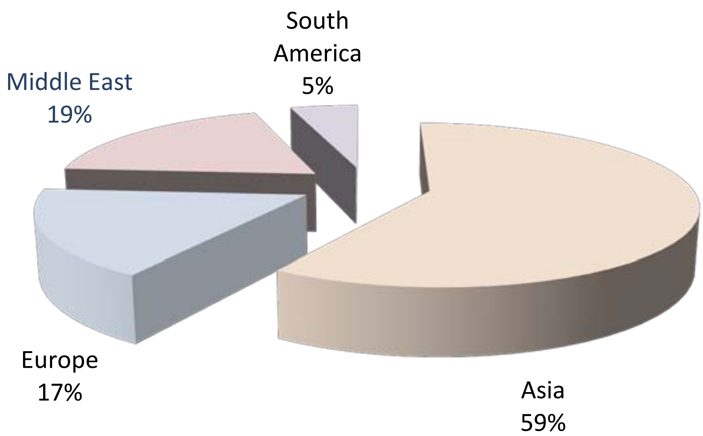


Automation 2011 – historic achievements & growth

119 km. 2011 has brought the greatest growth in the history of UTO; over 100 km of automated lines inaugurated in a single year.

Significantly, most of this **growth** takes place **outside Europe** (**83%**); Asia stands out with 70 km. Middle East also presents high growth numbers, particularly when the 22,5 km of Dubai are complemented with the lines in Makkah and Riyadh (totalling in this case 52 new km in 2011).

Figure 5: UTO km inaugurated in 2011
Geographic distribution



4 new lines join the UTO club; in **Busan** Lines 4 and Busan-Gimhae LRT, Green Line in **Dubai**, and Shin Bundang in **Seoul**

Figure 6: Cities inaugurating new lines and extensions in 2011

Getting longer - **21 extra km in existing lines**, with expansions in Sao Paulo (Line 4), Torino (Line 1), Barcelona (Line 9) and Singapore (North-East Line and Circle Line).

Paris L1 is converted

In 2008 Nuremberg completed the first conversion project, but in 2011 Paris Line 1 demonstrates that it is possible to convert high capacity lines without service interruption, opening the way to many more projects. Line 1 serves along its **16.6 km** three *départements* (Paris, Val de Marne, Hauts de Seine), six *arrondisements*, and six *communes*- that is, 280,000 inhabitants and 330,000 jobs on a catchment area of 500m from the line. It is Paris' Metro most frequented line, with **725,000 daily passengers**, or 207 million yearly passengers – over 50% of them non-Parisian residents.

Line 1 is 25 stations, 13 of which offer connections to other major transport lines: 11 metro lines, 4 RER lines, 1 light rail line, 2 SNCF stations. It serves **16 of the 50 most heavily charged metro stations**, as well as **5 major interchange nodes**: La Defense, Charles de Gaulle-Etoile, Châtelet, Gare de Lyon and Nation. More information on Line 1 overleaf…

Better adapting supply to demand: Paris metro Line 1 automation

Gérald Churchill, Director of automated operations, RATP line 1

PROJECT TIMELINE

- **December 2002** Launch of feasibility studies
- **April 2004** Report presented to RATP Board
- **October 2005** Main contracts are awarded
- **July 2007** Line works begin
- **December 2007** Signature of agreement with transport unions
- **October 2008** Reception of the first MP05 at Valenciennes
- **March 2009** Installation of the first platform screen doors
- **May 2010** Service launch of the new centralized control command
- **April 2011** Completion of platform screen door installation and works on the line
- **8 July 2011** First MP05 in automated mode is injected in the line during daily commercial service, without passengers on board
- **3 November 2011** Service launch of the first eight MP05 automatic shuttles

The automation of Line 1 forms part of the programme to modernise the command and control systems of the Paris metro. The acknowledged benefits of Line 14 in terms of service quality and reactivity of supply to demand underpinned the decision of RATP to launch its ambitious project to automate Paris metro's busiest line in 2003.

Line 1 was chosen due to the difficulty of adapting supply to demand. Its route layout and passenger flows make Line 1 traffic unpredictable. Moreover, Line 1 was the only one that was at the right stage for revamping – economically-speaking – due to the age of its installations.

Full automation will enable the operator to anticipate variations in line loading and adapt supply to demand almost instantly. Moreover, the absence of driver-management constraints, as well as the expected performance of the new system, will:

- increase the operating speed of the line by cutting terminus turnaround times and optimally complying with speed profiles
- reduce the number of trains in reserve by optimising their line position

The system chosen by RATP is based on CBTC radio communication and a virtual block signalling system. This allows train headways to be cut to as little as 85 seconds compared to the present 105 seconds. Wayside signalling, necessary during the mixed operation phase, will be retained for operations in downgraded mode.

As part of the automation work, RATP has fitted half-height platform screen doors to all Line 1 platforms. The screen doors are vital for guaranteeing that there are no passengers or staff on the tracks. They also prevent intrusions – a major source of disruption in the Paris metro network – and secure platforms.

The Line 1 automation project is economically viable. Savings made from the redeployment of drivers to other lines mean that the return on investment from the additional cost of the Line 1 modernisation programme (fully automating all train movements and installing platform screen doors) will be achieved in under 10 years.

The project for automating Line 1also comes within the scope of RATP's sustainable development policy, as the higher operating speeds cut passengers' travel time. Alongside this, serious passenger accidents will be averted and energy consumption optimised.

Ultimately, the Line 1 automation project – thanks to system performance – will provide a transport capacity reserve of over 20%, the deployment of which will depend simply on rolling stock availability.

PARIS LINE 1 in some numbers…

49 trains of 6 cars

772 passengers per train

90,28 m long

max. speed 80 km/h

954 PSD = 5320 m

16 gap area detection systems

1000 CCTV cameras

1800 m^3 of concrete to reinforce & elevate platforms

7 automatism sections

80 radio bases

700 locations of beacons

94 AV transmission antennae

1 million code lines

Automation Atlas: Characteristics

Train capacity- ¾ of the trains have a **capacity below 700 passengers.** High capacity trains (over 700 passengers) are minority, at 24%.

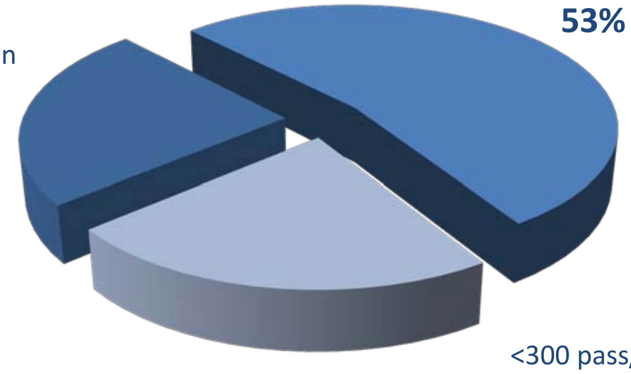


Figure 6: Train capacity (km in operation)

Intrusion control systems- 82 % of stations are equipped with platform screen doors.
Intrusion detection and prevention systems are necessary in any automated line. There are different solutions, which can be divided in 2 main groups: platform screen doors and detection sensor systems (which covers various solutions).

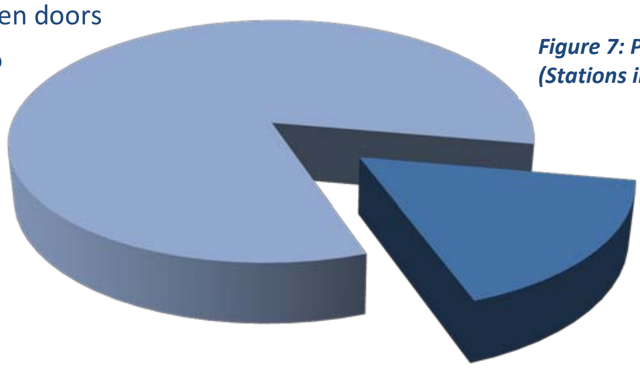


Figure 7: PSD & other track intrusion systems (Stations in operation)

Energy- 84 % of lines use the third rail. The typology of energy supply systems shows a clear dominance of third rail solutions, although in the last years, there is a growing trend towards the use of overhead catenary.

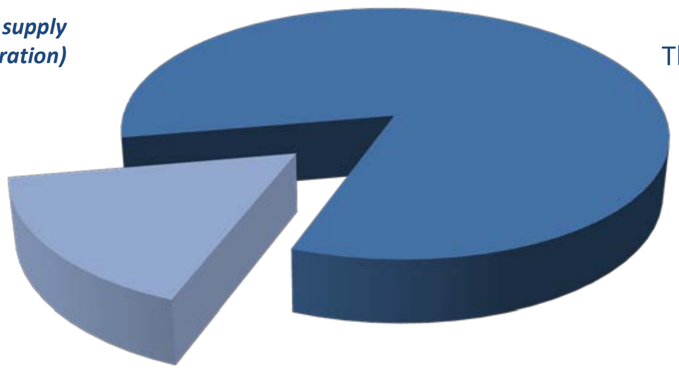
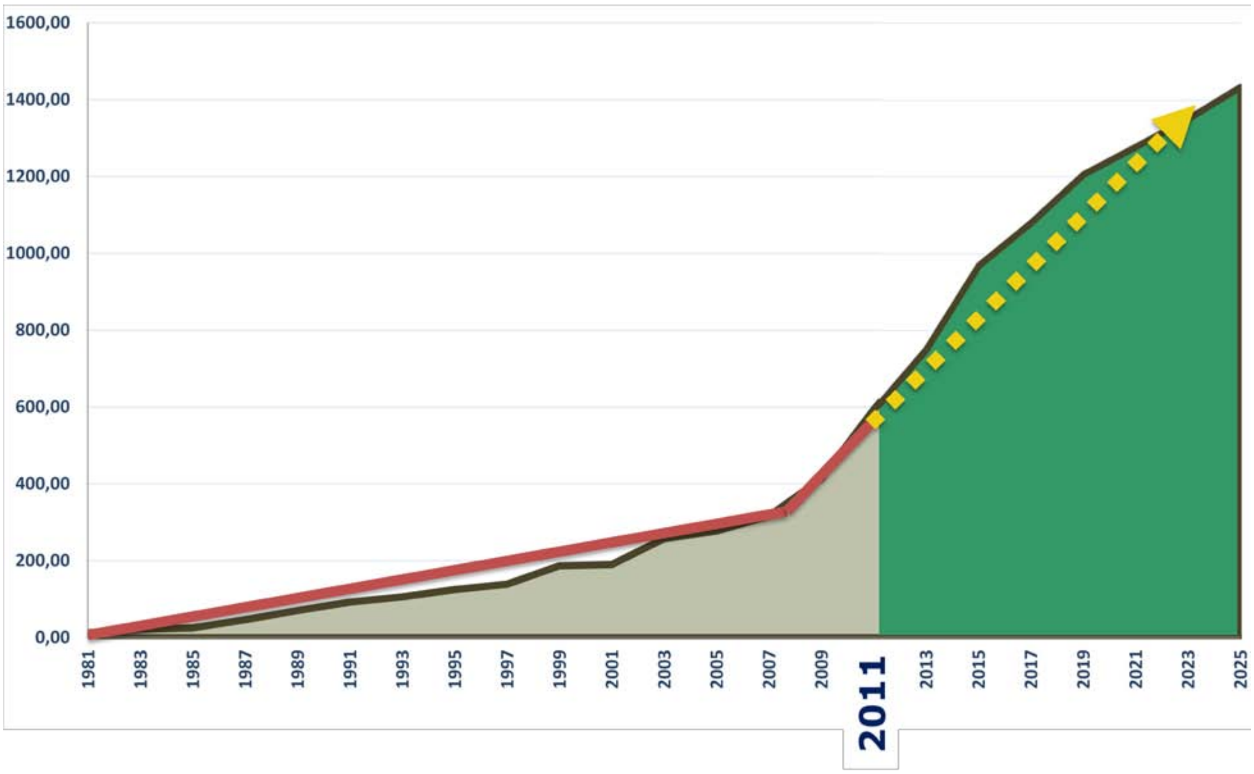


Figure 8: Energy supply (km in operation)

Automation Trends

Accelerated dynamism and growth- In the last five years, the number of kilometres in service has doubled, **(43 % in the last three years)** with the opening of as many automated lines km as in the last 30 years. This elevated growth rate is expected to continue in the coming decades (see below)

Figure 9: Expected evolution in automated lines (km)



Global reach- UTO is no longer a European bid; in the last 3 years, UTO lines have entered into service in new regions, such as Middle East (Dubai and the particular cases of Ryadh and Makkah) or South America (Sao Paolo), bringing automation to 4 continents. The 3 top cities in number of automated kilometres are actually outside Europe: Dubai, Vancouver and Singapore.

The preferred choice for new lines & systems- Hard data confirms the projections – for new lines, UTO is the predominant choice, particularly in Europe, but also in the Middle East. Some Asian countries seem to distance themselves from this trend, even if the Asian region is the largest one in terms of km growth for UTO. UTO is also the preferred option for cities that start a new metro system – this was the case for Dubai, Vancouver (a few years ago) but also for middle sized European cities such as Toulouse, Turin or Rennes.

A high capacity transport solution- In the last years, new automated lines have been implemented to respond to high capacity demand, such as the cases of Sao Paulo with a very high density and Makkah (which as noted is not in full UTO mode, but that will reach record levels during pilgrimage periods), confirming that UTO is a solution that brings together capacity and safety.

Those who try, repeat- In general, those cities that have already implemented a UTO line, will opt for automation again when planning further new lines. A good example is Vancouver: this pioneering city build its first UTO line in 1986, and has since opted twice for automation for new lines - in 2002 and 2009. Another similar case is Singapore; since the inauguration of its first UTO line in 2003, it has consistently continued with this option.

Conversion of existing lines- Paris has demonstrated that conversion is feasible even in complex and key lines, such as L1. The multiplication of conversion projects is a clear trend linked to the renewal of signalling systems and/or the rolling stock.

Improvement of processes and people- Most automation projects integrated in existing metro systems take advantage of the UTO line to launch significant changes within the operating model, characterised by an improvement in job profiles. Staff is freed from the most monotonous tasks and can be redeployed in positions with a higher professional value and satisfaction. In general, staff obtains more responsibility and autonomy, as well as a acquiring a more technical profile.

Signalling technology: CBTC- Automated, safe train movements are possible thanks to signalling technologies. Radiofrequency based signals are increasingly retained as the technical solution for data exchange, over induction loops, leaky cable and guided microwave beams. CBTC (Communications Based Train Control) allow for the bi-directional exchange of information between on board and wayside equipments. It simplifies the deployment of systems on the track, and opens new options such as facilitating other functions beyond signalling.

Client on focus– For new systems, there has been a significant increase in technology investment to facilitate the contact between client and operator. Beyond the compulsory intercom systems to attend to critical on-board communication requests from passengers, new lines integrate on-board CCTV systems that send images to the OCC in real time. Public address systems have also experienced significant improvements allowing to share more precise and up-to-date information on the level of service.

Critical project management- Automation translates into a higher level of complexity, due to the necessary integration of multiple critical sub-systems, such as signalling, energy, PSD, communications, etc. On the other hand, safety requirements in the design, implementation and testing phases contribute significantly to create new and more demanding project management tools.

The lack of standards for critical systems, and the high level of integration required (particularly for the signalling subsystems, PSD and communications) translates into more complex engineering, as well as the joint development by separate companies, when all systems have not been assigned to the same provider. To date, and maybe due to the lack of sufficient experience, the sector has not been able to create a modular standard that would open the field to new providers and facilitates the desirable level of interoperability. (Unlike ERTMS for long distance rail)

The UITP Observatory of Automated Metros

The Observatory of Automated Metros is a UITP body composed of leading operators in this sector worldwide. Its mission is to disseminate and share knowledge with a cross-cutting approach to all the business perspectives of automated lines operation. It also analyzes the global evolution identifying future trends, presenting them in periodical reports and events.

The Observatory is formed by the main UITP references from Automated Lines around the globe (*Barcelona, Copenhagen, Dubai, Hong Kong, Lausanne, Lille, Lyon, Nuremberg, Paris, Rennes, Roma, Sao Paulo, Singapore, Vancouver)*. Together, they cover different profiles, allowing for a unique, global perspective:

- From pioneering experiences to the most recent ones
- Systems with multiple technological solutions & transport capacity
- Global cultural diversity: Europe, Asia, Middle East, America...

Core Observatory activities:

- **Monitoring** the evolution of line automation development and implementation, with special attention in identifying trends.
- **Sharing** automation benefits and ways of solving implementation challenges, through the dissemination of studies and the organization of Seminars for operators planning automated projects
- **Studying key automation issues** identified by the Observatory, or together with other UITP bodies

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