Internet connectivity in underground rail systems

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EXECUTIVE SUMMARY

Urbanites are a mobile and hyper-connected community. Today, the expectations of travelers are increasing. Passengers expect a seamless surfing experience when travelling. As a consequence, internet connectivity in underground transport infrastructure is becoming a life-style aspect of paramount importance.

According to the results of the research, 77% of the metro systems surveyed provide some level of internet access in their underground installations, either in stations (73%) or on-board metro trains (58%).

In the future, 68% of metros plan on increasing their efforts to expand broadband connectivity over their existing stations in the coming 1-3 years, while only 5% do not.

Over the past years, Wi-Fi has been quite popular as a channel for connectivity in 51% metros (and will continue to grow up to 72%), as it can provide free-of-charge complimentary access to internet for users in a given geographic space. Currently, only 17% of metros charge their passengers for the use of Wi-Fi, and in the next 1-3 years this number should decrease to 4%.

Sixty percent of metros apply Wi-Fi restrictions today and a slight increase is expected in the coming years.

The dominant business model for investment and installation of the broadband connectivity in metro infrastructure is driven by the telecom investors, at least for mobile communication coverage. This model is expected to remain stable in the next few years.

1. INTRODUCTION

The number of metro networks in the world is on the rise. Since the beginning of the new millennium, over 45 new systems have begun service. Rapid development, together with a high level of service and convenience, makes metros a very popular and effective urban transport mode.

Today, 148 cities have a metro, adding up to a total of 11,000 km and 9,000 stations distributed in 540 lines. Over 150 million passengers travel on metros every day, which amounts to 45 billion trips per year.

Metro systems are a global presence/urban mobility solution. The major part of the world's metro networks is located in Asia and Europe (50 and 45 networks respectively), followed by other regions: 16 in Eurasia, 16 in Latin America, 15 in North America and 6 in the Middle East and North Africa (MENA) region.

Six out of the 10 busiest networks worldwide in terms of number of passengers are located in Asia (Tokyo, Seoul, Beijing, Shanghai, Guangzhou and Hong Kong). The other 4 systems are evenly distributed between Eurasia (Moscow), North America (New York City), Latin America (Mexico City) and Europe (Paris) (Figure 1).

Figure 1: Top 10 busiest networks in the world (billion passengers per year)
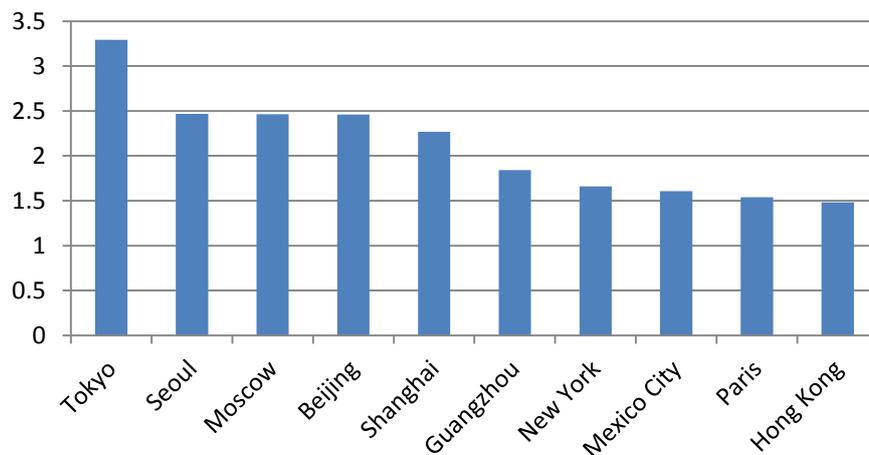
Unsurprisingly, half of the top 10 cities with the longest networks belong to Asia (Shanghai, Beijing, Seoul, Tokyo, and Guangzhou). The complete top 10 is shown in Figure 2.

Figure 2: Top 10 cities in networks length in the world (kilometers)
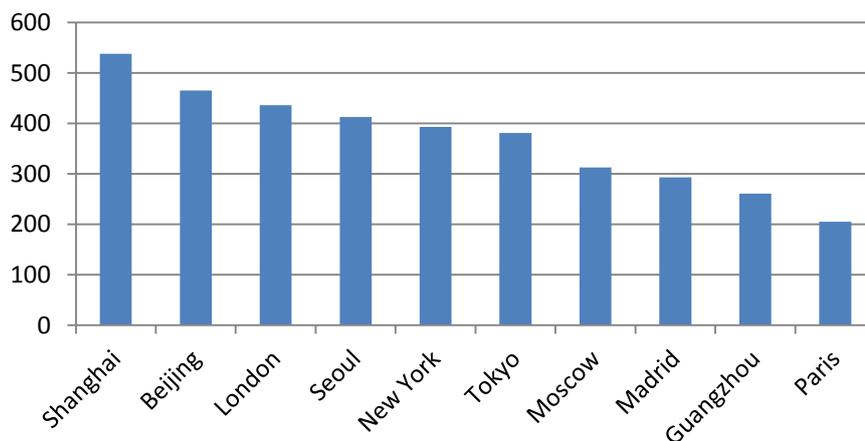
2. METROS AND CONNECTIVITY : OBJECTIVES OF THE STUDY

In parallel to the expansion of the metro networks, the last decades have also seen a change in the business culture of the public transport sector, focusing on the complete passenger experience and leading to increased levels of service. Service providers are constantly developing new options to improve the comfort and convenience of passengers and attract more users to their networks.

Travelers' expectations today are getting ever more demanding: urbanites are a mobile and hyper-connected community.

With the evolution from conventional mobile phones to smart devices (phone, tablets, etc.), people expect uninterrupted and fast broadband connection for their multiple devices at any location. They expect a seamless surfing experience – even when they are travelling in underground metro systems. As a consequence, internet connectivity is becoming a subject of paramount importance for the attractiveness and competitiveness of metros.

In the last decade, mobile phone communication platforms and signal in metros have experienced rapid growth. The development of this service and

absence of comprehensive research triggered this study, in partnership with the New Cities Foundation, an independent non-profit organization dedicated to making cities across the world more inclusive, dynamic and creative. The main purpose is to give a general overview of internet access in metros in order to "map" current practices and to depict the evolution of future trends in this fast-evolving subject.

The study makes a distinction between stations and trains. The reason is that the technicalities and operating conditions to deploy broadband services are different: stations are confined (by definition stationary) environment while trains are mobile assets, "covered" by ground-based equipment (terminals, antennas, leaky cables, etc.) installed along the tunnels. And in fact, the study shows that not all metro networks provide connectivity service for their whole system. A number of metros offer internet connectivity either in stations, or on trains.

This research is based upon a questionnaire distributed to all metro operators worldwide complemented with additional information originating from telephone follow-up one-to-one discussions. The research was conducted between 7 March and 12 May 2014.

The collected data is presented in an aggregated way by group of countries. There are six regions[1]:

- Asia-Pacific
- Eurasia
- Europe
- Latin America
- MENA
- North America

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[1] There is no metro in Africa.

3. SURVEY RESPONSE

A total of 48 metro systems from 28 countries took part in this research (see Table 1). They are distributed among the 6 geographical regions in the following way:

- Asia-Pacific – 11 systems
- Eurasia – 6 systems
- Europe – 17 systems
- Latin America – 6 systems
- MENA – 2 systems
- North America – 6 systems

Table 1: Participating countries per region

Region	Participating countries
Asia-Pacific	China, India, Japan, Korea, Singapore, Taiwan, Thailand
Eurasia	Kazakhstan, Russian Federation, Ukraine
Europe	Belgium, Czech Republic, Denmark, France, Germany, Greece, Italy, Netherlands, Spain, United Kingdom
Latin America	Argentina, Brazil, Chile, Mexico
MENA	Iran, United Arab Emirates
North America	Canada, USA

Figure 3: Participating metro systems per region (percentage from total in region)
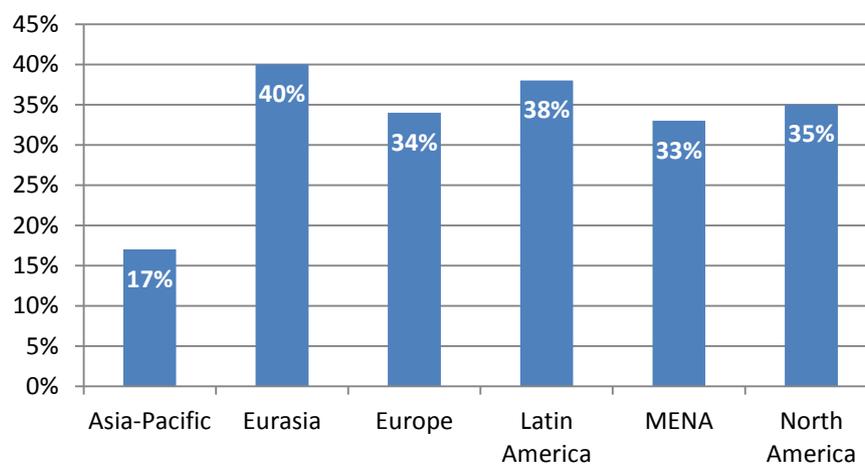
These percentages reflect the response rate from each region. The survey results cover 32% of all metro networks in the world. This includes the largest systems in terms of patronage, line length and total number of stations (see Table 2), and therefore the study can be said to reflect the reality of over half the world's metro sector. This coverage makes it possible to assess the current situation of the most progressive metro systems and to draw an outline of future development. Indeed, these larger metro networks are generally more advanced, often acting as "trend-setters or leaders" in their respective regions or even internationally.

Table 2: Survey feedback

	Responses / total metros	Passengers (% of the total patronage)	Line length (% of the total network length)	Station (% of the total stat° numbers)
Asia-Pacific	17%	56%	40%	40%
Eurasia	40%	67%	59%	57%
Europe	34%	67%	56%	63%
Latin America	38%	59%	63%	68%
MENA	33%	33%	57%	48%
North America	35%	97%	50%	61%
Total	**32%**	**62%**	**49%**	**53%**

4. SURVEY RESULTS

Seventy-seven percent of metro systems surveyed provide some level of internet access in their underground installations (37 systems). This can be full or partial coverage. It can also be through mobile network and/or Wi-Fi. Figure 4 shows the distribution among the 6 regions.

Figure 4: Metro operators offering internet connection per region (in blue)

| Asia-Pacific | Eurasia | Europe |
| 91% | 33% | 88% |

| Latin America | MENA | North America |
| 67% | 100% | 67% |
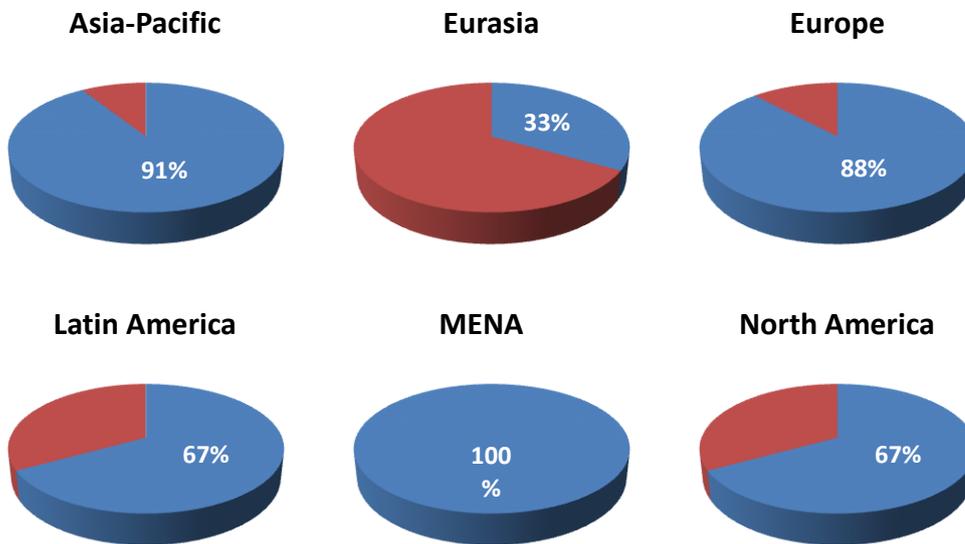
The high level of coverage depicted for MENA and Asia may be influenced by the lower number of systems in the sample, but above all, it reflects their more recent construction, as opposed to older networks in Europe or North America, where the systems were predominantly built before 1980 (56 systems) or even before World War II (18 systems).

Among those metros offering no or only partial internet access, 69% of the operators surveyed plan to provide or expand broadband connectivity in the next 1-3 years. Figure 5 shows the distribution among the 6 regions.

Figure 5: Metro operators planning to offer/expand internet connection per region (in blue)

Asia-Pacific

Eurasia

Europe

72%

17%

76%

Latin America

MENA

North America

83%

50%

83%
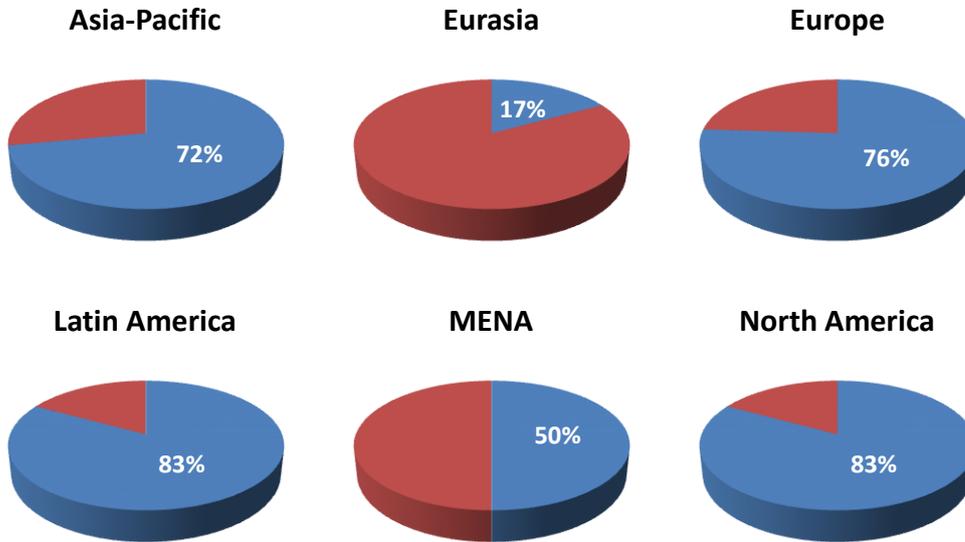
The deployment strategy of broadband connectivity is not the same for all metros: some provide it in stations, on trains, or both (see Figure 6).

Figure 6: Current global distribution of broadband connectivity coverage

25%

5%

70%

■ Stations only   ■ Trains only   ■ Stations and trains
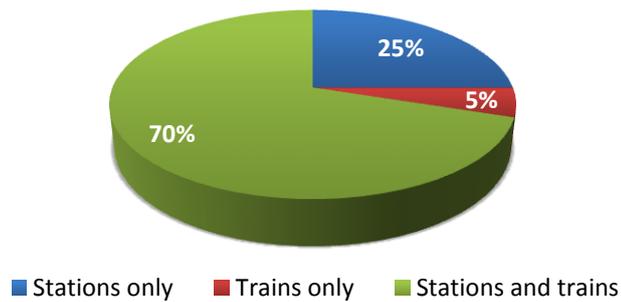
4.1 CONNECTIVITY IN STATIONS

A specific analysis of broadband availability in metro stations shows that 73% of metros offer internet connectivity to their passengers in underground stations. Sixty percent (21 systems) offer broadband connectivity in all stations and 40% (14 systems) only in selected stations.

4.1.1 Current situation

Figure 7: Percentage of metros with internet connectivity in stations
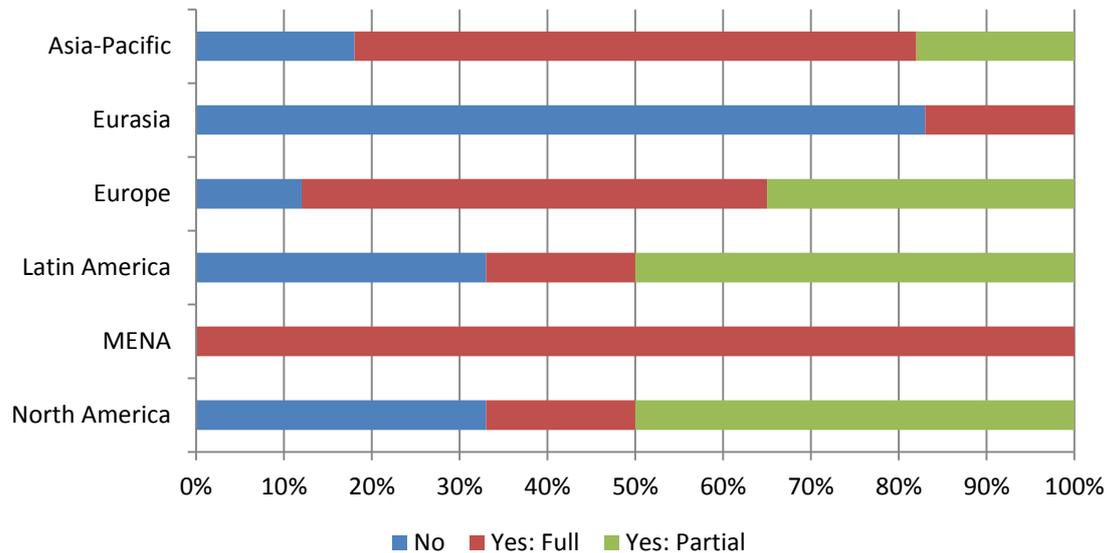
MENA, Europe and Asia-Pacific are the most advanced regions, with a maximum of 15% that do not offer connectivity. In the Americas, this proportion doubles to 30%, while in Eurasia, a large majority of systems do not offer any coverage (yet). Trends from Figure 11 do not seem to point towards a rapid change in Eurasia.

Among the metros offering connectivity, it is possible to observe an evolution of the technologies deployed over time by comparing the initial and current situation.

Figure 8: Regional breakdown of connectivity launch over time in regions (per 5-year period)
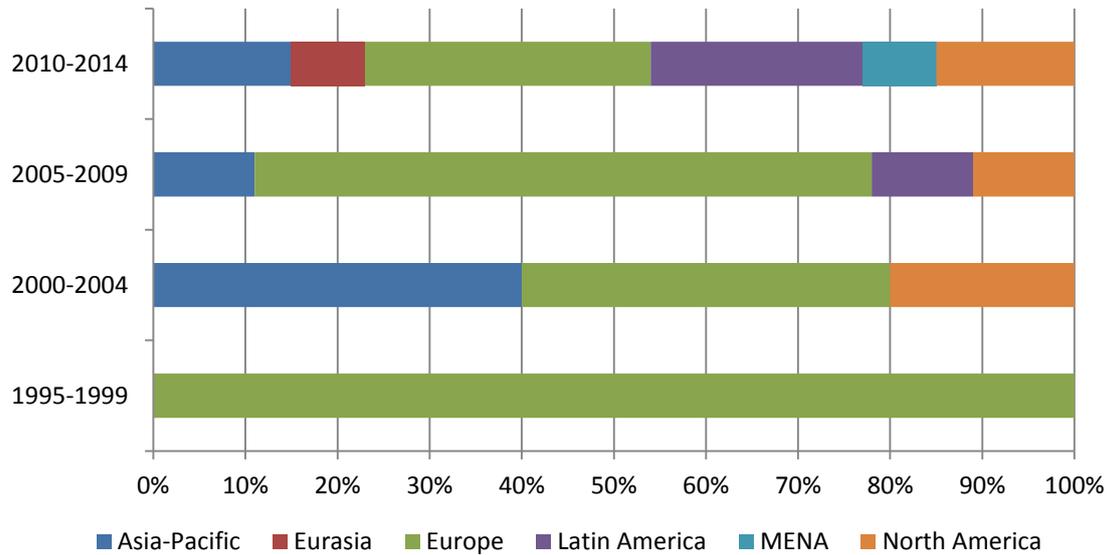
Europe and Asia were the first regions to deploy mobile and/or Wi-Fi connectivity in their underground assets as early as the mid-90's or early 2000's. The Americas followed in the middle of the last decade, while Eurasia and MENA have just recently begun.

Figure 9: Type or level of mobile connectivity provided initially (full and partial coverage)
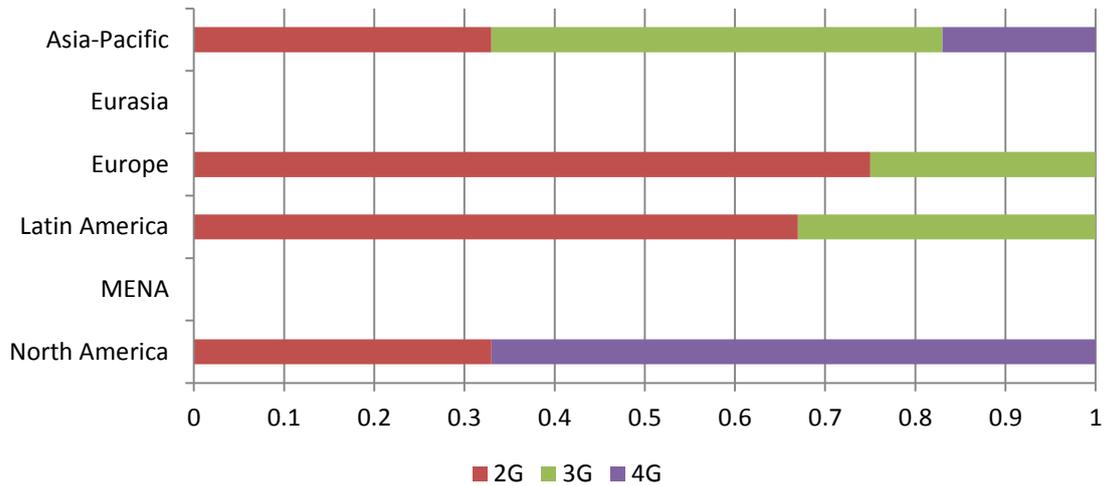
Figure 10: Type or level of mobile connectivity provided currently (full and partial coverage)
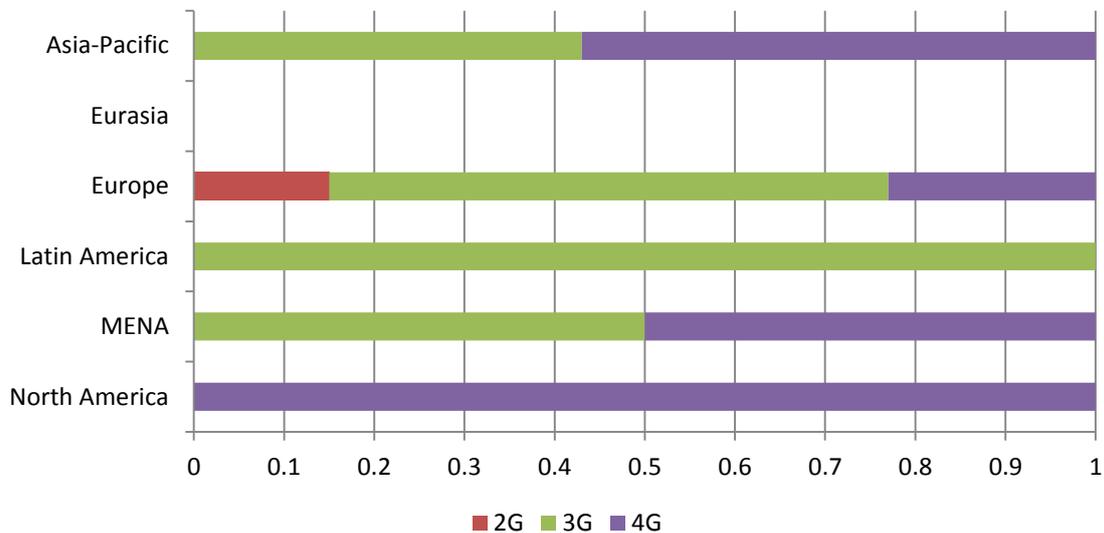
The initial provision of internet connectivity in Eurasia and MENA was through Wi-Fi. MENA has since introduced mobile communication coverage. Eurasia remains with Wi-Fi only at this stage.

As European and Asian metros were the first to be equipped with mobile technology (see Figure 8 above), it is not surprising that they feature a higher proportion of older generation technologies. The Americas, which started later, had an opportunity to start with the latest mobile generation. In 2014,

not surprisingly, 3G and 4G mobile communication have been established everywhere.

Full coverage (100% of stations) is provided by 60% of metros. The remaining 40% of metros offer connectivity only in selected stations. These have been clustered in four groups reflecting low, medium-low, medium-high or high connectivity coverage as of today.

Table 3: Partial internet connectivity coverage in stations

Percentage of stations with connectivity	Cities
<25%	Marseille, Athens, Rotterdam, Rio de Janeiro, Vancouver, New York City
25-50%	London
50-75%	-
>75%	Buenos Aires, Sao Paolo, Philadelphia

Table 4 shows the evolution of connectivity type and technologies over time:

- Wi-Fi is still gaining in popularity.
- As far as mobile communication is concerned, the newer mobile communication generations are logically gaining ground to the detriment of the older ones.

Table 4: Change in tendency of different connectivity types provision in stations

Type/level of connectivity	Wi-Fi	2G	3G	4G
Provided initially	36%	42%	21%	9%
Provided currently	51%	6%	43%	31%
Percentage change	+41%	-86%	+104%	+244%

4.1.2 Perspectives for the future

Figure 11: Percentage of metros planning to retrofit existing stations (next 1-3 years)
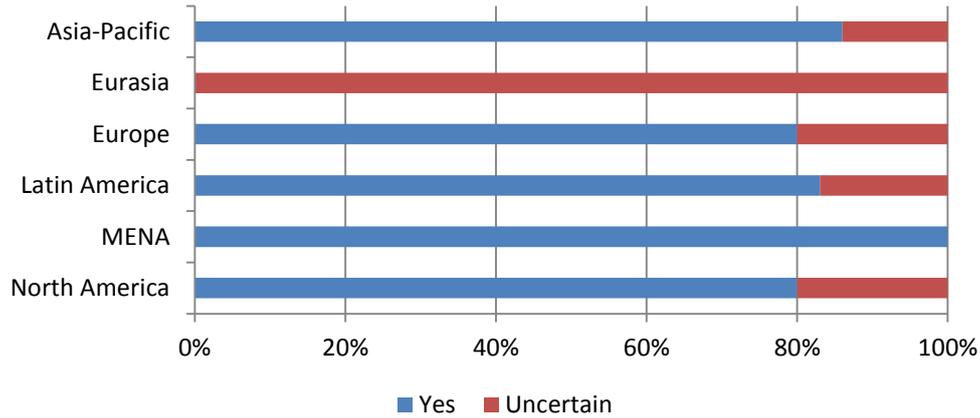
With the exception of Eurasian operators, a large majority of metros plan to increase their efforts to expand broadband connectivity in existing stations in the coming 1-3 years.

Figure 12: Percentage of metros planning to design new stations with connectivity
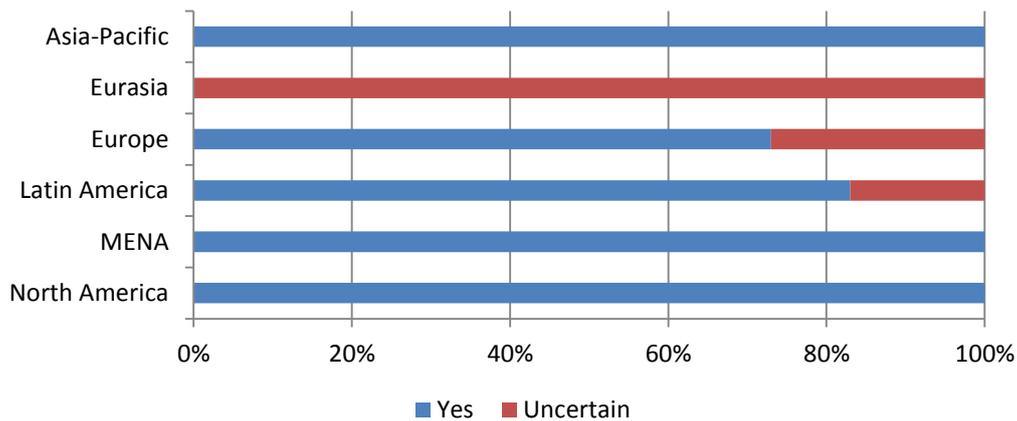
In the future, most new metros stations will be designed from scratch as "digital stations", with the exception of Eurasia, where the uncertainty level is very high.

4.2 CONNECTIVITY IN TRAINS

Fifty-eight percent of metros offer internet access to their passengers during their ride on metro trains. Among these, 71% (20 systems) offer broadband connectivity on all their lines, while 29% (8 systems) offer it only on some lines. These are lower levels than for stations, due to technical complexity and higher installation costs.

4.2.1 Current situation

Asia and MENA are the most advanced regions in provision of on-board connectivity. Europe and the Americas follow, but it should be noted that the level of connectivity on trains is significantly lower than in stations. In Eurasia, on-board connectivity is at similar low levels as for stations.

Figure 13: Percentage of metros with internet connectivity in trains
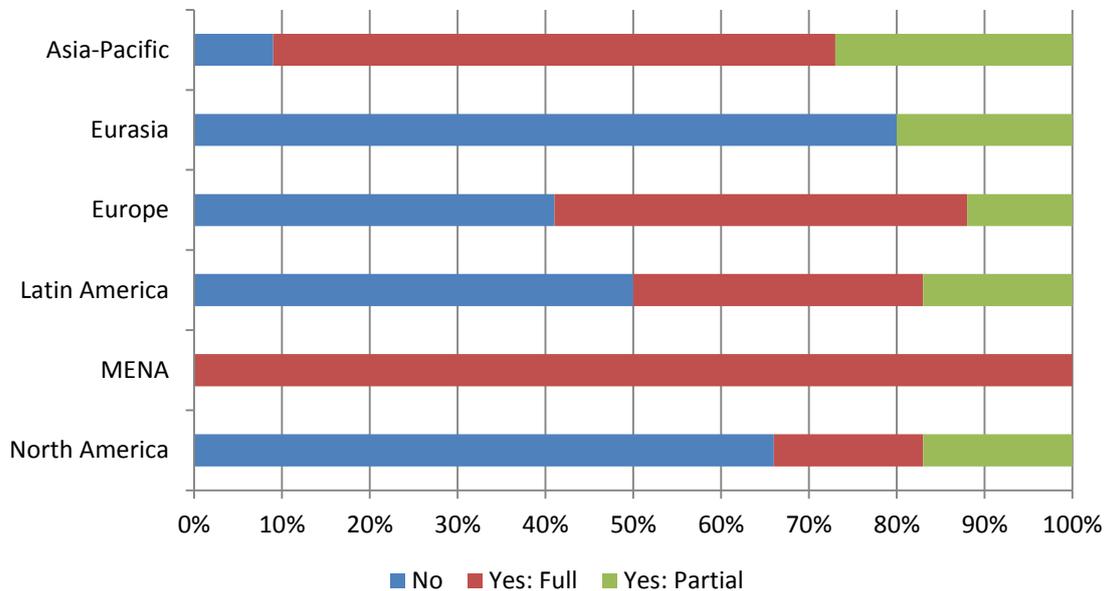
Figure 14: Regional breakdown of connectivity launch over time (per 5-year period)
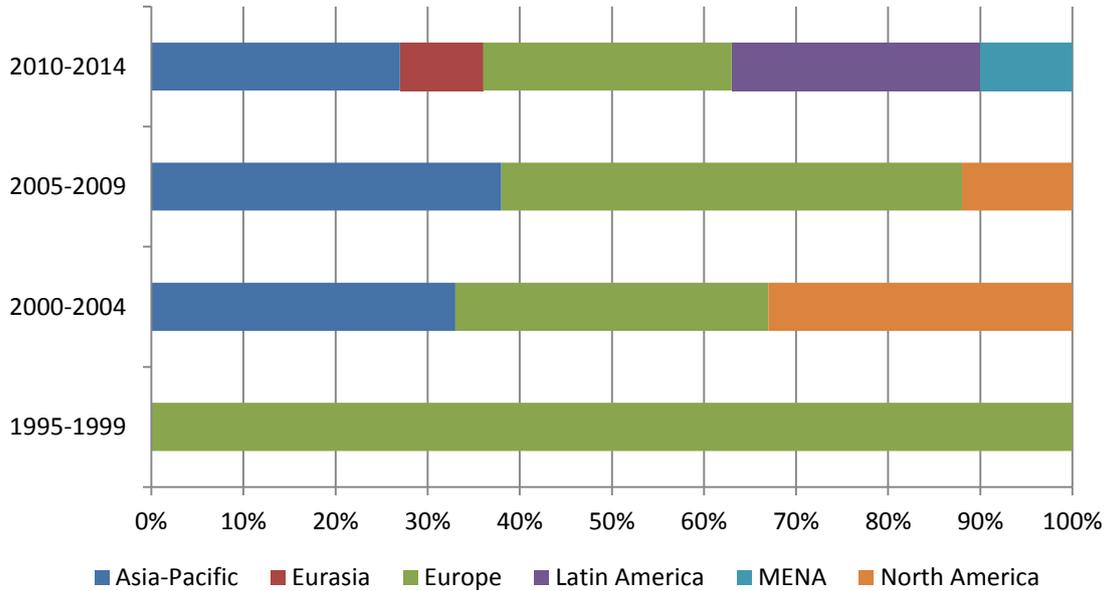
As in the case of stations, Europe and Asia were also the first regions to provide on-board connectivity as early as the mid-90's or early 2000's. They were followed by North America in the middle of the last decade, while MENA, Latin America and Eurasia have just recently started.

Figure 15: Type or level of mobile connectivity (both full and partial coverage)
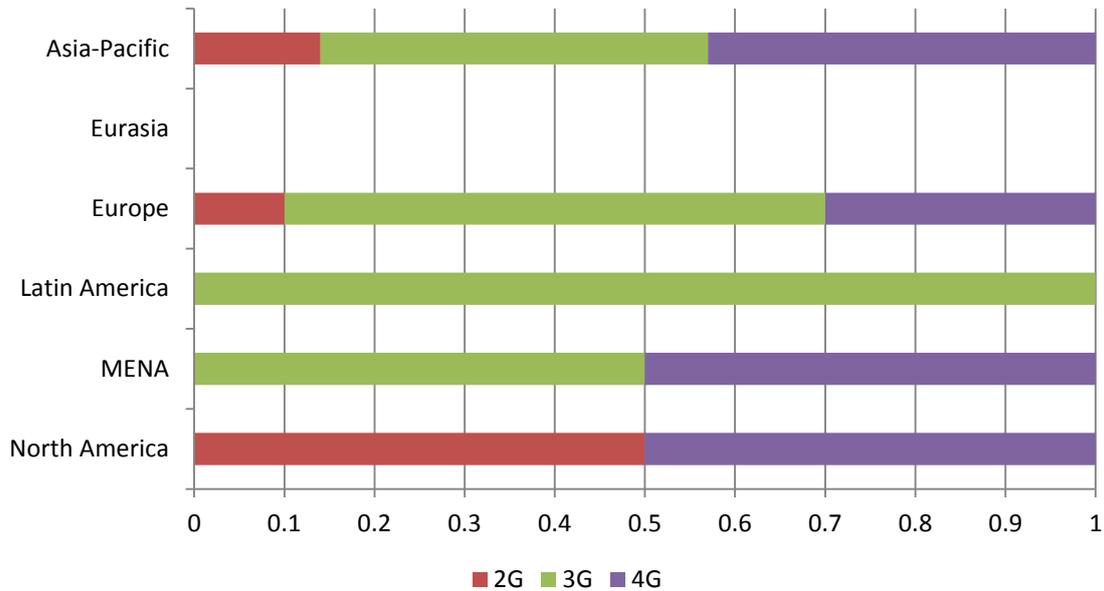
The provision of internet connectivity on-board trains in Eurasia is made exclusively through Wi-Fi.

Twenty-nine percent of metros offer on-board connectivity only in part of their tunnels. As can be expected, this is the case for some of the longest metros. They have been clustered in four groups reflecting current levels of low, medium-low, medium-high or high connectivity coverage.

Table 5: Partial internet connectivity coverage in trains

Percentage of total lines with connectivity	Cities
<25%	-
25-50%	Moscow, Vancouver
50-75%	Barcelona
>75%	Beijing, Buenos Aires
Unspecified	Bangalore, Rotterdam, Tokyo

Perspectives for the future

Figure 16: Number of metros planning to install internet in existing lines (next 1-3 years)
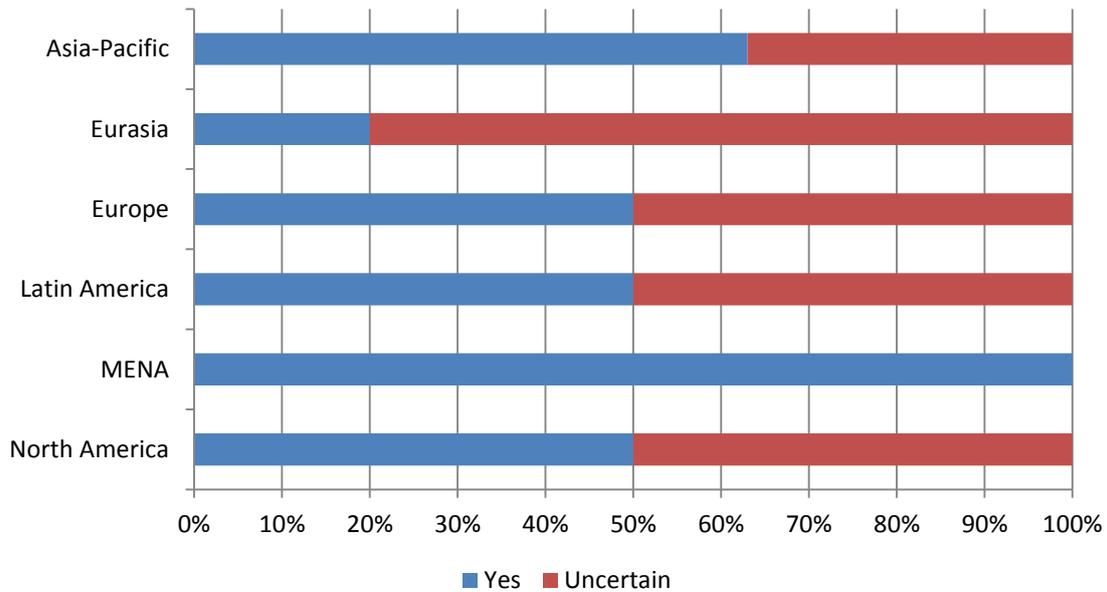
With the exception of Eurasia, a slight majority of metros plan to increase their efforts to expand broadband connectivity in tunnels in the coming 1-3 years, but the level of certainty is lower than for stations. It should be noted that while survey responses depicted higher levels of certainty when considering deployment in new stations, tunnels do not enjoy the same positive differentiation when planning deployment on new infrastructure, with uncertainty stated at similar levels to those for existing tunnels. The only exception to this is Latin America, where metros indicate even less certainty over future deployment in new tunnels.

Figure 17: Number of metros planning to design new lines with internet (next 1-3 years)
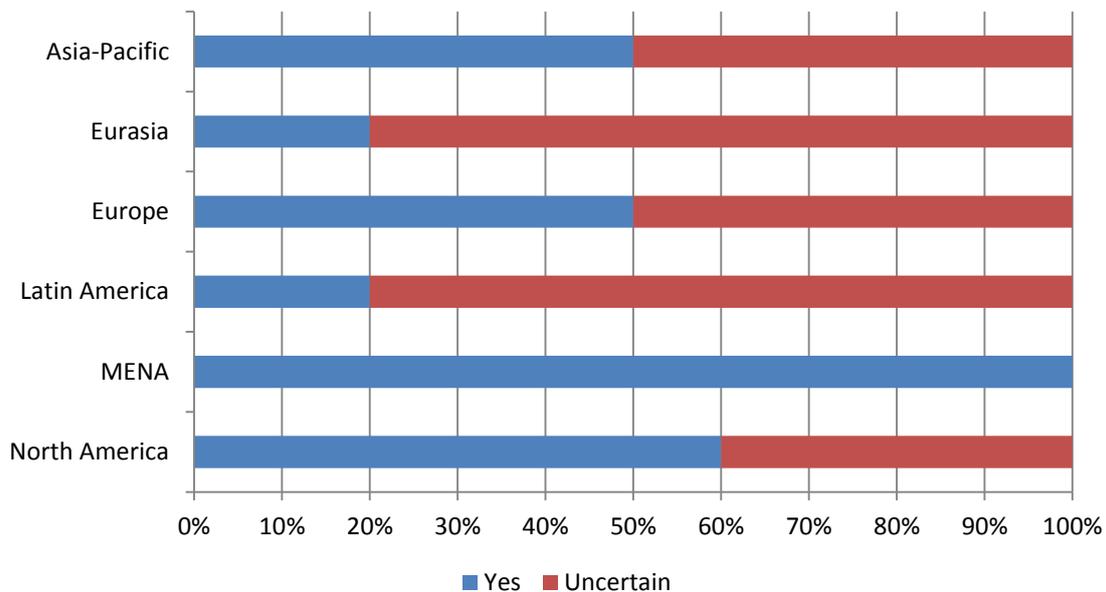
With the exception of Eurasia and Latin America, a slight majority of metros plan to increase their efforts to deliver broadband connectivity in new tunneled lines in the coming 1-3 years. The level of certainty is lower than for retrofitting existing tunnels in Asia-pacific and Latin America, higher in North America and equal in Europe, Eurasia and MENA.

If figure 12 showed that most future metros stations will be designed from scratch as "digital stations", figure 17 reveals that there is still significant uncertainty about the suitability and feasibility to design fully digital metros.

4.3   WI-FI CONNECTION

Wi-Fi broadband supply has been quite popular in the past, as it can provide free-of-charge complimentary access to internet for users in a given geographic space.

Wi-Fi can be quickly and easily installed in stations. It is more challenging to install Wi-Fi on trains because of the relatively low power signal derived from leaky cables that requires base stations to be installed at intervals of 300-500 meters to support uninterrupted connectivity.

In addition, the quality of Wi-Fi connection is affected by the number of users logging on to the system. With the multiplication of megabit/sec.-hungry applications and internet use, Wi-Fi restrictions may turn out to be a necessary step for metro operators to take: 60% of metros currently have Wi-Fi restrictions in place and a slight increase is expected in the coming years.

One of the possible reasons is the rapid development of mobile technology. Increased use of smartphones and "bandwidth hungry applications" has led to rapid growth in mobile data traffic volumes (e.g. video streaming). People watching videos and listening to music via their phones use higher amounts of mobile data than other users. In addition to strictly technical reasons, the provision of "too generous" internet access can be undesirable for metros, it can encourage travelers to loiter in stations and hamper rapid passenger boarding and the fluidity of crowd movement required, especially during rush hours.

Different types of Wi-FI restrictions are aimed at controlling the amount of data consumed by a user. The types of restrictions and tendency of their application in the future is shown on figures 18 and 19.

Figure 18: Application of Wi-Fi restrictions.
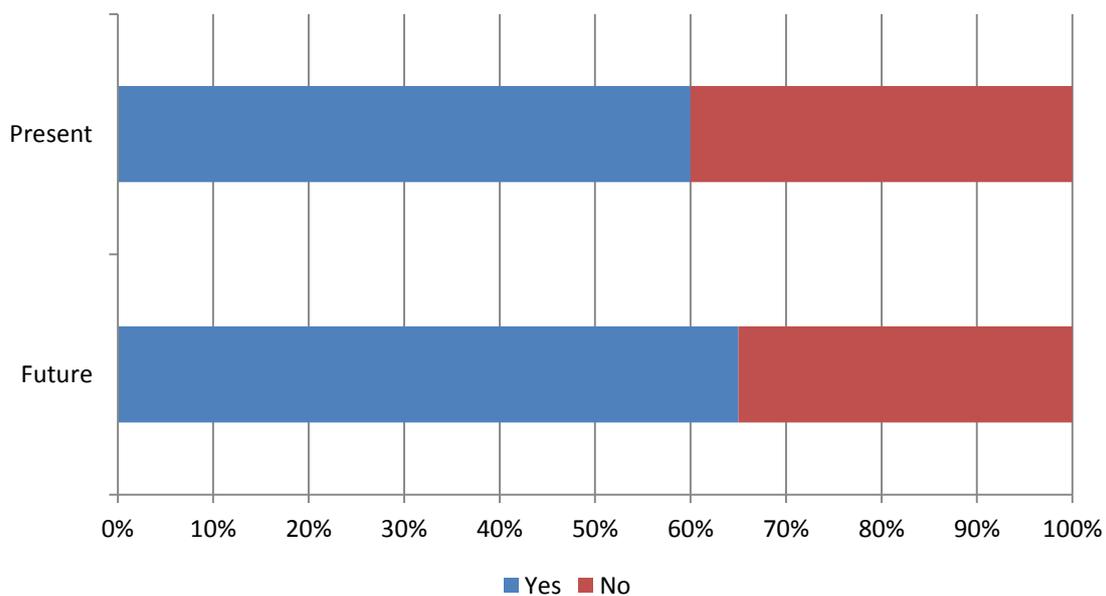
Figure 19: Types of restriction in use.
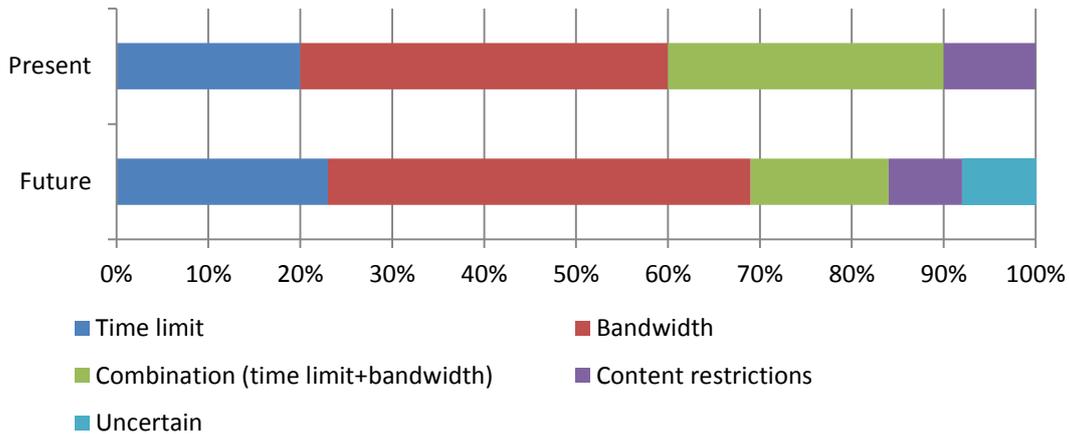
Bandwidth restrictions range between 512 kbps and 1Mbps. Time restrictions range between 15 and 60 minutes per day. The Dockland metro[2] in London has a tight policy on the content of visited sites[3].

Today, 90% of metros with Wi-Fi facilities are offering the service free-of-charge, and this trend is expected to continue in future.

Figure 20: Wi-Fi usage fee.

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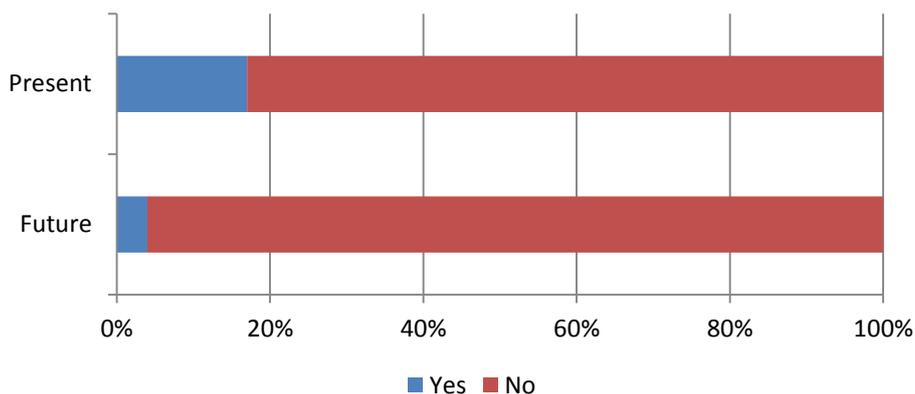
[2] Metro "sub-network" serving the eastern part of London and the former docks areas, where regeneration efforts have attracted thousands of jobs and residents in the past 25 years. The area was one key location of the Olympic Games in 2012.

[3] Access is filtered at the ISP level so that the following types of sites are blocked: suicide, self-harm, pro-anorexia and eating disorders, discriminatory language, encouragement of drug use, repeated / aggressive use of *** words, pornography, violence and gore.

4.4   BUSINESS MODEL AND TELECOM PROVIDERS

The dominant model for deployment of broadband connectivity in metro infrastructure places the responsibility for investment and installation on telecom investors, at least for mobile communication coverage. This model is expected to remain stable in the next few years.

However, in the specific case of Wi-Fi deployment, the model seems to differ, with implementation more frequently driven by "local" stakeholders such as the metro company itself or the city government.

Figure 21: Suppliers of infrastructure and services

■ Telecom company   ■ Metro operator
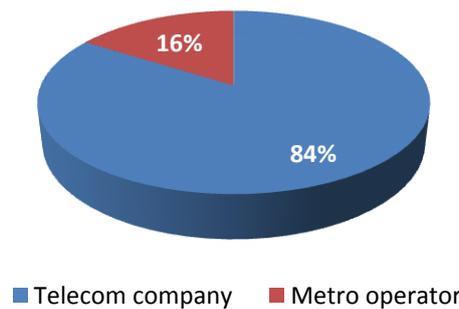
Where mobile communication is available, 79% of metros offer multiple-operator access. Only 21% of metros are in a "monopoly" relationship with a single telecom provider (Figure 22).

Figure 22: Number of mobile operators offering connectivity in the system

■ 1 operator   ■ 2 operators   ■ 3 operators   ■ >3 operators
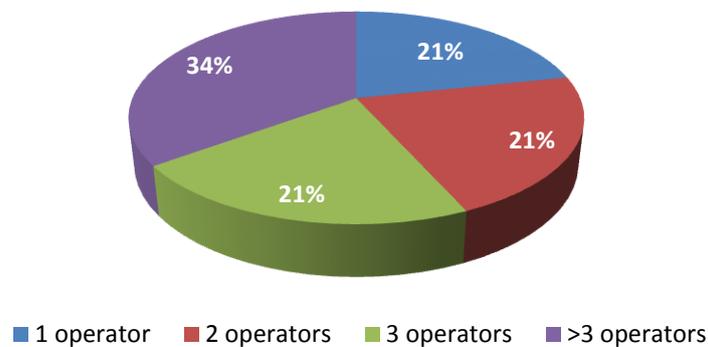
5. WHERE DO WE GO FROM HERE?

Urbanites are a mobile and hyper-connected community. Today, the expectations of travelers are increasing and passengers expect a seamless surfing experience when travelling. Indeed, access to Internet connectivity is becoming a key life-style factor in assessing quality of life in cities.

This study provides evidence-based demonstration that a majority of metros already provide internet connectivity to their customers, at least in stations, and that their efforts to expand broadband connectivity will continue. However these efforts will primarily and more certainly focus on station coverage rather than in tunnels. The coming months and years will mark a shift towards the latest technologies, as illustrated in figures 23 and 24:

Figure 23: Mobile internet in stations.
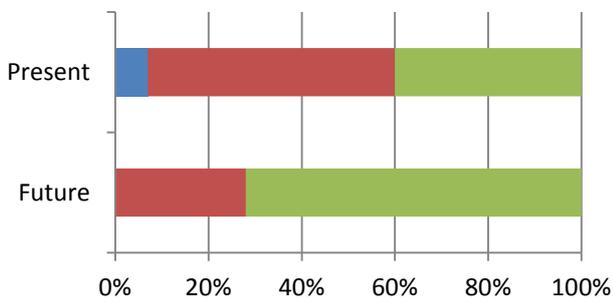
Figure 24: Mobile internet in trains.
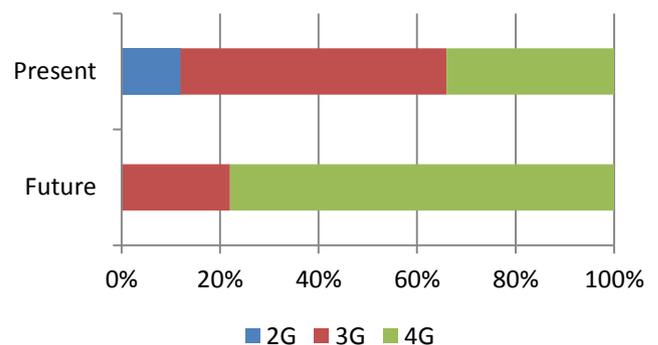
From this starting point, a number of challenges or questions can be derived for the medium and long-term future:

- The study revealed the current lower level of internet on-board connectivity compared to stations. At the same time, the stated intentions for future deployment in tunnels show more uncertainty than for deployment in stations. The existing gap will therefore not necessarily narrow down in the next years. This "resistance" can be explained by the complexity and costs, as well as by a series of operational constraints. How to overcome the apparent reluctance or uncertainty about providing broadband internet access on-board trains (in tunnels)?

- Metro companies are in general involved in a number of international technical fora such as ISO, IEC and ICT Standard Board[4]. They are therefore well aware of progress underway to develop and standardize upcoming technologies, and understand also very accurately the fast pace of evolution of communication technologies and their obsolescence. In such a context, how to convince metros about 4G mobile technology deployment, when they are aware that 4G LTE (long term evolution) and 5G are already "in the pipeline"?

- With upcoming 4G LTE and 5G, is it realistic to design safety-related train control command functions through conventional mobile communication? Nowadays, train movements are partly or fully remote controlled (driverless) from an Operation Control Centre (OCC). Safe communication between train and ground is performed by so-called CBTC (Communication-based Train Control). Safety is so critical that CBTC uses exclusively separate dedicated telecom channels owned and installed by the metro companies. With the increased data transfer capabilities of future telecom standards, it may be possible to transmit CBTC data through conventional mobile communication, thereby avoiding the installation of dedicated telecommunication infrastructure. Early tests are underway in China. In case of successful outcome, this will probably impact the dominant business model of telecom being in charge of investing "alone" in the telecom assets.

As the first rigorous investigation into Internet accessibility in underground metro systems in cities around the world, this study provides the basis for future comparative explorations of the impact of subway connectivity on urban life. For example, some broader questions that this study raises are:

- Why do people connect to the Internet underground? What do they do?
- How does a connected trip impact areas such as customer satisfaction, productivity, retail, loyalty, yield per user and so on?
- Are there correlations between the level of underground Internet connectivity and propensity to use public transport, or with cities' competitiveness, or economic productivity?

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[4] International Standard Organisation, International Electro-technical Committee, Information and Communication Technologies Standardisation Board

In the future, new qualitative studies could be designed to answer these questions, for example, through comparative case studies that explore impact on social dimensions such as citizen satisfaction with their public transportation systems, productivity, safety and overall quality of life.

About UITP:

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The New Cities Foundation is a leading global non-profit organization, with a vision to build more inclusive, dynamic and creative cities benefiting people and society. Its mission is to incubate, promote and scale urban innovations through collaborative partnerships between government, business, academia and civil society.

The New Cities Foundation hosts a number of leadership events on the most pressing urban issues, including its flagship event, the New Cities Summit. The Foundation's applied research wing, the **Urban (co)LAB,** manages a number of projects including Task Forces, thought leadership activities and competitions.

An independent, non-profit organization, the New Cities Foundation was created in 2010 and is financed by its corporate members. Overall, its members include some of the most forward-thinking companies, universities, cities and city organizations around the world. The New Cities Foundation's Founding Members are Cisco and Ericsson.

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