WIK-Consult • Report

Study for Stokab

A tale of five cities:

The implications of broadband business models on choice, price and quality

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1 Executive summary

A key focus of the proposed European Electronic Communications Code is to boost competition and investment in very high capacity broadband. In turn, achieving ubiquitous high capacity broadband could support wider productivity gains,[1] and the development of smart applications for businesses, individuals and the public sector, benefiting society as a whole.[2]

In this study, prepared for Stokab, we analyse the effects of different business models on deployment and competition in high speed broadband across five cities and assess the practical outcomes for consumers, in terms of quality, choice and price, as well as the implications for innovation and participation in the digital economy.

The business models

The cities covered in the exercise are London, Stockholm, Paris, Madrid and Hamburg. They were chosen because they represent distinct models for the deployment of very high capacity broadband.

- **Stockholm: wholesale only model**. Stockholm has pursued a horizontal approach towards broadband provision. A distinct feature is that one of the three infrastructure operators, the municipally owned fibre operator Stokab, operates a fibre-to-the-home (FTTH/B) network on the basis of a 'wholesale only' model, providing dark fibre to service providers and companies. The incumbent Telia has also legally separated its access division to create a distinct infrastructure provider Skanova.

- **London: separation of the incumbent.** Service competition is also a feature of the market in London, but is more reliant on regulated access to the network of the incumbent operator BT. BT has agreed to the legal separation of its access division (after more than 10 years of functional separation). Access to BT's NGA (FTTC/VDSL) network is provided on the basis of Virtual Unbundled Local Access (VULA) – a form of 'bitstream'. There is only one other widespread infrastructure provider, the cable operator Virgin Media.

- **Paris and Madrid: end to end infrastructure competition.** Competition in high speed broadband in Paris and Madrid is primarily on the basis of end-to-end infrastructure competition in FTTH/B. Operators deploy their own fibre networks to the base of buildings and share the in-building wiring. There are three major infrastructure providers in these cities and a further smaller infrastructure player. There is also some limited service competition on the basis of commercial (normally bitstream) offers.

1 In a study for the European Commission to support the Impact Assessment for the Review of the Framework for electronic communications, SMART 2015/0005, WIK, Ecorys and VVA found evidence that increasing broadband speeds and boosting the coverage of next generation mobile networks could drive productivity across a number of sectors.

2 Examples are self-driving cars, smart cities, e-education and healthcare, remote working

- **Hamburg: regional utility.** Alongside the incumbent and cable, Hamburg benefits from competition from a regional utility-owned FTTH/B network, Wilhelmtel. Wilhelmtel offers its own retail services, and has also started wholesaling to other providers. The incumbent is focused on deploying FTTC/VDSL vectoring and also provides bitstream wholesale services over this network.

The outcomes experienced in these cities are summarised below.

Availability

FTTH/B infrastructure is widely available in Stockholm, Paris and Madrid. There is partial FTTH/B coverage from Wilhelmtel in Hamburg, while FTTH/B in London is limited. As regards high speed mobile connectivity, LTE is most widely available to end-users in Stockholm and Madrid, while the lowest availability was reported in Paris and Hamburg.

Table 1-1: Coverage by technology Q1 2017

	Hamburg	London	Madrid	Paris	Stockholm
FTTH/B	71.4%	4.5%	>90%	90%	93%
FTTC/VDSL	>90% (est)	95%	Limited	Limited	23%
Docsis 3.0	>50%	65%	~50%	High	78%
LTE[3]	68%	74%	80%	68%	87%

Sources: various, see case studies. LTE coverage from Opensignal Feb 2017

Quality

The quality of both fixed and mobile Internet as measured by actual average speeds experienced by users is highest in Paris and Stockholm – both FTTH/B cities, and lowest in Hamburg and London – cities with extensive FTTC/VDSL networks.

3 % time LTE is available to end-users as measured by Opensignal Feb 2017 The best performing 4G cities in Europe https://opensignal.com/blog/2017/02/23/data-dive-what-are-the-best-performing-4g-cities-in-europe/

Table 1-2: Average fixed and mobile Internet download speeds 2016

	Hamburg	London	Madrid	Paris	Stockholm
Average download Mbit/s	29.02	28.79	48.08	71.74	71.85
Mobile speeds Mbit/s	15.65	16.77	18.84	19.37	20.97

Source: Ookla Netindex (extracted from European Digital City Index 2016)

The lead taken by Stockholm and Paris in broadband quality is reflected in the advertised offers available. While in these two cities 1Gbit/s offers were available on a widespread basis, in the other cities compared, the highest download speeds offered reached 300-400Mbit/s.

Upload speeds for the high speed offers in Stockholm and Madrid as well as Paris are also considerably higher than those in the cities dominated by FTTC and cable, and symmetric offers are widely available. Upload bandwidths are vital for cloud computing and video conferencing services, and may also be key to upcoming IoT applications associated with the development of 5G.[4]

Choice

All the cities apart from London benefit from at least 3 infrastructure providers with significant scale. All of these infrastructure providers (with the exception of Stokab in Stockholm) also offer retail services. However, the degree of further service competition differs in the cities studied. There is the greatest choice of service providers available in Stockholm (more than 100 service providers have a contract to use the wholesale only Stokab network) There is also a significant degree of service competition on the soon-to-be legally separated BT Openreach platform (23 service providers offering residential service).

There is a difference however in the kind of choices available between London and Stockholm. Whereas in London, retail offers based on BT's VULA platform are similar in terms of their features, bandwidth and pricing tiers, there are greater differences in the offers provided on Stokab's network – which feature different downstream and upstream bandwidth configurations. This may result from the fact that the dark fibre offer from Stokab enables considerably more service differentiation than the VULA offer of BT.

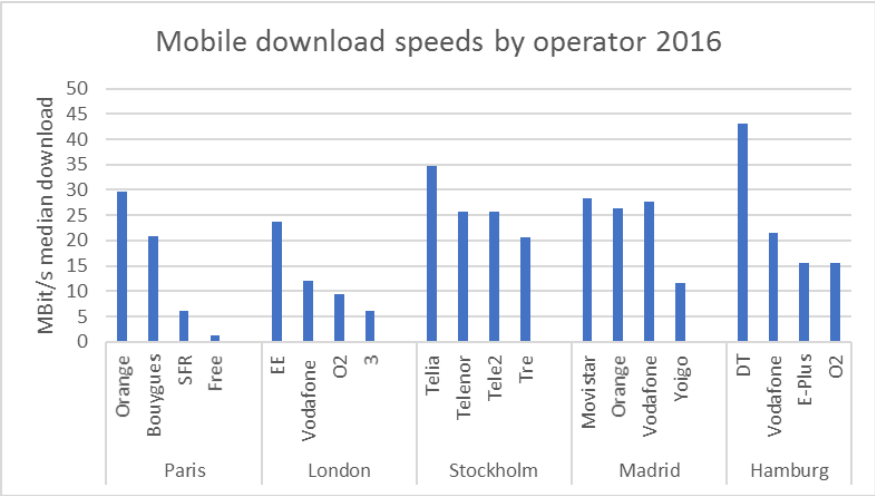
There is considerably less variety of service competition in the other cities. This may be due to the fact that infrastructure providers in the other cities are vertically integrated, and wholesaling forms a less important part of their business model.

4 Most existing IoT applications are narrowband, but this may change with the introduction of 5G capabilities

Unlike all the other cities, where bundled offers (of at least telephony (fixed or mobile) + broadband) predominate, in Stockholm services are typically sold separately. This provides greater scope for consumers to choose not only between communication providers but also to use mobile telephony or over-the-top (OTT) voice and video services as an alternative to traditional integrated services, providing an additional source of competition. PTS reported that in 2015 40% of respondents to a survey on communications usage in Sweden used only mobile (and not fixed) telephony, a figure that had increased significantly since 2013.[5]

Competition and choice in mobile broadband is also more highly developed in Stockholm than in the other cities. As can be seen in the figure below, Stockholm is the only city from those studied where high speed mobile (of around 20Mbit/s) is available from four providers. This is consistent with the findings of a previous study which noted that Stockholm was in 2015, the only city in the world with four competing LTE networks[6] One reason could be that in Stockholm dark fibre backhaul is widely available from a supplier which is not bound to any operator[7]. In Madrid, three mobile providers could offer such speeds. These are the same operators as have significant FTTH deployment within Madrid, while the smaller operator's offer lay significantly behind in terms of the median speeds offered. In the other cities, there were significant gaps between the speeds offered by the incumbent and smaller mobile operators, which may lack their own extensive fibre infrastructure.

Figure 1-1: Median mobile download speeds by operator and city



Source: Rootmetrics Q1 2016 except Hamburg (Speedtest) Q2-Q3 2016

5 http://statistik.pts.se/individ/download/2015/Individunders%C3%B6kning_2015_Rapport.pdf

6 Benoit Felten (2015) https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2719401 notes that Stockholm is now the only city in the world with four competing LTE networks. One was deployed by incumbent TeliaSonera and two others by competitive players Telenor and Tele2. These two companies co-financed a joint-venture infrastructure company called Net4Mobility, which deploys and manages the access and aggregation parts of the LTE network for both companies.

7 Net4Mobility clearly states that without Stokab they would not have a business: the density of cell sites for LTE is much greater than it is for 3G, and having access to affordable dark fiber to connect the cell sites has been a crucial aspect of the joint venture's viability.

Price

As regards pricing for residential broadband, **Stockholm and Paris are the only cities from those compared in which there are standard widespread offers from multiple providers for Gigabit bandwidths, and Stockholm was the only city in which it is standard practice to buy broadband on a standalone basis rather than as part of a bundle**.

For a benchmark price of around €40 per month (excl VAT), speeds of 200, 300Mbit/s can be achieved respectively in London and Madrid, or 400Mbit/s in Hamburg (cable areas only). **In Stockholm and Paris the same price would enable download speeds of 1Gbit/s based on offers available on operator websites**,[8]

It should be noted that **when offers to apartment buildings are also considered,**[9] **prices for high bandwidth broadband in Stockholm can be considerably lower than that reported on operator websites, below €10 per month for 1Gbit/s symmetric.** Actual charges for retail business lines at 100Mbit/s and 1Gbit/s[10] were also found to be cheaper in Stockholm than London and Paris (as well as Berlin and Amsterdam) in the context of a study conducted in 2015.[11]

Figure 1-2: Broadband and dark fibre pricing across six European cities, 2015

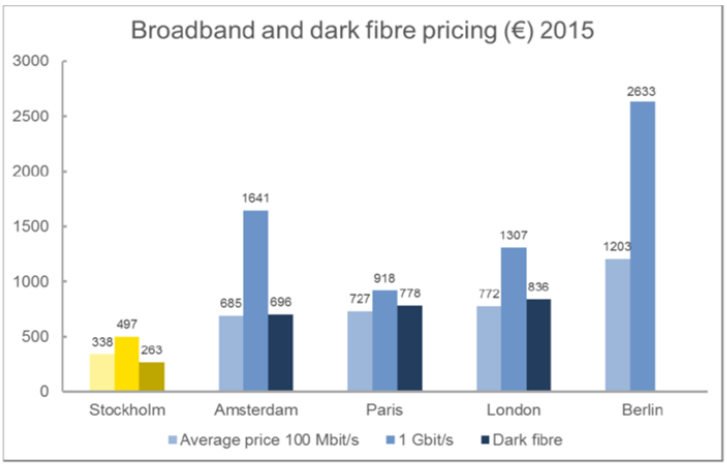


Figure 1: Average price per month (EUR) based on 36 monthly fees and connection fee – 100 Mbit/s, 1Gbit/s, and dark fibre.

Source: United Minds (2015).

8 Based on the lowest price from operators with coverage of at least 50% of households including any introductory discounts distributed over 24 months. Offers in Paris also include telephony and TV

9 Arrangements with apartment buildings in Stockholm are common as the in-building wiring is owned by the apartment owner

10 Based on request to a sample of operators

11 United Mind (2015). The corporate price of high-speed broadband: A comparative Study between five European cities.

Policy implications

Our sample of five cities is too small to draw definitive conclusions about the role that business models may have played in influencing the outcomes. However, taking into account other research, including academic research and studies conducted by WIK-Consult for the European Commission,[12] they suggest that:

- **Disruptive entry from a new infrastructure competitor is important.** Relying on competition between legacy infrastructure-based operators (incumbent and cable) may not provide enough competitive stimulus to drive upgrades in access infrastructure to FTTH/B. In London, the only city with two networks in the sample, the incumbent is relying on gradual upgrades of the copper network to FTTC/VDSL and then G.fast in order to compete with cable, with negative effects on quality. In all the other cities, the 'new entrant' – ie the municipality in Stockholm, utility in Hamburg, and alternative operators in Paris and Madrid, provided the impetus to upgrade to FTTH/B.

- **Wholesale only models and end-to-end infrastructure competition models can both be effective in driving FTTH/B deployment in major cities.** The wholesale only municipal model of Stockholm and the model in which end-to-end infrastructure-based competition was encouraged through duct access and in-building wiring. (Paris and Madrid) have both achieved positive deployment outcomes for FTTH/B. These conclusions mirror those reached by WIK in the context of the study "Regulatory in particular access regimes for network investment in Europe".[13]

- **Wholesale only models based on dark fibre may help to avoid risks of oligopolistic outcomes in the retail market.** Concentrated oligopolistic markets can be associated with positive outcomes for speeds, prices and innovative bundles. This seems to be the case in Paris. However, it is also possible that the players may choose in parallel to limit the speeds made available over their networks. For example, although there are other positive aspects around market developments in Hamburg, it is interesting to see that Gigabit offers are not widely available, even though the underlying FTTH network should be capable of supporting these speeds. Where one player is wholesale only and offers passive infrastructure access, the risk of restrictions on quality is minimised, as a number of service providers can compete in the installation of active equipment. This potential for competition in the active equipment tends to drive competition to maximise quality (including download and upload speeds as well as other characteristics), in a similar manner as was seen for unbundling of the copper local loop.[14] The greater variety of service

12 Notably "Regulatory, in particular access, regimes for network investment in Europe" 2015/0002 and "Support for the preparation of the Impact Assessment accompanying the review of the Framework for electronic communications" SMART 2015/0002

13 SMART 2015/0002. See also SMART 2015/0005

14 See Nardotto et al (2015) Unbundling the incumbent, evidence from UK broadband http://onlinelibrary.wiley.com/doi/10.1111/jeea.12127/full

providers may also mean that there is greater choice in the types of service available, and niche providers may emerge to serve specific customer needs.

- **Wholesale only models may serve to constrain bundling practices.** It is interesting to note that in Paris and Madrid, the major broadband providers are also mobile operators. The available offers show that bundled services (triple play and increasingly quadruple play – with mobile) play a very significant role in those markets. The fact that competition is based primarily on vertically integrated infrastructure providers is likely to reinforce this practice, as each operator needs to maximize both scale and scope in order to make a return on the high investment required in deploying fibre. In contrast, most retail offers available in Stockholm are not bundled. The availability of a neutral fibre infrastructure may increase the potential for smaller broadband providers to play a role in the retail market, and reduces the need for mobile operators to invest heavily in their own fixed infrastructure in order to support their mobile business. Standalone fixed or mobile broadband provision may thus be more viable, injecting further competitive pressure in the market.

- **Wholesale only fibre models can support deployment and competition in next generation mobile networks and IoT applications.** It is interesting to note that mobile speeds in Stockholm are high relative to the other cities and that there are fewer differences between the speeds offered by different operators. There are indications that this competition for quality in mobile broadband was supported by the ready availability of dark fibre backhaul in Stockolm from Stokab on an 'operator-neutral' basis.[15] In contrast, operators in other cities may have had less favourable conditions for backhaul and/or greater need to build their own fibre backhaul. The availability of an operator-neutral network, supporting multiple service providers, may also offer advantages in enabling niche providers to develop IoT applications for the low latency 5G environment. It also enables public services to benefit from competitive tendering for public communication services, avoiding lock-in with one or two integrated infrastructure and service providers.

- **Competition which is based on VULA or bitstream is unlikely to be a substitute for genuine infrastructure competition or competition based on dark fibre.** Out of the cities assessed, London has the most limited degree of infrastructure competition in residential broadband provision, and the highest share of competition based on virtual unbundled local access. Although the retail market may ostensibly appear competitive, with a number of operators present in the provision of fast broadband, it does not seem that this kind of competitive model which relies significantly on bitstream delivers as strong results as those pursued in the other cities. In particular, the degree of competition in price and quality (speed) appears to be relatively limited. The same issues may apply in Hamburg, where service competition is also based mainly on bitstream. This observation is supported by a range of literature and

15 See also Benoit Felten (2015)

analysis which suggests that while infrastructure-based competition, and access competition based on passive access (unbundled network elements) can both contribute to enhancing service quality,[16] competition based on bitstream may have less significant effects.[17]

- **Incentivising FTTC/VDSL vectoring deployment might set back competition in FTTH/B.** A common feature of the two cities which fared worst in metrics relating to broadband deployment and quality – London and Hamburg - is that the incumbent has in both cases opted to deploy FTTC/VDSL rather than more performant FTTH/B technology. In contrast, while the Swedish incumbent Telia, originally planned a mixed strategy based on FTTC/VDSL alongside FTTH,[18] it subsequently shifted its strategy to place focus on FTTH/B,[19] and incumbents in Madrid and Paris opted for FTTH/B from the outset. One reason for the incumbents' technological choices in Paris, Madrid and Stockholm may have been competitive pressure from alternative operators and investors that were planning or had constructed their own FTTH/B networks. However, this would not explain the choice of the German incumbent in Hamburg to continue its pursuit of a FTTC/VDSL strategy despite the presence of a competitor – Wilhelmtel - installing FTTH/B. It is possible that the regulatory regime in Germany which allows and even encourages the deployment of technologies which increase the speeds available over the legacy copper network such as vectoring, may have reduced the need for the incumbent to upgrade its network to FTTH/B in order to compete with rivals. In other words, there is a risk that regulation which favours shorter term, lower cost but less performant, technological solutions may harm longer term investment incentives.

16 See for example Nardotto, Valletti (2015) Unbundling the incumbent: evidence from UK broadband http://onlinelibrary.wiley.com/doi/10.1111/jeea.12127/full
17 See for example Calzada and Martinez (2014) broadband prices in the European Union
18 See Telia announcement 2008 http://telekomidag.se/telia-storsatsar-pa-fast-bredband/
19 See for example news regarding Telia's fibre expansion https://www.telecompaper.com/news/telia-starts-new-ftth-expansion-campaign--1122471

2 Introduction

A key focus of the proposed European Electronic Communications Code is to boost competition and investment in very high capacity broadband. In turn, achieving ubiquitous high capacity broadband could support wider productivity gains,[20] and the development of smart applications for businesses, individuals and the public sector, benefiting society as a whole.[21]

In this study, prepared for Stokab, we analyse the effects of different business models on deployment and competition in high speed broadband across five cities and assess the practical outcomes for consumers, in terms of quality, choice and price, as well as the implications for innovation and participation in the digital economy.

The cities covered in the exercise are London, Stockholm, Paris, Madrid and Hamburg. They were chosen because they represent distinct models for the deployment of very high capacity broadband

The study is structured as follows:

- Chapter 3 describes the context in which fast broadband deployments are taking place
- Chapter 4 discusses the broadband targets and regulatory approaches to NGA
- Business models are discussed in chapter 5
- Chapter 6 discusses broadband outcomes for consumers and businesses, in terms of availability, quality, choice and pricing
- Chapter 7 summaries economic and social impacts
- Conclusions are presented in chapter 8

More detailed information concerning each of the five cities is contained in the case studies presented in the annex.

20 In a study for the European Commission to support the Impact Assessment for the Review of the Framework for electronic communications, SMART 2015/0005, WIK, Ecorys and VVA found evidence that increasing broadband speeds and boosting the coverage of next generation mobile networks could drive productivity across a number of sectors.

21 Examples are self-driving cars, smart cities, e-education and healthcare, remote working

3 Context

When assessing the drivers of broadband deployment and diffusion, it is important to consider the context. High population densities and the presence of large apartments and business premises tend to improve the economics of deploying FTTB by reducing the cost of deployment per household or allowing a single fibre to be shared amongst multiple occupants of a large building. These factors are amongst those which contributed to a high degree of FTTH/B deployment in Japan and South Korea.[22] Wealth, as measured through GDP per capita, can also influence the extent to which there may be capacity to pay for high bandwidth connections. Lastly, the ease of doing business, amongst other factors, may influence the degree to which smaller companies and start-ups engage in deploying infrastructure, providing services and developing innovative applications. The table below summarises these metrics for the cities considered in this study.

Table 3-1: Contextual metrics

Metric	Source	Stockholm	London	Paris	Madrid	Hamburg
Population density (per sq m)	Eurostat 2016	328.7	1154.2	997.2	328.7	446.3
Share of buildings with five floors or more	Housing_UK (for London, Paris, Madrid), Stockholm, MDU: Lee et al	46	13	59	60	
GDP per capita (€)	Eurostat 2013	63,256	46,942	53,578	30,320	43,199
Ease of doing business (ranking 1=highest)	OECD 2016 - country level	9	7	29	32	17

It can be seen that Paris and Madrid both benefit from a high proportion of buildings with five or more floors, which should facilitate the deployment of fibre to the building. Just under 50% of buildings in Stockholm are also of this scale. The proportion of large multi-dwelling units is lower in London. However, London (and also Paris) benefit from a high overall population density, which should reduce the per building cost of deployment. Estimated GDP per capita in the considered cities varies depending on the source and the footprint under review. However, the figures suggest that average GDP is high relative to other regions in those countries. Madrid has the lowest GDP per capita of the considered cities, and therefore may potentially offer the most challenges concerning affordability of high speed broadband.

22 See discussion in WIK (2015) Competition and investment, an analysis of the drivers of superfast broadband

4 Regulatory regimes

The cities considered differ as regards their Government's ambitions for broadband deployment as well as the regulatory approach taken to Next Generation Access by the national regulatory authorities.

4.1 Broadband targets

The degree of broadband ambition pursued by national Governments towards NGA varies in the considered countries.

- The most ambitious targets have been set by Governments in Sweden and France. The Swedish Government has set a target for 90% of households and businesses to have access to at least 100 Mbit/s by 2020,[23] while 98% of the population should have access to a minimum speed of 1Gbit/s by 2025.[24] Meanwhile, in France, the Government is targeting 100% coverage of 100Mbit/s by 2022.

- More modest national targets have been applied in the UK, Germany and Spain. In Germany the Government has set a target that all German households should have broadband access at a minimum capacity of 50 Mbit/s by the end of 2018, although there are initiatives to boost the availability of Gigabit connectivity in the longer term. The national targets adopted in Spain directly mirror those of the EU Digital Agenda for Europe – ie full coverage of 30Mbit/s and 50% take-up of 100Mbit/s by 2020.

4.2 NGA regulation

The five cities reflect three models of NGA regulation, with differing focus on infrastructure vs service competition:

- **Regulation in London (UK) and Stockholm (Sweden) historically tended to focus on ensuring intramodal (access-based) competition on the incumbent NGA network,** while reflecting any perceived risk in NGA deployment (restricted to single dwelling units in Sweden) through the wholesale pricing regime. Regulated wholesale access to NGA networks in London is on the basis of Virtual Unbundled Local Access, while in Stockholm the point to point architecture of the incumbent's FTTH network allowed unbundling of the fibre loop. Regulation in these markets was technologically neutral, with no explicit preference given to FTTC or FTTH deployment – although Ofcom's more

23 Regeringens proposition 1999/2000:86, Ett informationssamhälle för alla, (An information society for all), 29 March 2000.
24 Regeringskansliet (2016), Sverige helt uppkopplat 2025 - en bredbandsstrategi.

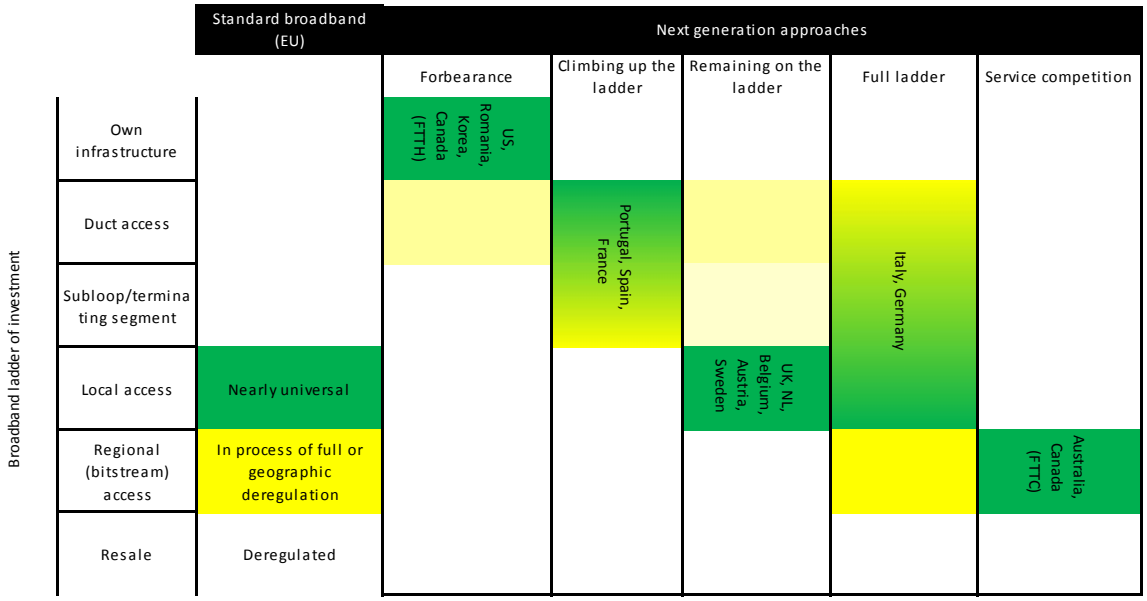
recent decisions have focused on the need to foster competitive investment in FTTH.[25]

- The **regulatory approach in Germany also focused on ensuring intramodal competition on the incumbent NGA network** through access (bitstream) regulation, coupled with flexible pricing to support investment, but in addition sought to foster competitive investment in FTTC/VDSL through attention to the pricing of SLU and availability of duct access to the street cabinet. The German NRA has also adopted **decisions on FTTC VDSL vectoring which provided incentives respectively for ‚first movers' (first vectoring decision) and DT (second vectoring decision) to invest in this technology**.

- **Regulation in Paris (France) and Madrid (Spain) has aimed at facilitating end-to-end infrastructure competition in FTTH/B, through a focus on SMP duct access regulation and symmetric regulation concerning access to in-building wiring.** There are no requirements in these cities for the incumbent to offer wholesale access to its NGA network.

The approaches taken to regulation of Next Generation Access in these five countries and others at the time when the original decisions were made (around 2010) are summarised in the table below, which highlights where regulators placed most focus in the 'ladder of investment' for broadband deployment.

Table 4-1: Regulatory approaches to Next Generation Access (2010)



Source: WIK-Consult, SMART 2015/0002

25 Specifically, Ofcom is consulting on a revision to duct and pole access remedies with a view to supporting competitive investment in FTTH/B – see https://www.ofcom.org.uk/consultations-and-statements/category-2/duct-pole-access-remedies

5 Business models

There are four distinct business models for NGA deployment in the cities considered. These are described below and depicted in diagrams.

In London, there are **two main infrastructure operators (incumbent and cable) and a number of service providers** providing services on the basis of the incumbents' regulated wholesale broadband offers. The incumbent BT is deploying primarily **FTTC/VDSL** technologies. It provides VULA (a form of wholesale bitstream access) from its **functionally separated (soon to be legally separated, but wholly owned) unit** Openreach and unregulated bitstream access. Alternative operators and BT's own retail residential and business units provide retail services on the basis of BT's wholesale offers. The cable operator is vertically integrated and is not active in providing wholesale offers for the residential broadband market.

Table 5-1: London - Business/competitive model for broadband

<table>
<tr><td>Incumbent retail</td><td>Altnet</td><td rowspan="2">Cable</td></tr>
<tr><td colspan="2">Incumbent (legal separation) FTTC VULA</td></tr>
</table>

Source: WIK-Consult

In Stockholm, there is **infrastructure competition between three network operators**, one of which – Stokab - offers **dark fibre on a wholesale only basis**, and is not active in the retail market. The cable operator is vertically integrated. The incumbent TeliaSonera provides wholesale access to unbundled fibre and FTTC/VDSL VULA on regulated terms through its legally separated unit Skanova to alternative operators as well as its own retail arm – with some similarities to the Openreach model, although it has not been formally recognised as representing functional separation by the NRA. The presence of the municipal wholesale only network in Stockholm is the main factor differentiating the competitive structure in Stockholm compared with London.

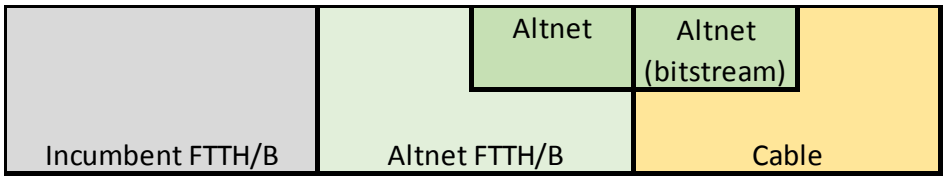
Table 5-2: Stockholm - Business/competitive model for broadband

<table>
<tr><td>Incumbent retail</td><td>Altnet</td><td>Altnet</td><td>Incumbent retail</td><td>Cable</td><td rowspan="2">Cable</td></tr>
<tr><td colspan="2">Incumbent (legal separation) FTTH/B/C</td><td colspan="3">Municipal Wholesale only FTTH/B Dark fibre</td></tr>
</table>

Source: WIK-Consult

In Paris and Madrid, NGA services are provided mainly on the basis of **end-to-end infrastructure competition between 3-4 operators** including cable. The main technology used by the incumbents and alternative operators is **FTTH/B**. Alternative operators make use of regulated duct access from the incumbent or other physical infrastructure access (such as sewer access) to deploy fibre to the base of the building. The in-building wiring is shared on the basis of symmetric regulation applying to all operators, with disputes settled by the NRA. All the main infrastructure providers are vertically integrated and active in mobile as well as fixed markets. Wholesale access to the NGA network of the incumbent is not regulated in Paris or Madrid, but there is some commercial wholesaling by alternative network operators and cable.

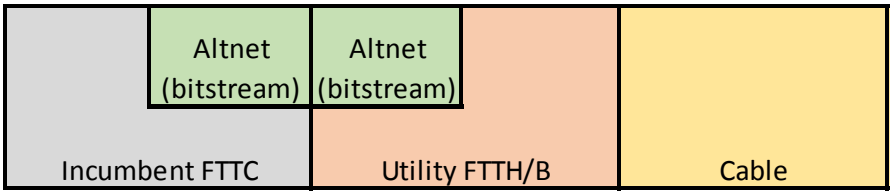
Table 5-3: Paris, Madrid - Business/competitive model for broadband



Source: WIK-Consult

In Hamburg, there is infrastructure competition in NGA between three vertically integrated operators including cable. **The incumbent has deployed FTTC/VDSL and plans to use vectoring technology**. **Wilhelm tel, a subsidiary of the energy provider, is installing FTTH/B**. The incumbent offers regulated wholesale bitstream access to service providers, while Wilhelmtel has signed commercial wholesaling arrangements, also on the basis of bitstream. The key differences between the competitive dynamics in Hamburg compared with Stockholm is that **all infrastructure providers are also active in the retail market and wholesaling is on the basis of bitstream offers.**

Table 5-4: Hamburg - Business/competitive model for broadband



Source: WIK-Consult

6 Broadband outcomes for consumers and businesses

6.1 Availability of very high capacity infrastructure

A review of available regional data shows that **FTTH/B infrastructure is widely available in Stockholm, Paris and Madrid**. There is partial FTTH/B coverage from Wilhelmtel in Hamburg, while the incumbent offers FTTC/VDSL across a wide footprint. FTTH/B in London is very limited. NGA access is supplied by the incumbent on the basis of FTTC/VDSL. All the considered cities benefit from partial coverage of Docsis 3.0 cable networks, which allows us to consider how the role of other market actors may have influenced outcomes in high speed broadband.

Table 6-1: Coverage by technology Q1 2017

	Hamburg	London	Madrid	Paris	Stockholm
FTTH/B	71.4%	4.5%	>90%	90%	93%
FTTC/VDSL	>90% (est)	95%	Limited	Limited	23%
Docsis 3.0	>50%	65%	~50%	High	78%
LTE[26]	68%	74%	80%	68%	87%

Sources: various, see case studies. LTE coverage from Opensignal Feb 2017

As regards high speed mobile connectivity, LTE is most widely available to end-users in Stockholm and Madrid, while the lowest availability was reported in Paris and Hamburg.

6.2 Quality

There is no granular data available concerning the take-up of offers at different advertised speeds across the considered cities. However, data from Ookla provides an estimate of the actual average download speeds obtained in the five cities as well as the mobile download speeds.

Here, a clear distinction can be seen. **The quality of both fixed and mobile Internet is highest in Paris and Stockholm – both FTTH/B cities, and lowest in Hamburg and London – cities with extensive FTTC/VDSL networks**. Although it too benefits from widespread FTTH/B the outcomes in Madrid fall short of those in Paris and Stockholm.

26 % time LTE is available to end-users as measured by Opensignal Feb 2017 The best performing 4G cities in Europe https://opensignal.com/blog/2017/02/23/data-dive-what-are-the-best-performing-4g-cities-in-europe/

The reasons are not known. One explanation might be if there is widespread take-up of 50Mbit/s offers or those reflecting copper speeds.

Table 6-2: Average fixed and mobile Internet download speeds 2016

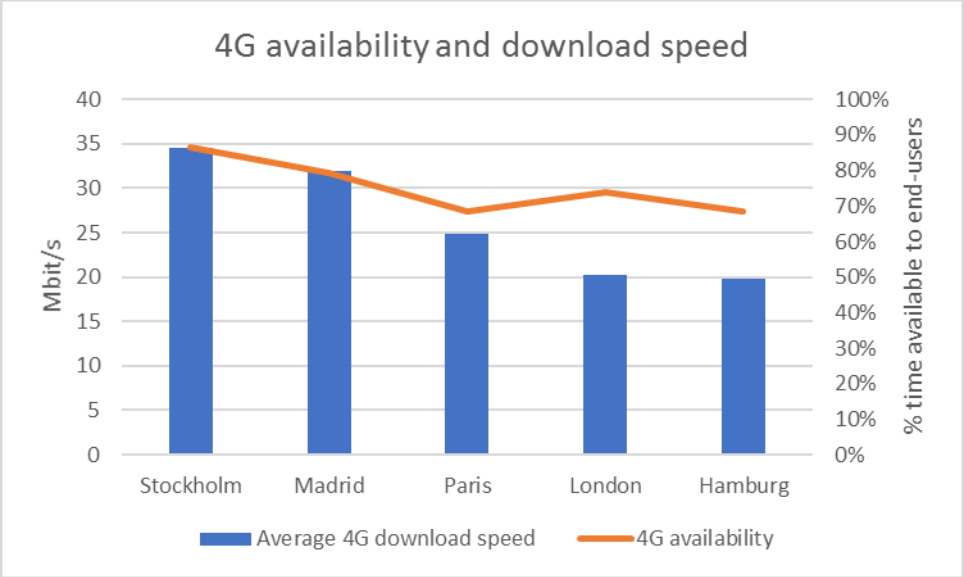
	Hamburg	London	Madrid	Paris	Stockholm
Average download Mbit/s	29.02	28.79	48.08	71.74	71.85
Mobile speeds Mbit/s	15.65	16.77	18.84	19.37	20.97

Source: Ookla Netindex (extracted from European Digital City Index 2016)

Moreover, available offers in the cities reviewed show that **upload speeds in Stockholm and Madrid as well as Paris are considerably higher than those in the cities dominated by FTTC and cable**. Whereas the cable operator in Hamburg offers upload bandwidth of just 12Mbit/s for a 200Mbit/s connection (and upload speeds are not widely reported in London or elsewhere in the UK), T3, Universal broadband and Bahnhof in Stockholm offer speeds of 250/100Mbit/s and symmetric offers are widely available in Stockholm as well as Madrid and Paris. Upload bandwidths are vital for cloud computing and video conferencing services, and may also be key to upcoming IoT, virtual reality applications and public services such as distance medicine.

The high mobile quality of Stockholm and comparatively poor quality of mobile broadband over 4G in London and Hamburg is confirmed in data published by Opensignal in February 2017. Overall, Stockholm achieved the 6th highest 4G speeds out of 30 cities compared, while London and Hamburg were placed at the end of the rankings. In general, Opensignal noted that “German cities routinely fell to the bottom of the table in both metrics [availability and speed]”.

Figure 6-1: 4G availability and speed 2017



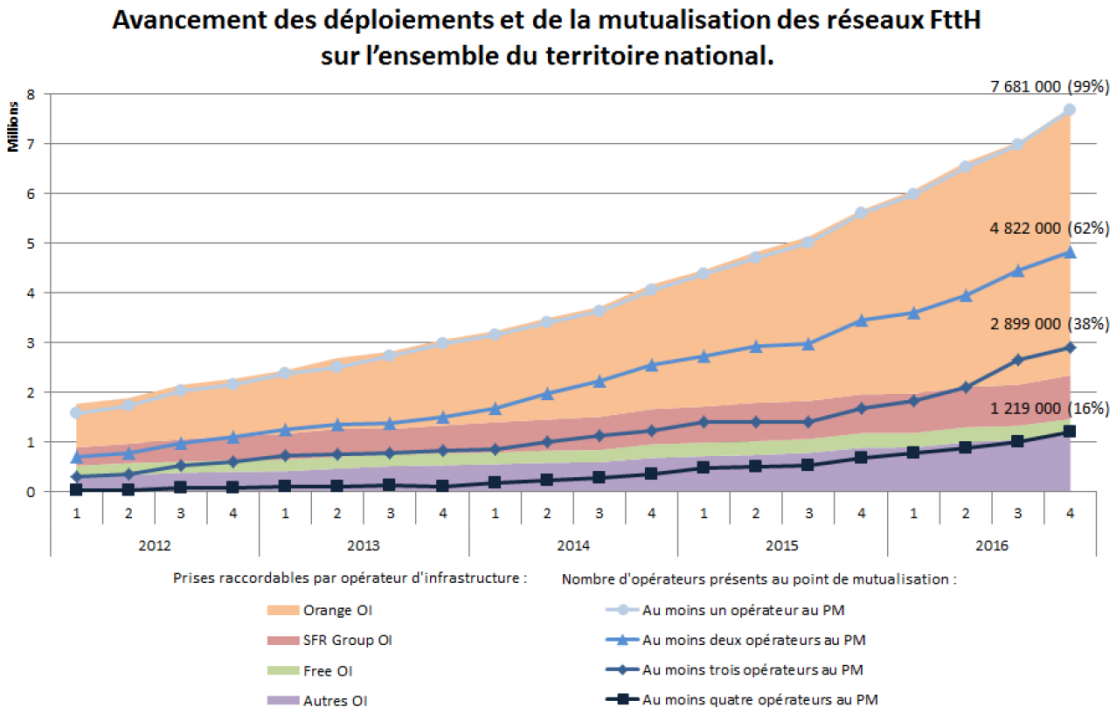
Source: Opensignal best performing 4G cities in Europe[27]

6.3 Choice

All the cities with the exception of London benefit from at least 3 significant infrastructure-based competitors in NGA. However, as illustrated in data provided by the French NRA ARCEP concerning choice of FTTH infrastructure providers in 'very dense areas' (see following figure), the coverage of infrastructure-based providers does not overlap precisely and therefore individual households may not always be served by all three providers. More specifically, in the case of very dense areas in France (mainly Paris), only around 66% of households have access to at least 2 FTTH offers (resulting in three available high bandwidth providers if cable is also present).

27 https://opensignal.com/blog/2017/02/23/data-dive-what-are-the-best-performing-4g-cities-in-europe/

Figure 6-2: Deployment and choice in FTTH broadband in very dense areas



Source: ARCEP high speed broadband observatory

At the retail level, the degree of choice – over and beyond those offered by the infrastructure operators themselves (the incumbent, cable, and 1-2 investing alternative operators in Paris, Madrid and Hamburg), depends on the business model pursued by the infrastructure providers.

As can be seen in the table below, access-based service providers play a more significant role in the retail markets in Stockholm and London than in the other cities. This reflects the fact that regulatory and business models in Paris and Madrid have favoured infrastructure competition, while the wholesale only model of Stokab, and the separation of BT in the UK have supported a greater variety of service providers.

Table 6-3: Infrastructure and service competition in residential broadband

	Hamburg	London	Madrid	Paris	Stockholm
Infrastructures	4	2	3-4	3-4	3
Service providers	~5	Numerous (23 res. on Openreach)	~6	~6	Numerous (>100 on Stokab)

Source: WIK estimates

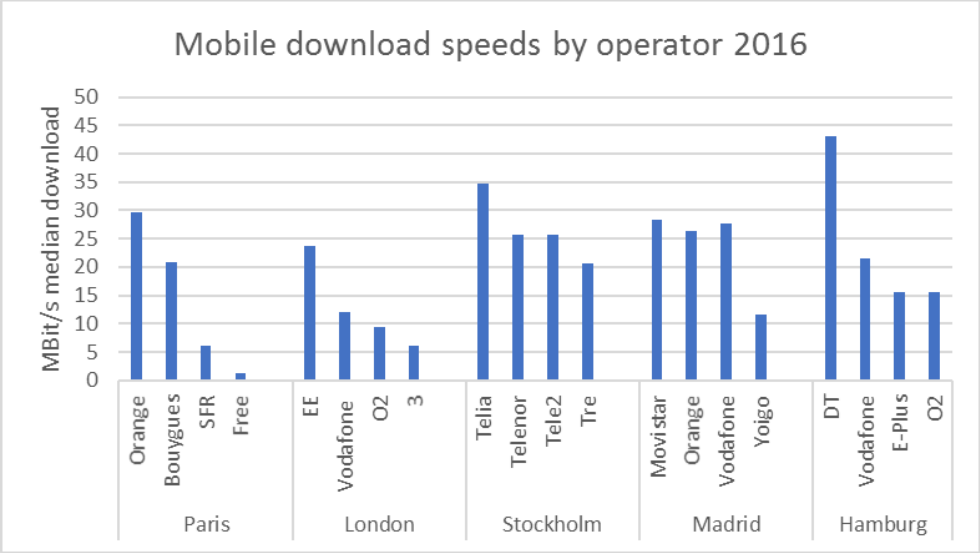
Large numbers of service providers may not however imply greater choice – as further discussed in the section on pricing below. The product and pricing structure for VULA in

the UK, which ties access seekers to specific quality and pricing tiers, tends to result in similar retail offers by service providers relying on the BT Openreach platform, whereas the **availability of dark fibre in Stockholm for a flat fee could be expected to result in greater differentiation in the retail offers from service providers**.

Another interesting observation is that **bundled offers of at least double play (broadband and voice, sometimes with mobile) are prevalent in all cities except for Stockholm, where the individual services are typically available separately**. The unbundling of communication services in Stockholm (and Sweden more widely) is likely to have been supported by the presence of a wholesale only provider. The unbundled service model can serve to enable customer's use of mobile telephony as a substitute for fixed, as well as allowing over-the-top content services such as Netflix to be used as an alternative to broadcast television. This should increase the degree of choice available to end-users.

As regards competition and choice in mobile, it is striking that **the quality of mobile broadband differs significantly amongst different operators in London, Paris and Hamburg, but is in general higher as well as more evenly distributed in in Stockholm and Madrid** – with the exception of Yoigo. Various factors may play a role including spectrum. However, it is also possible that the existence of Stokab as an operator neutral dark fibre network – may have enabled alternative operators to deploy 4G networks more rapidly and achieve higher speeds in Stockholm, supporting vibrant competition amongst them. In contrast in the other cities, operators without an extensive self-built fibre network are likely to have been at a disadvantage compared with the incumbent.

Figure 6-3: Median mobile download speeds by operator and city



Source: Rootmetrics Q1 2016 except Hamburg (Speedtest) Q2-Q3 2016

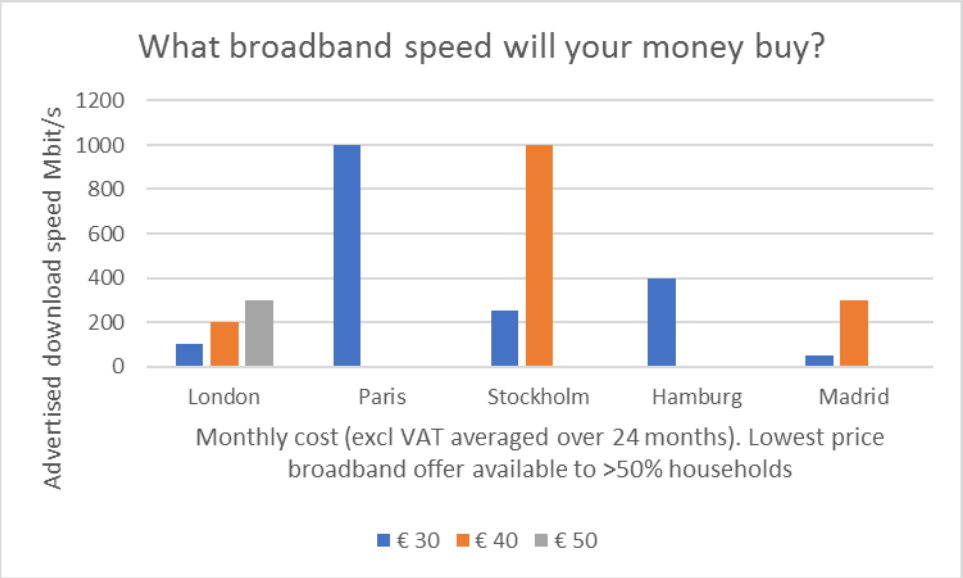
6.4 Broadband offers and pricing

6.4.1 Residential broadband

The fact that broadband is typically sold on a standalone basis in Stockholm, makes it difficult to make direct like for like comparisons of residential broadband pricing between Stockholm and the other cities, in which bundling is prevalent.

However, some observations can nonetheless be made. A first noteworthy point is that Stockholm and Paris are the only cities out of those examined in which Gigabit offers are widely available for residential customers from more than one provider (multiple in the case of Stockholm, and three-four in the case of Paris). While according to advertised promotions, Gigabit offers are available from alternative operators in Paris[28] and Stockholm for €30-40 per month, the same price would only achieve broadband speeds of 400Mbit/s in Hamburg, 300Mbit/s in Madrid and 200Mbit/s in London. It is also notable that at the highest speeds available, there is a choice of only one provider (the cable operator) in London and Hamburg.

Figure 6-4: Broadband speeds available at benchmark price points May 2017[29]



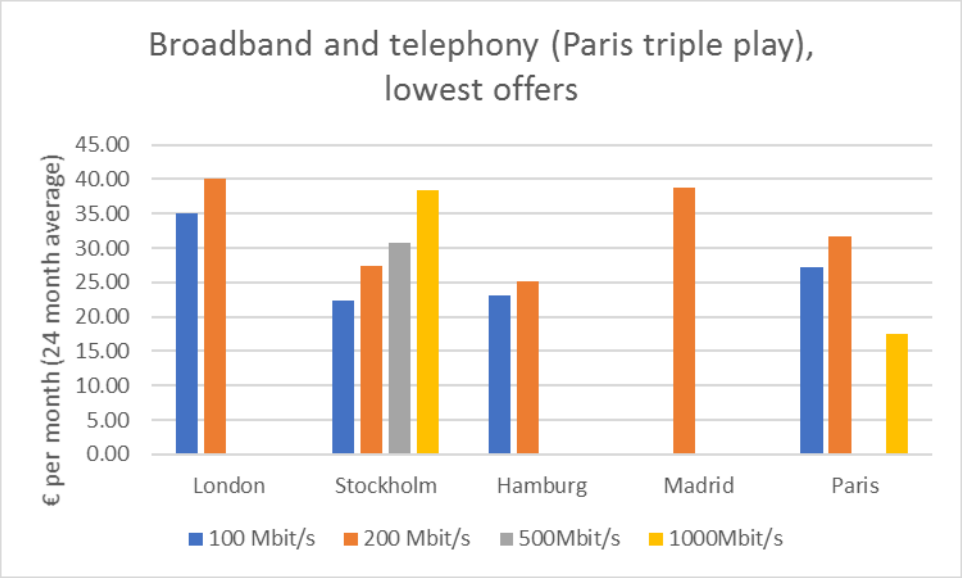
Source: WIK-Consult based on operator websites

28 Gigabit offers in Paris are typically available as part of a triple play offer with telephony and TV

29 Average monthly charges were calculated over a 24 month period. Discounts are included for the applicable period (typically 3-12 months), with the remaining time charged at the standard rate. VAT is excluded to ensure comparability. The lowest price offer amongst the incumbent, cable and alternative operators with significant coverage in the local area (>50% households) is shown. Where a variety of upload speeds are available, the lowest price, typically associated with the lowest upload speed has been taken. The following providers are reflected. London – Virgin Media, Paris – Free, Bouygues, Stockholm, T3, Bahnhof, Universal Telecom, Hamburg - Vodafone, Madrid – Jazztel, Masmovil. Offers are based on single play (broadband only) in Stockholm and London, Double play in Hamburg and Madrid (broadband + telephony) and triple play (broadband + telephony + TV) in Paris

Comparing the lowest widespread offers for broadband and telephony at 100Mbit/s and above clearly illustrates the speed limitations in London, Hamburg and Madrid, and the relative value offered in Stockholm and Paris compared with the other cities.

Figure 6-5: Broadband and telephony – lowest offers[30]



Source: WIK based on operator websites

Paris provides an interesting example of a market in which new entrants have introduced triple play gigabit products at aggressive prices, with little or no premium above the charges offered for ADSL broadband, in contrast with more established operators, which are offering 100Mbit/s, 200Mbit/s and 500Mbit/s offerings under a tiered pricing structure. On the basis of advertised charges, the Gigabit offers in Paris appear to provide the best value across the five cities considered. However, their geographic availability may be limited and Paris is a relatively recent market for fibre compared with Stockholm, with limited underlying demand for fibre.[31] It will be interesting to observe whether prices increase in Paris, once the transition to FTTH/B from legacy copper networks, which may currently constrain charges, has been completed. The predominance of triple and quadruple play bundles in Paris, may also provide an opportunity for operators to cross-subsidise the monthly rental through pay-TV and telephone services.

30 Average monthly charges were calculated over a 24 month period. Discounts are included for the applicable period (typically 3-12 months), with the remaining time charged at the standard rate. VAT is excluded to ensure comparability. The lowest price offer amongst the incumbent, cable and alternative operators with significant coverage in the local area (>50% households) is shown. Where a variety of upload speeds are available, the lowest price, typically associated with the lowest upload speed has been taken. The following providers are reflected. London – Virgin Media, Paris – Free, Bouygues, Stockholm - Universal Telecom, Hamburg - Vodafone, Madrid – Masmovil. Offers are based on broadband and basic telephony in Stockholm, London, Hamburg and Madrid (broadband + telephony) and triple play (broadband + telephony + TV) in Paris due to the lack of widespread double play offers.

31 See discussion in WIK 2015 Competition and Investment: analysing the drivers of superfast broadband

As regards Stockholm, there are now well-established pricing tiers for broadband, and the opportunity to purchase telephony and TV (if at all) from multiple sources. **When longer term (typically 5 year) offers to apartment buildings are also considered,**[32] **prices for high bandwidth broadband in Stockholm can be considerably lower than that reported on operator websites - below €10 per month for 1Gbit/s symmetric,** although comparisons with other cities in this regard cannot be readily made.

6.4.2 Business connectivity

Businesses rely on high capacity symmetric connections to link their sites, support value chains and communicate with customers. Dedicated fibre connections – sold as 'high capacity leased lines' have long been available for large business customers, and are often competitively supplied, although competition is typically limited to dense business districts.[33] The deployment of widespread fibre connectivity has the potential to bring benefits which approach those of leased lines to smaller sites and businesses and to reduce the costs of such connectivity significantly.

There are no publicly available studies which compare business access prices for the five cities that are considered within this study. However, a 2015 study by United Mind, which compared charges for business connectivity based on fibre connections of 100 Mbit/s and 1 Gbit/s as well as of the average prices for dark fibre between five European cities shows that Stockholm had substantially lower retail prices than London and Paris. Berlin's prices stood out as comparatively high, and there is no availability of dark fibre, constraining the innovation potential for competitors and businesses (see Figure 6-6).[34]

32 Arrangements with apartment buildings in Stockholm are common as the in-building wiring is owned by the apartment owner

33 See for example Ofcom BCMR for an analysis of the UK market, and the wider analysis in WIK (2013) Business communications, economic growth and the competitive challenge

http://www.wik.org/index.php?id=studiedetails&L=1&tx_ttnews%5Btt_news%5D=1495&tx_ttnews%5BbackPid%5D=85&cHash=a9e4e3bd338c4ef2657dd066dc3d21a5

34 United Mind (2015). The corporate price of high-speed broadband: A comparative Study between five European cities.

Figure 6-6: Broadband and dark fibre pricing across six European cities, 2015

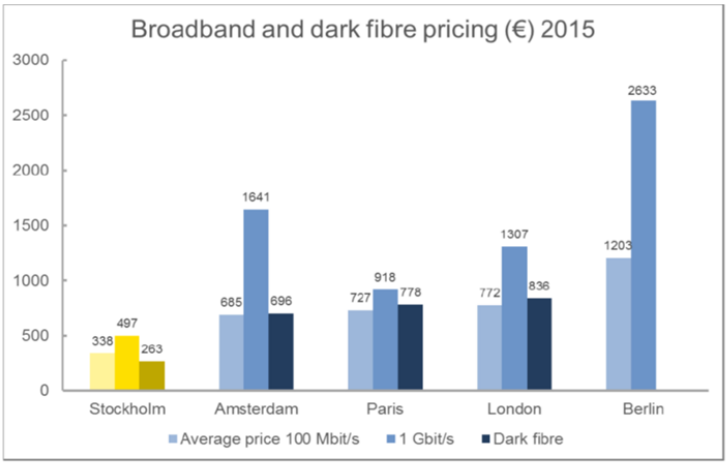


Figure 1: Average price per month (EUR) based on 36 monthly fees and connection fee – 100 Mbit/s, 1Gbit/s, and dark fibre.

Source: United Minds (2015).

6.5 Connectivity metrics – bringing it together

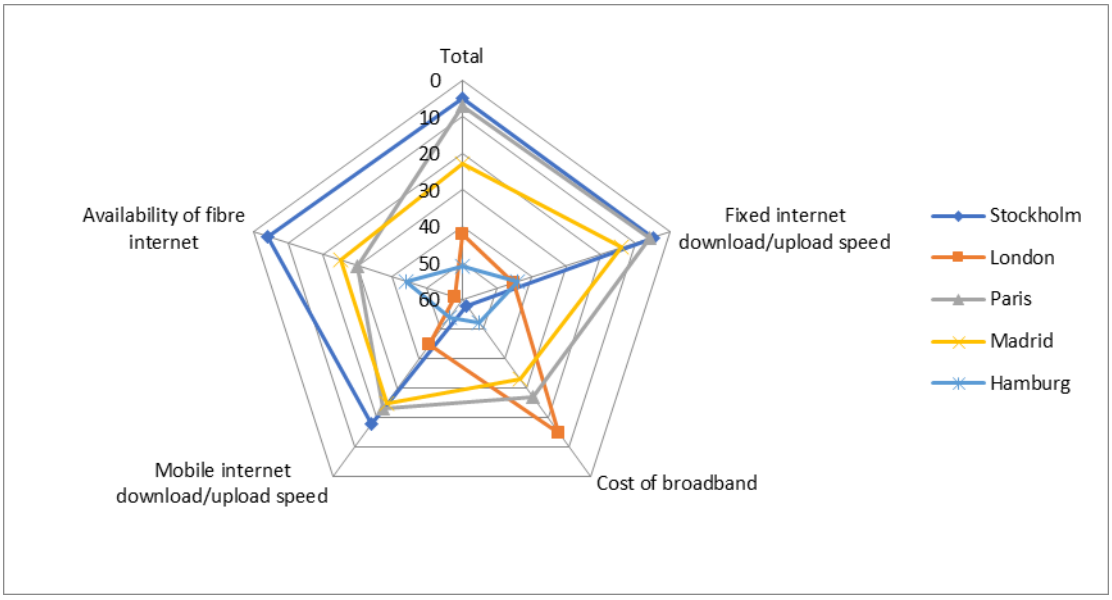
Composite indices have been developed, which aim to combine the different facets of 'connectivity' such as availability, speed and the price of broadband infrastructure.

One such measure is the European Digital City Index (EDCI) developed for the Commission by NESTA.[35]

As can be seen in Figure 5, under the EDCI Stockholm, Paris and Madrid outperform London and Hamburg on all measures apart from cost. The high ranking of London as regards the cost of broadband is likely to result from the fact that lower (copper-based) broadband speeds are available for a relatively low price in London. However, as discussed in section 6.4.1, there are no widely available equivalents in London to the residential very high bandwidth offers that are available in capitals such as Stockholm, Madrid and Paris.

35 NESTA (2016), European Digital City Index, https://digitalcityindex.eu.

Figure 6-7: Digital infrastructure across cities, 2016



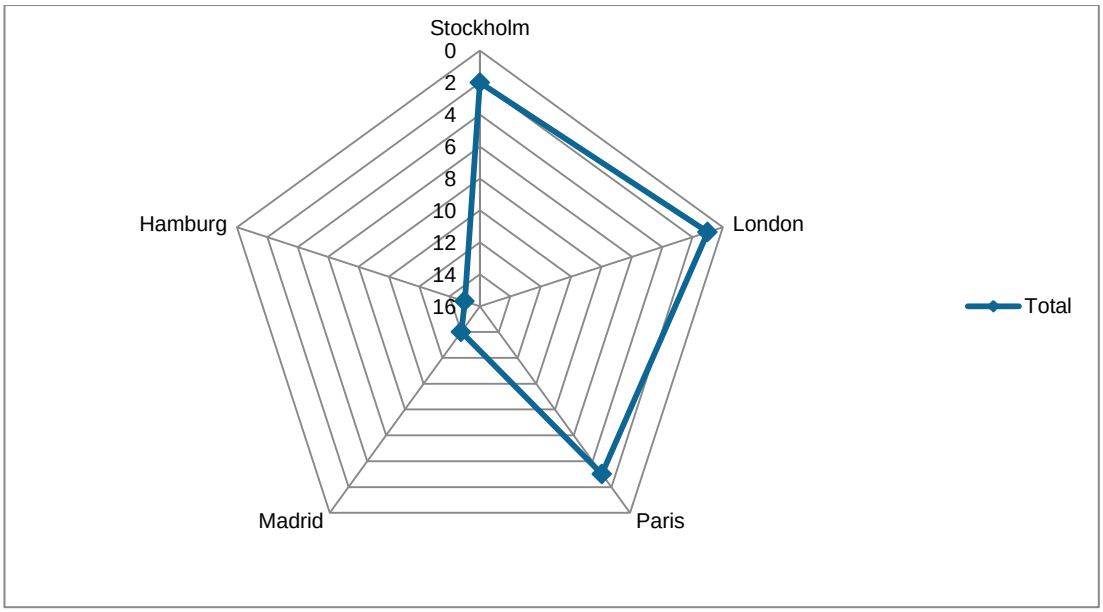
Source: WIK based on NESTA (2016), https://digitalcityindex.eu; EDCI includes 60 European cities.

7 Economic and social impacts

Widespread high capacity connectivity is a vital enabler for success in the wider digital economy and should provide support for high-tech employment as well as online services.

Over a range of metrics, London, Stockholm and Paris all perform strongly within the EDCI as a whole (seeFigure 7-1), while Madrid and Hamburg are placed some way behind the leading 'digital cities'.

Figure 7-1: European Digital City Index, ranking by total, 2016

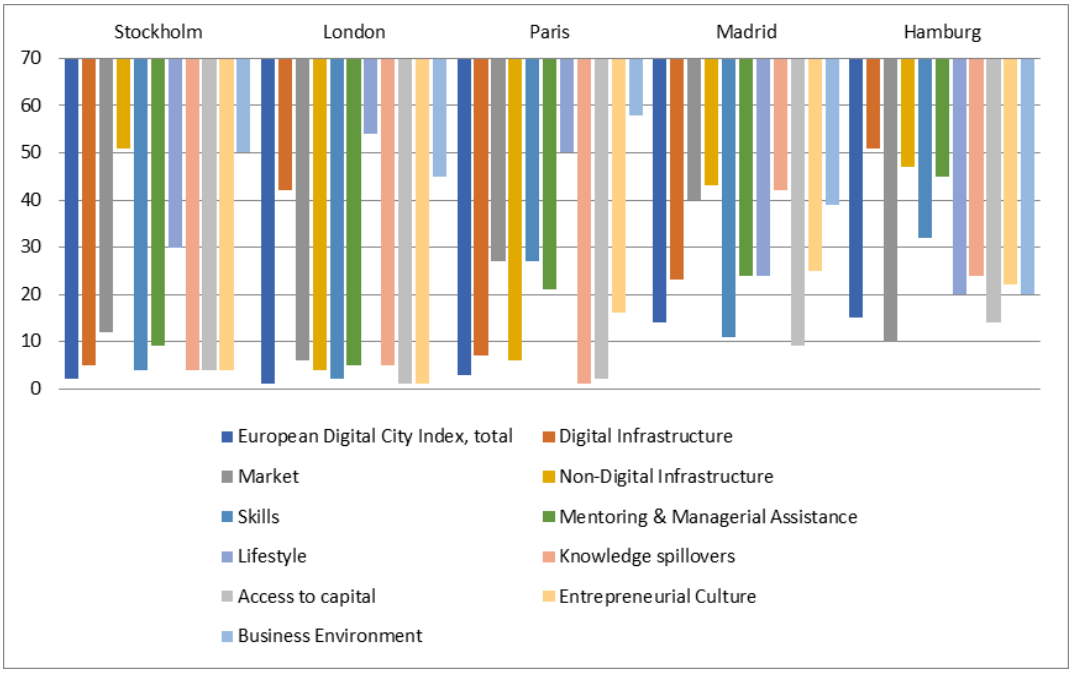


Source: WIK based on NESTA (2016), https://digitalcityindex.eu; EDCI includes 60 European cities

However, the overall figures mask distinct areas of strength and weakness.

As can be seen in the figure below, Stockholm's strength lies in its digital infrastructure, high-tech skills, access to capital, knowledge spillovers and entrepreneurial culture. However, its business environment and non-digital infrastructure – hold it back from reaching first place in the ranking.

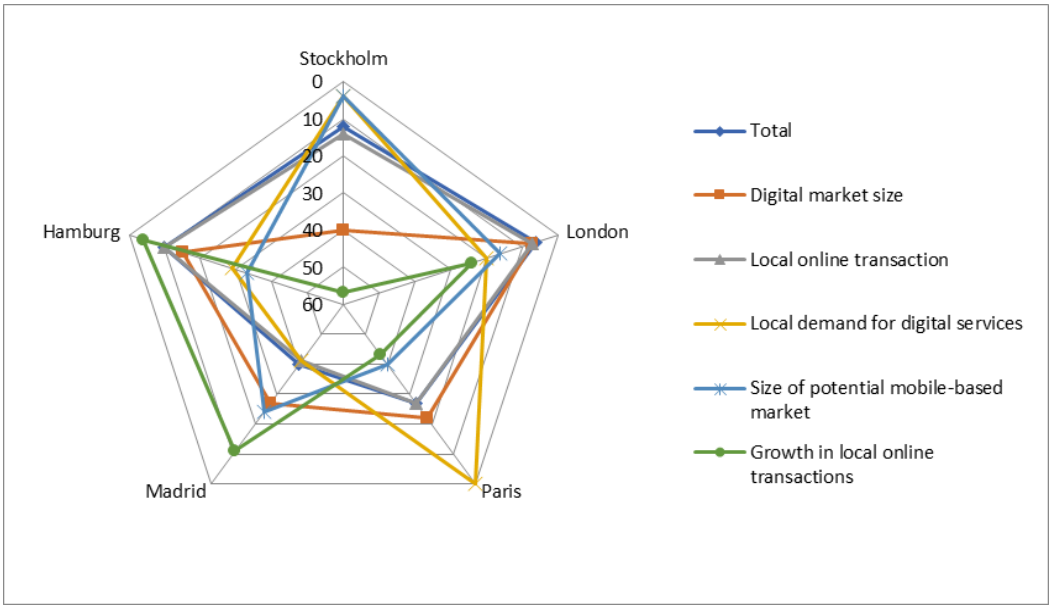
Figure 7-2: European Digital City Index, ranking by indicators and total, 2016



Source: WIK based on NESTA (2016), https://digitalcityindex.eu; EDCI includes 60 European cities.

On the other hand, London is weak in digital infrastructure, but compensates through its strength in non-digital infrastructure, and a significant digital market supported by high customer demand for online services, as indicated through the EDCI index (see Figure 7-3).

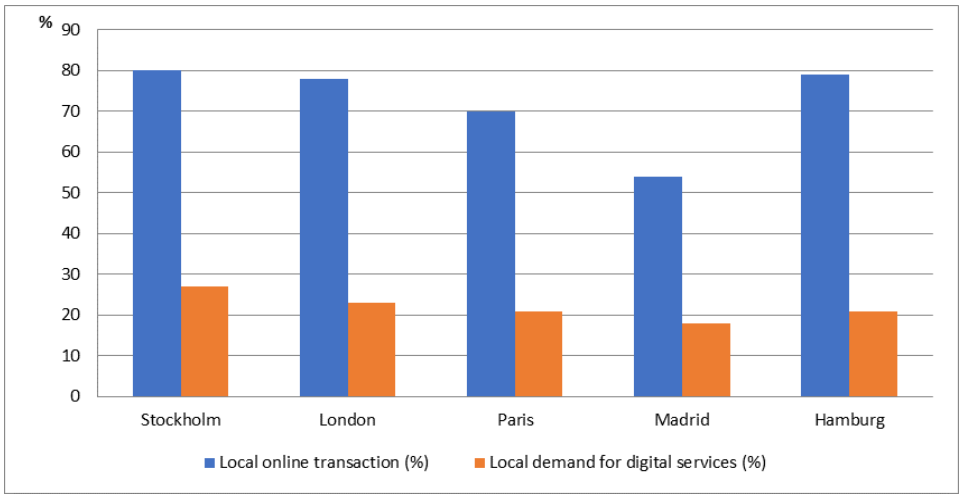
Figure 7-3: Digital Market across cities, 2016



Source: WIK based on NESTA (2016), https://digitalcityindex.eu; EDCI includes 60 European cities.

Data from Eurostat concerning the share of enterprises' total turnover from e-commerce, and the percentage of Internet users who bought or ordered goods or services for private use over the internet in the past 12 months also confirms the important role played by **demand for online services** in Stockholm as well as London and Hamburg – and highlights weaknesses in this area in Paris and Madrid (see following figure).

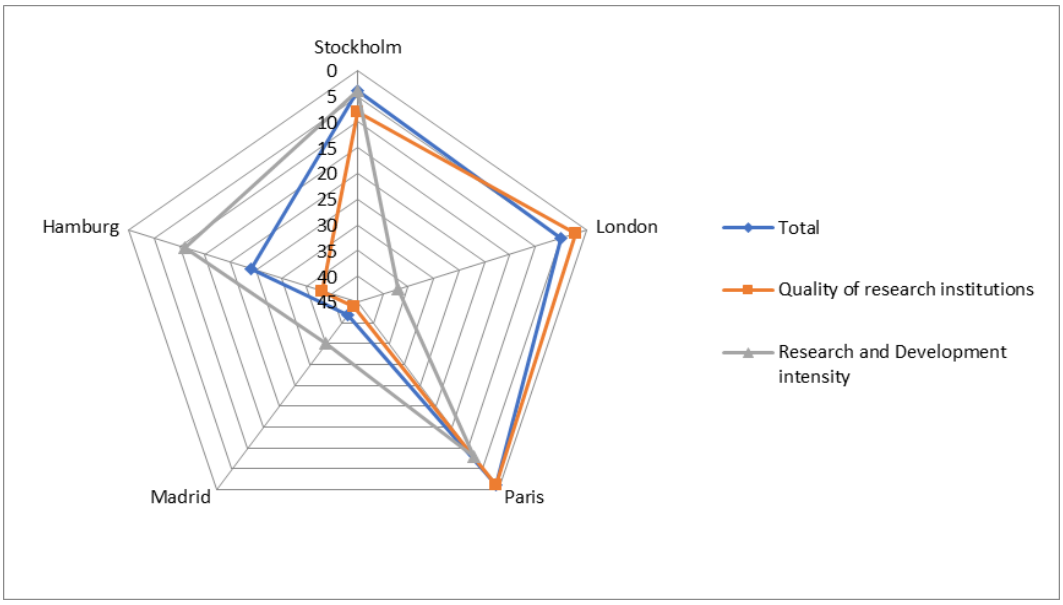
Figure 7-4: Demand for digital services and local online transaction, 2015



Source: WIK based on Eurostat.

Madrid is also held back by the lower intensity of R&D compared with Paris, London and Stockholm (see figure below).

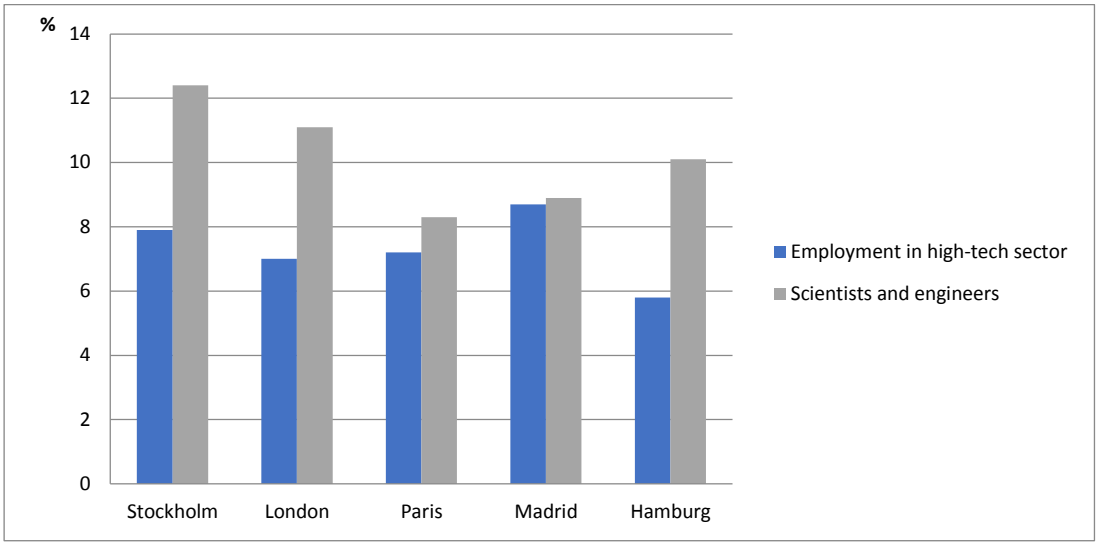
Figure 7-5: Knowledge spillovers across cities, 2016



Source: WIK based on NESTA (2016), https://digitalcityindex.eu; EDCI includes 60 European cities.

However, employment in the high-tech sector is relatively high in Madrid, with Stockholm also benefiting from a high proportion of ICT workers.

Figure 7-6: Employment in science and high-tech, 2015



Source: WIK based on Eurostat

8 Conclusions

8.1 Overall performance

Focusing on cities rather than countries, which tend to encompass more diverse characteristics, allows us to look at a more granular level at what might be driving differences in broadband outcomes and digital competitiveness.

In this context some striking features appear:

- Stockholm's underlying characteristics such as its population density do not suggest that it should have cost advantages in the deployment of fibre compared with the other considered cities. Yet, **Stockholm has achieved strong results across nearly all the indicators examined**. **It has a high degree of FTTH/B coverage, strong levels of both infrastructure and service competition and consumers benefit from amongst the highest broadband speeds.** 1Gbit/s fibre is routinely available, with low prices offered especially to those in multi-dwelling units. **Services are typically offered on an unbundled basis**, allowing end-users to utilize OTT or mobile, rather than being tied into services from a single provider. **Operator-neutral dark fibre has also benefited mobile operators deploying 4G, and may provide an open platform for future IoT and 5G applications.** Stockholm also scores highly across a range of 'digital city' metrics and benefits from high demand for digital services.

- Although it scores highly in many aspects of e-commerce, digital entrepreneurship and skills, **London performs poorly as regards connectivity, and the quality of residential connections in relation to their price**. There is a relatively wide choice of service providers. However**, offers which are based on BT's wholesale offerings are often similar** – mirroring each other as regards speed and price tiers. Like Stockholm, London features a cable operator with a significant footprint and an incumbent which is subject to a form of separation. The main difference as regards the business model for next generation broadband deployment between London and Stockholm is that Stockholm has an additional infrastructure provider which offers dark fibre on a wholesale only basis. Another factor that may explain some of the developments in London is that the **regulatory regime for NGA access in the UK provided for flexible pricing conditions for the incumbent's FTTC/VDSL deployment** since 2010, thereby providing some incentive for investment in this technology.

- **There is relatively high FTTH/B availability in Hamburg (>70%). However, the broadband offers over FTTH do not appear to take full advantage of the network's capability, and actual speeds received by customers are poor by comparison with Stockholm, Paris and Madrid**. There are a high degree of online transactions, but Hamburg does not rank well in most other metrics relating to digital society and industry. As regards business models, the main difference between Stockholm and Hamburg is that unlike Stokab, the

challenger infrastructure provider is vertically integrated. We understand that it has concluded wholesaling agreements, but the effects of such agreements are limited for the moment. Another important difference between Hamburg and the other cities, is that the **German regulator has actively sought to enable and incentivize the deployment of FTTC/VDSL vectoring**.

- Paris and Madrid both have high levels of FTTH/B coverage and similar market structures based on end-to-end infrastructure competition amongst a core group of 3-4 vertically integrated telecom operators which offer TV and mobile alongside fixed broadband. **Bundled offers are common**. In both cases, FTTH/B coverage has been supported by the prevalence of multi-dwelling units alongside efforts to foster infrastructure competition through access to ducts and in-building wiring. However, the similarities end there. 100Mbit/s is the entry-level product and Gigabit broadband is readily available in Paris. However, bandwidths offered in Madrid are typically lower (with 50Mbit/s as an entry-level product), and may imply that the **capabilities of the network in Madrid are not being fully exploited**. Prices in Madrid are also higher than in Paris. **Possibly as a result of these different bandwidth and pricing strategies – average actual speeds in Paris are considerably higher than in Madrid. Paris also performs more strongly in certain digital economy and society metrics than Madrid.**

8.2 Implications for business models examined

Our sample of five cities is too small to draw definitive conclusions about the role that business models may have played in influencing the outcomes. However, taking into account other research, including academic research and studies conducted by WIK-Consult for the European Commission,[36] they suggest that:

- **Disruptive entry from a new infrastructure competitor is important.** Relying on competition between legacy infrastructure-based operators (incumbent and cable) may not provide enough competitive stimulus to drive upgrades in access infrastructure to FTTH/B. In London, the only city with two networks in the sample, the incumbent is relying on gradual upgrades of the copper network to FTTC/VDSL and then G.fast in order to compete with cable, with negative effects on quality. In all the other cities, the 'new entrant' – ie the municipality in Stockholm, utility in Hamburg, and alternative operators in Paris and Madrid, provided the impetus to upgrade to FTTH/B.

- **Wholesale only models and end-to-end infrastructure competition models can both be effective in driving FTTH/B deployment in major cities.** There are two business models from those examined which seemed to result in strong availability of FTTH/B – the wholesale only municipal model of Stockholm and

36 Notably "Regulatory, in particular access, regimes for network investment in Europe" 2015/0002 and "Support for the preparation of the Impact Assessment accompanying the review of the Framework for electronic communications" SMART 2015/0002

the model in which end-to-end infrastructure-based competition has been encouraged through duct access and in-building wiring. (Paris and Madrid). These conclusions mirror those reached by WIK in the context of the study "Regulatory in particular access regimes for network investment in Europe".[37]

- **Wholesale only models based on dark fibre may help to avoid risks of oligopolistic outcomes in the retail market.** Concentrated markets with vertically integrated players may give rise to different outcomes. Relatively concentrated market may be associated with positive outcomes for speeds, prices and innovative bundles as for example seen in Paris. However, it is also possible that the players may choose to limit the speeds made available over their networks. This can be seen to a certain extent in Madrid and Hamburg, where Gigabit offers are not widely available, even though the underlying network should be capable of supporting these speeds. Speed limits and highly tiered pricing structures are also present in the US,[38] which features a duopoly in infrastructure in many areas. Where one player is wholesale only and offers passive infrastructure access, the risk of restrictions on quality is minimised, as a number of service providers can compete in the installation of active equipment. This potential for competition in the active equipment tends to drive competition in quality, in a similar manner as was seen for unbundling of the copper local loop.[39] The greater variety of service providers may also mean that there is greater choice in the types of service available, and niche providers may emerge to serve specific customer needs.

- **Wholesale only models may serve to constrain bundling practices.** It is interesting to note that in Paris and Madrid, the major broadband providers are also mobile operators. The available offers show that bundled services (triple play and increasingly quadruple play – with mobile) play a very significant role in those markets. The fact that competition is based primarily on vertically integrated infrastructure providers is likely to reinforce this practice, as each operator needs to maximize both scale and scope in order to make a return on the high investment required in deploying fibre. In contrast, most retail offers available in Stockholm are not bundled. The availability of a neutral fibre infrastructure may increase the potential for smaller broadband providers to play a role in the retail market, and reduces the need for mobile operators to invest heavily in their own fixed infrastructure in order to support their mobile business. Standalone fixed or mobile broadband provision may thus be more viable, injecting further competitive pressure in the market.

- **Wholesale only fibre models can support deployment and competition in next generation mobile networks.** It is interesting to note that mobile speeds in Stockholm are high relative to the other cities and that there are fewer differences between the speeds offered by different operators. This competition

37 SMART 2015/0002. See also SMART 2015/0005
38 See SMART 2015/0002
39 See Nardotto et al (2015) Unbundling the incumbent, evidence from UK broadband http://onlinelibrary.wiley.com/doi/10.1111/jeea.12127/full

for quality in mobile broadband may have been supported by the ready availability of dark fibre backhaul in Stockolm from Stokab on an 'operator-neutral' basis. In contrast, operators in other cities may have had less favourable conditions for backhaul, with greater need for their own fibre deployments, and commercial backhauling offers supplied by business operators, which often have their own downstream operations. The availability of an operator-neutral network, supporting multiple service providers, may also offer advantages in enabling niche providers to develop IoT applications. It also enables public services to benefit from competitive tendering for public communication services, avoiding lock-in with one or two integrated infrastructure and service providers.

- **Competition which is based on VULA or bitstream is unlikely to be a substitute for genuine infrastructure competition or competition based on dark fibre.** Out of the cities assessed, London has the most limited degree of infrastructure competition in residential broadband provision, and the highest share of competition based on virtual unbundled local access. Although the retail market may ostensibly appear competitive, with a number of operators present in the provision of fast broadband, it does not seem that this kind of competitive model which relies significantly on bitstream delivers as strong results as those pursued in the other cities. In particular, the degree of competition in price and quality (speed) appears to be relatively limited. This observation is supported by a range of literature and analysis which suggests that while infrastructure-based competition, and access competition based on passive access (unbundled network elements) can both contribute to enhancing service quality,[40] competition based on bitstream may have less significant effects. [41]

- **Incentivising FTTC/VDSL vectoring deployment might set back competition in FTTH/B.** A common feature of the two cities which fared worst in metrics relating to broadband deployment and quality – London and Hamburg - is that the incumbent has in both cases opted to deploy FTTC/VDSL rather than more performant FTTH/B technology. In contrast, while the Swedish incumbent Telia, originally planned a mixed strategy based on FTTC/VDSL alongside FTTH,[42] it was not able to sustain this strategy, and subsequently shifted its strategy to place more focus on FTTH/B. Incumbents in Madrid and Paris opted for FTTH/B from the outset. One reason for the incumbents' technological choices in Paris, Madrid and Stockholm may have been competitive pressure from alternative operators and investors that were planning or had constructed their own FTTH/B networks. However, this would not explain the choice of the German incumbent in Hamburg to continue its pursuit of a FTTC/VDSL strategy despite the presence of a competitor – Wilhelmtel - installing FTTH/B. It is possible that the regulatory regime in

40 See for example Nardotto, Valletti (2015) Unbundling the incumbent: evidence from UK broadband http://onlinelibrary.wiley.com/doi/10.1111/jeea.12127/full
41 See for example Calzada and Martinez (2014) broadband prices in the European Union
42 See Telia announcement 2008 http://telekomidag.se/telia-storsatsar-pa-fast-bredband/

Germany which allows and even encourages the deployment of technologies which increase the speeds available over the legacy copper network such as vectoring, may have reduced the need for the incumbent to upgrade its network to FTTH/B in order to compete with rivals. In other words, there is a risk that regulation which favours shorter term, lower cost, solutions may harm longer term investment incentives.

Annex: Case Studies

9 Case study: Hamburg

9.1 Context

Hamburg is the second largest city in Germany. It has a population of around 1.8m and accommodates around 867,691 private households. The population density is 2,366 persons per square km,[43] which is significantly above the German average of 230 persons per square km. Flats comprise just over 60 percent of Hamburg's accommodation.[44]

At €61,700 GDP per capita, Hamburg belongs to the leading regions in Europe (206 per cent above the European average).[45]

9.2 Broadband policy and regulation

The first German broadband strategy was developed by the Federal government in 2009. It set a target that all German households should have broadband access at a minimum capacity of 50 Mbit/s by the end of 2018. In the medium to long term, the government considers gigabit-ready networks as an important factor in driving economic growth. In 2014, the Federal Ministry of Transport and Digital Infrastructure invited large and small companies and their associations to fund the "Alliance for a Digital Germany". This group has announced that market players are planning to invest 100 Billion Euro up to 2025 to provide gigabit-ready access infrastructure.[46]

Currently, approximately 76 percent of all German households have access to infrastructures offering download speeds of at least 50 Mbit/s.[47] However, there were only around 2.2m FTTB/H connections in 2016 (homes passed), of which only 576.000 households have subscribed to communications services based on this infrastructure (homes connected).[48] NGA deployment is mainly driven by market forces, with complementary support from the Federal Government, the State Governments and local authorities. For example, to avoid a digital divide, the German Federal Government has committed 4 Billion Euro for NGA deployment in unserved regions.

The approach of the German regulatory authority, BNetzA, to NGA regulation has been to enable alternative operators to 'climb up the ladder of investment' to FTTC, while also incentivizing investments by the incumbent DT in FTTC through the wholesale pricing regime. The aim was to achieve both intramodal competition and a degree of inter-modal competition.

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43 Statistisches Bundesamt 2015
44 Statistisches Amt für Hamburg und Schleswig-Holstein, Zensus 2011, Gebäude und Wohnungen. Land Hamburg, 2013.
45 2015, Eurostat
46 https://www.bmvi.de/SharedDocs/DE/Pressemitteilungen/2017/029-dobrindt-netzallianz.html
47 Bundesministerium für Verkehr und digitale Infrastruktur.
48 Bundesnetzagentur, Jahresbericht 2016, p. 53.

BNetzA aimed to enable entrants to install FTTC/VDSL through attention to the pricing of SLU as well as mandating access to DT's ducts (or dark fibre in the absence of duct access) in the segment between the street cabinet and MDF site. BNetzA also aimed to ensure through margin squeeze tests across the value chain[49] that DT's wholesale prices did not the effect of undermining alternative operators' investments in FTTC. However, duct access was not mandated across the full length of the DT access network – thereby rendering end-to-end competition through FTTH/B deployment challenging.

In relation to FTTH, the access to be provided by DT depends on the network topology. In the case of point-to-point architecture, DT is required to unbundle the fibre loop at the Optical Distribution Frame (ODF). In case of point-to-multipoint architecture, DT is required to provide access either at the splitter closest to the end-customer or by employing wavelength division multiplexing (WDM).

Furthermore, BNetzA adopted a Decision which had the effect of tightening SMP regulatory controls on NGA. Key aspects are that (i) mandated NGA bitstream with a local rather than only regional access[50] handover on the basis of Ethernet technology;[51] BNetzA justified this strengthened approach on the basis that FTTC/VDSL is expected to become a new 'anchor' product replacing LLU over time especially as the implementation of vectoring is expected to result in a further decline in physical unbundling, thus limiting the ability of unbundlers to continue to compete downstream.

Although FTTH is limited in Germany, and no remedy has been introduced in practice, BNetzA's regulatory decisions on NGA bitstream apply in principle to all forms of FTTx including FTTH, without distinction.

Another regulatory ruling which has influenced the technological choice for NGA in Germany is BNetzA's approach to VDSL vectoring. In its first decision regarding vectoring of 2013,[52] BNetzA approved the need for exclusivity for vectoring in each individual street cabinet to exploit the further gains in broadband speed that could be achieved. However, BNetzA introduced a model of competition for the market, in which the first mover to equip a particular street cabinet with vectoring had the exclusive right to serve all customers in that cabinet area with broadband access on the basis of the vectoring technology, subject to an obligation to offer to other operators bitstream access or on request VULA at the cabinet. Cabinets close to MDF sites, were however excluded from this process. This decision was followed by a significant deployment of VDSL-vectoring.

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49 Involving retail wholesale margin assessments as well as assessments between wholesale products
50 900 point of interconnection compared with 73 for regional IP NGA bitstream
51 Similar to, but not described as VULA. Mandated in the context of the market for Wholesale Central Access (market 3b). Ethernet had previously been mandated (regional access), but not applied
52 See BNetzA, Az. BK 3d-12/131.

In a second vectoring decision taken in 2016[53] BNetzA agreed to approve exclusive rights for DT to serve street cabinets near the MDF in exchange for an investment commitment to provide service to the vast majority of users in these areas.[54]

The first decision on vectoring, coupled with the lack of available and effective physical infrastructure access across the length of the incumbent access network, may have steered investments towards vectoring in preference to FTTH/B. In practice, FTTH/B deployment in Germany as a whole remains limited.

9.3 Main operators and business models at the wholesale level

9.3.1 Business models and wholesale offers

There are four residential infrastructure-based NGA operators with significant coverage in Hamburg. The incumbent DT has deployed FTTC/VDSL-Vectoring and provides regulated wholesale access services over this network. WilhemTel a subsidiary of the utility of Norderstedt[55] focuses primarily on installing fibre to the building/home networks[56] and offers wholesale products (layer2 bitstream) over this network on commercial terms. The deployment of the FTTB/H network in Hamburg is done in close cooperation (co-investment) with willy.tel a private company serving retail customers in Hamburg. Vodafone operates a cable network in Hamburg, but is not active in the wholesale market.[57] Versatel who acquired the partial fibre optical access network of Hansenet[58] is also present in the local market. Versatel offers wholesale services to its mother company 1&1 and serves business customers under its own brand.

9.3.2 Coverage

In 2016 94,4 percent of all households in Hamburg had access to infrastructure with a minimum capacity of 50 Mbit/s.[59] The availability of access at a minimum capacity of 16 Mbit/s lies above 95 percent. However, there are still some “white spaces” as regards NGA coverage in Hamburg. According to the City of Hamburg, 12.000 households have only access to a capacity of 30 Mbit/s or less.[60] To close the digital gap Hamburg will provide state aid to cover those areas.

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53 BNetzA, BK 3g-15/004, 2016.

54 Only under certain, tight circumstances alternative operators have the possibility to deploy VDSL-Vectoring at street cabinets near the MDF.

55 The publicly owned utility of Norderstedt founded wilhelm.tel in 1999. Wilhelm.tel deployed a fibre optical network which covers almost the whole city of Norderstedt (95 percent of 33000 households) which is located in the north of Hamburg. Wilhelm.tel was the first mover as regards triple play offers.

56 The length of the fibre optical access network is about 1200 km.

57 Primacom another cable operator is present in Hamburg as well.

58 Hansenet was foundet by the utility HEW in 1995. Based on the local loop unbundling Hansenet offered telecommunication services in Hamburg. In addition, Hansenet deployed a FTTH/B network in Hamburg.

59 BT-Drs 18/10156.

60 Begleitdokument zur Bekanntmachung der Senatskanzlei der Freien und Hansestadt Hamburg vom 9.1.2017.

The availability of FTTB/H lies at 71,4 percent of all households, which is extremely high in comparison with the German average.[61] The footprint of the cable network lies above 50 percent.

As DT plans to extend its VDSL2-Vectoring deployment and WilhemTel[62] intends to increase its regional FTTH/B footprint in Hamburg, the degree of infrastructure-based competition will increase such that many households already have or will have the choice of two or three infrastructure providers (including cable) offering broadband at speeds of 100Mbit/s.

9.4 Retail superfast broadband provision

There are four end-to-end infrastructure operators active in the retail market for private customers. In addition, service providers such as 1&1 and Telefonica offer retail services which rely on DT's and Versatel's infrastructure. The market share of WilhelmTel in the retail market is about 30 percent.[63]

Further offers could be expected on the basis of wholesale access from WilhemTel's network. WilhemTel has concluded wholesale agreements with Telefonica and 1&1.[64] 1&1 as a purchaser of access capacity aims to offeer new products with download speed of 200 Mbit/s.[65]

Business customers are served by four additional mostly regionally focussed network operators.

As Table 9-1 shows, DT offers are capped at 100Mbit/s due to the limited capabilities of the cupper platform. With DOCSIS 3.0 Vodafone is able to offer higher download speeds. However, in contrast with certain other European cities, there are no Gigabit-offers on the market.

9.4.1 Quality

It is notable that the highest downstream bandwidth offers in Hamburg is not able to match comparable offers in Stockholm, Paris or Madrid. In some of the cities the 'base offerings' lie at 100Mbit/s and above. Amongst the offers reviewed in the other cities, the advertised speeds offered by DT and Vodafone in Hamburg are comparable only with those offered in London, which are also based on an FTTC/VDSL platform.

Furthermore, there are still some parts of Hamburg, where only basic broadband offers with download speeds of less than 20Mbit/s are available.

61 BT-Drs 18/10156.
62 In cooperation with willy.tel.
63 According to market experts.
64 See www.golem.de
65 www.golem.de

City-based data from Ookla for 2016 confirms that actual broadband access speeds in Hamburg were low relative to the other cities (with the exception of London). Currently, the average performance is as follows: 34,87 Mbit/s downlink and 17,23 Mbit/s uplink speed.

Wilhelm Tel is ranked first as regards up- and download capacity (97,61 versus 102,99).[66] Vodafone can offer download speed of 100,99 Mbit/s and an upload speed of 12,09 Mbit/s. Versatel which serves primarily business customers offers broadband connections comparable with the services WilhelmTel offers. Market leader DT offers 47,38 Mbit/s downlink and 9,53 uplink speeds.[67]

9.4.2 Pricing

Pricing of double play (broadband and voice) offers in Hamburg are lower to prices in the other cities examined. However, in other cities higher bandwidth is offered. Whereas the highest bandwidth in Hamburg is capped at 400 Mbit/s (downlink), in Paris offers go up to 1000 Mbit/s. The monthly charge for the lowest price offers of the above mentioned retailers was €27,45 for 16Mbit/s and €32,45 for 100Mbit/s, which compares unfavourably to offers in other cities which were either less expensive or offered additional bandwidth and/or TV for a similar charge.

Table 9-1: Retail offers in Hamburg

Company	Download (Mbit/s)	Upload (Mbit/s)	Monthly price of 2 years contract (Euro)
DT	16	2,4	27,45
DT	100	40	32,45
Vodafone	100	6	27,49
Vodafone	400	25	32,49
WilhelmTel	100	20	40,90
Primacom via verivox	120	6	17,91

9.4.3 Choice

There is a reasonable degree of choice in retail broadband services in Hamburg, with offers from DT, Vodafone, WilhelmTel, willyTel, O2 and 1&1.

However, it is notable that the offers of DT and Vodafone are very similar although Vodafone offers a higher download speed.

66 WilhelmTel conducted a pilot with a special product of 200 Mbit/s broadband speed. As the take rate was extremely low, the company put plans on hold to offer those products on a regular base.

67 http://www.speedtest.net/reports/germany

9.5 Business

9.5.1 Pricing

A WIK study of wholesale incumbent Reference Offer Ethernet charges of February 2017 reveals lower pricing in Germany relative to Reference Offer charges in France and Spain, but higher pricing relative to UK. Whereas there are regulated 1 Gbit/s Ethernet offers in Spain and France, these do not exist in Germany.

Dark fibre is available. However, prices of dark fibre are not available.

Table 9-2: Wholesale prices in Hamburg

	100Mbit/s	1Gbit/s	Dark fibre
Wholesale Openreach RO Q1 2017 (WIK-Consult)[68]	€192	€420	Na

WilhelmTel offers wholesale access (Layer2 bitstream) to its FTTH/B network on commercial terms. The pricing is lower than comparable wholesale products based on VDSL2-Vectoring.

9.5.2 Innovation

Hamburg is places a high priority on smart city development. Due to the port, ICT innovation in logistics plays an important role in Hamburg.

Furthermore, Hamburg is piloting a project to install virtual citizen kiosks in shopping malls and other public arenas. Through its Internet of Everything approach, Hamburg is connecting street lights to sensors. These systems recognize the degree of traffic and control lighting accordingly.

According to the Innovation City Index Hamburg was ranked 31 in 2015 and 40th in 2016/17.[69]

9.6 Social

All schools in Hamburg have access to fibre optical networks. This is unique in Germany.

68 Ref
69 http://www.innovation-cities.com/innovation-cities-index-2015-global/9609

10 Case study: London

10.1 Context

London is the capital city of the United Kingdom (UK). It has a population of around 8.6m and accommodates around 5m private households,[70] and 445,000 businesses.[71] London has a relatively high population density for a capital, with 1,791 persons per square km.[72] Flats comprise just over half of London's accommodation.[73]

At €67,500 per annum, London has a high GDP per capita relative to the rest of the UK.

10.2 Broadband policy and regulation

The regulatory approach towards next generation access networks in the UK was historically focused on promoting service (intramodal) competition through separation of the incumbent operator BT, while providing incentives for the incumbent, to upgrade its legacy copper infrastructure, through the pricing regime for access to BT's NGA network. As such Ofcom's expectation, at least in the initial phase, was that there would not be significant additional end-to-end infrastructure competition in the provision of fast broadband services. A single nationwide regulatory approach to NGA has been pursued.

Functional separation of the UK incumbent BT followed a 2005 strategic review by the NRA Ofcom.[74] Undertakings in relation to the separation were agreed by Ofcom in 2006[75] under its remit as a Competition Authority with responsibilities in the telecommunications sector.

Functional separation, and the strong enforcement of non-discrimination which should result from this approach, later provided one of the justifications behind Ofcom permitting BT to offer NGA access on the basis of flexible pricing in its market analysis of market 4 (now 3a) in 2010.[76] Its argument was that flexible pricing would support BT's investment in FTTx during a period of uncertainty – while competition from cable and LLU would ensure that wholesale charges were not excessive. The regulatory conditions on NGA pricing were further tightened with the publication of rules

70 2015, Eurostat – Private households (excluding institutional households)
71 2015, Eurostat
72 OECD 2014
73 https://www.london.gov.uk/sites/default/files/housing_in_london_2015.pdf
74 Ofcom strategic Review 2005 http://stakeholders.ofcom.org.uk/binaries/consultations/752417/statement/statement.pdf
75 BT Undertakings http://stakeholders.ofcom.org.uk/binaries/telecoms/policy/bt/consolidated.pdf
76 Ofcom statement – review of the wholesale local access market https://www.ofcom.org.uk/__data/assets/pdf_file/0027/37935/wla_statement.pdf

concerning margin squeeze for NGA access (VULA) in 2015,[77] but pricing flexibility was retained.

Following a strategic review published in 2016,[78] Ofcom took further steps to tighten regulatory controls on Openreach. In March 2017, BT agreed to legal separation of its Openreach access unit,[79] under pressure from Ofcom, which had threatened to mandate the terms of this separation.[80] In the context of its ongoing market analysis for market 3a, Ofcom has also proposed to apply a charge control for VULA services offering speeds of up to 40Mbit/s.[81] Higher speeds would however still fall under the 'flexible charging' regime, in order to preserve investment incentives.

At the same time, Ofcom has also proposed to apply stricter regulatory controls on access to BT's physical infrastructure (ducts and poles) with the aim of fostering infrastructure competition in FTTH networks. This would represent a shift in focus from Ofcom's previous position, which had largely centred on incentivising BT's FTTx deployment through the regulatory pricing regime. A consultation on duct and pole access remedies was published in April 2017.[82]

10.3 Main operators and business models at the wholesale level

10.3.1 Business models and wholesale offers

There are two infrastructure-based operators with widespread coverage in the London area. BT the incumbent provides wholesale services through a functionally separated (soon to be legally separated) access unit, but is also active in retail service provision to consumers and businesses. The main residential wholesale broadband NGA products offered by BT are based on 'virtual unbundling' – a form of Ethernet bitstream. Fibre-based dedicated access is today only available from BT through a point to point Ethernet leased line, available at speeds of up to 10Gbit/s. However, following regulatory intervention from Ofcom, BT will start supplying dark fibre access from October 2017.[83]

Virgin Media is a vertically integrated cable operator which supplies broadband services alongside TV and telephone access to consumers and (mainly) small businesses.

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77 Ofcom statement: approach to the VULA margin https://www.ofcom.org.uk/__data/assets/pdf_file/0015/72420/vula_margin_final_statement.pdf
78 Ofcom 2016 initial conclusions from the strategic review of Digital Communications https://www.ofcom.org.uk/phones-telecoms-and-internet/information-for-industry/policy/digital-comms-review/conclusions-strategic-review-digital-Communications
79 https://www.ofcom.org.uk/about-ofcom/latest/media/media-releases/2017/bt-agrees-to-legal-separation-of-openreach
80 https://www.ofcom.org.uk/about-ofcom/latest/media/media-releases/2016/update-on-plans-to-reform-openreach
81 Ofcom WLA market review consultation March 2017 https://www.ofcom.org.uk/__data/assets/pdf_file/0033/99636/Vol1-Market-review.pdf
82 https://www.ofcom.org.uk/consultations-and-statements/category-2/duct-pole-access-remedies
83 https://www.openreach.co.uk/orpg/home/products/darkfibreaccess/darkfibreaccess.do

10.3.2 Coverage

BT's FTTC/VDSL coverage is estimated at 95% in the London area.[84] However, the maximum speeds offered by BT over the FTTC/VDSL network are 76Mbit/s, and are available only where the network quality permits this. There is only one mass-market broadband provider, the cable operator Virgin Media, which offers speeds of 100Mbit/s and above in London. Its cable footprint in London is thought to cover around two thirds of households.[85] Coverage of FTTP and FTTH in London are just 4.5% with a strong concentration on business premises.

As BT deploys G.fast and FTTP in selected areas of London, the degree of infrastructure-based competition will increase such that it is likely that by 2020, there will be a choice of two infrastructure providers offering broadband at speeds of 100Mbit/s or more for at least 50% households. Competition in FTTP is however likely to remain limited, as the majority of the very high speed deployment is likely to be based on G.fast (by BT) and Docsis (by Virgin) – see projections from Point Topic in the chart below.

Table 10-1: Point topic 2020 projections[86]

Government Office Region (coverage in 2020)	HH in Cable footprint (%)	Bus in Cable footprint (%)	HH in FTTP footprint (%)	Bus. in FTTP footprint (%)	HH in G.fast footprint (%)	Bus. in G.fast footprint (%)	Households in ultrafast footprint (%)	Business premises in ultrafast footprint (%)
East Midlands	59.7%	50.3%	5.0%	66.6%	30.7%	32.9%	63.9%	83.2%
East of England	55.9%	44.8%	4.2%	66.2%	26.4%	28.4%	60.7%	82.8%
London	88.6%	72.3%	9.2%	70.4%	52.9%	41.2%	95.0%	94.6%
North East	58.5%	41.9%	2.8%	65.7%	33.7%	35.5%	64.8%	84.1%
North West	67.9%	51.2%	5.1%	67.5%	39.7%	39.9%	75.7%	88.4%
Northern Ireland	29.8%	20.1%	5.7%	75.5%	27.2%	24.6%	39.3%	82.7%
Scotland	51.3%	41.5%	8.4%	69.6%	54.3%	49.5%	61.0%	84.9%
South East	61.1%	53.8%	4.3%	63.3%	24.6%	23.9%	65.6%	83.5%
South West	42.1%	33.3%	8.9%	66.3%	17.3%	15.7%	50.5%	78.0%
Wales	23.0%	13.7%	11.5%	69.8%	30.5%	31.0%	40.5%	79.2%
West Midlands	69.5%	60.2%	5.3%	68.1%	42.8%	47.4%	74.5%	88.5%
Yorkshire and The Humber	54.3%	44.1%	7.7%	67.7%	29.0%	31.6%	63.2%	85.6%
UK	**59.2%**	**48.1%**	**6.5%**	**67.7%**	**35.0%**	**34.3%**	**66.1%**	**79.4%**

Source:

The limited expectations concerning FTTP deployment are confirmed by operator announcements. In August 2016 BT announced that it would trial the deployment of 3,000 FTTP lines in Mayfair, London, and plans to serve 360,000 additional homes and businesses in London by 2020 in Westminster, Holborn and City of London.[87] Meanwhile, Virgin Media has announced the expansion of its network in London to cover an additional 450,000 households by the end of 2018. However, of these only a relatively small proportion are likely to be via FTTP rather than cable.[88]

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84 http://labs.thinkbroadband.com/local/london
85 http://labs.thinkbroadband.com/local/london
86 https://mediacentre.vodafone.co.uk/pressrelease/1503/
87 http://www.ispreview.co.uk/index.php/2016/06/bt-confirm-first-business-areas-get-fttp-broadband-rollout.html http://www.ispreview.co.uk/index.php/2016/08/bt-openreach-demo-ultrafast-fttp-broadband-mayfair-london.html.
88 Virgin Media plans direct fibre connections to 40,000 homes and businesses in Barnet http://www.virginmedia.com/corporate/media-centre/press-releases/ultrafast-broadband-boost.html

10.4 Retail superfast broadband provision

The two largest providers of super-fast broadband on a national basis are Virgin Media and BT Retail. There were 4.73m BT 'Infinity' subscribers and 4.75m superfast Virgin Media customers at the end of 2016. A further 2.4m 'superfast' connections were sold by non-BT retail providers on the BT Openreach platform (around one third of BT Openreach connections), of which a majority are likely to have been supplied in the London area by Talk Talk and Sky (nowTV). PointTopic[89] lists a total of 23 residential providers and 71 business providers as offering services on the Openreach Fttx platform.

However, due to the limited bandwidth capabilities of the Openreach FTTx platform with most offers capped at 76Mbit/s, Virgin Media currently has a virtual monopoly in the provision of broadband at speeds of above 100Mbit/s. BT retail and other service providers relying on the BT Openreach platform may however gain share over time as BT's network is upgraded to G.fast and (in some locations) FTTP.

10.5 Outcomes

10.5.1 Residential

10.5.2 Quality

It is notable that the non-cable downstream bandwidth offers in London – clustered between 30-80Mbit/s, are lower than those offered in Stockholm, Madrid and Paris – where 'base offerings' lie at 100Mbit/s and above. Little or no information was provided concerning advertised upload speeds. Amongst the offers reviewed in the other countries, the advertised speeds in London are comparable only with those offered by DT and Vodafone in Hamburg, which are also offered on an FTTC/VDSL platform.

Moreover, during the process of 'mystery shopping' price checks, it became apparent that in certain densely populated areas of London, including parts of Westminster (postcodes W1 and SW1), only basic broadband offers with download speeds of less than 20Mbit/s were available.

Low advertised speeds are also reflected in low actual speeds. Thinkbroadband reported[90] an average download speed for London at Q1 2017 of 31Mbit/s (upload 6.6Mbit/s), while the speeds provided by Openreach averaged 21Mbit/s.

City-based data from Ookla for 2016 confirms that actual broadband access speeds in London were low relative to the other cities (with the exception of Hamburg). Download speeds were reported as 28.8Mbit/s with mobile at 16.8Mbit/s.[91]

89 March 2017 http://point-topic.com/free-analysis/superfast-uk-full-fibre-ahead/
90 http://labs.thinkbroadband.com/local/london

10.5.2.1 Pricing

Pricing of double play (broadband and voice) offers in London are high relative to prices in the other cities examined, especially when the low bandwidths are taken into account. The monthly charge for the lowest price offers during the offer period was €31.86 for 38Mbit/s and €37.76 for 76Mbit/s, which compares unfavourably to offers in other cities which were either less expensive or offered additional bandwidth and/or TV for a similar charge. Virgin Media cable offers offered better performance, but were also relatively expensive compared with similar offers in other cities.

Table 10-2: Download speed and retail prices in London

Company	Download (Mbit/s)	Monthly price (GBP)
TalkTalk	38	27
TalkTalk	76	32
BT	52	34.99
BT	76	44.99
Virgin Media	100	32
Virgin Media	200	37

10.5.2.2 Choice

There is a reasonable degree of choice in retail broadband services in London, with offers from BT, Plusnet (a BT subsidiary), Talk Talk, Sky, Everything Everywhere and Vodafone generally available. Virgin Media is also available to around two thirds of London households.

However, it is notable that the offers which rely on the Openreach platform (most offers with the exception of Virgin Media) are very similar as regards download speeds with most offers providing 38Mbits or 76Mbits download. This may be due to the wholesale pricing structure of the wholesale VULA offer under which prices are linked to specific speed tiers.

10.5.3 Business

10.5.3.1 Pricing

A 2015 study on retail pricing for business access[92] suggests that retail offers for 100Mbit/s and 1Gbit/s symmetric bandwidth were in available in London for an average

91 Data from European Digital Cities Index 2016

92 United Minds: The corporate price of high-speed broadband https://www.stokab.se/Documents/Nyheter%20bilagor/UnitedMinds_Stokab_CorporationsBroadband_2015_english.pdf

of €772 and €1307 per month respectively. Dark fibre was available at an average retail price of €836.

As of April 2017, BT was offering 100Mbit/s Ethernet retail leased lines from £487 per month (€575) (connection free for 3 year contract),[93] while a similar connection from the alternative infrastructure provider Hyperoptic[94] was available from £350 per month (€413), although the footprint is limited.[95]

As of February 2017, 100Mbit/s local access Wholesale Ethernet access was available through a BT Openreach Reference Offer for €226 per month (connection charge distributed over 24 months), while 1Gbit/s was available for €350.

Table 10-3: Retail average and wholesale prices in London

	100Mbit/s	1Gbit/s	Dark fibre
Retail average 2015 (United Minds)[96]	€772	€1307	€836
Wholesale Openreach RO Q1 2017 (WIK-Consult)[97]	€226	€350	na

Pricing benchmarks suggest that charges for business connectivity in London are reasonable by European standards, especially when charges for the geographically limited infrastructure-based competitors are taken into account, but lie above the rates offered in Stockholm.

10.5.3.2 Innovation

According to PwC Cities of opportunity report for 2015, London is highly ranked on various metrics including software development, ICT usage and Internet access in schools. However, it lags Stockholm and Paris on the quality of broadband and mobile speeds. Out of the five cities studied, London had the second lowest proportion of employees working in the high tech sector and proportion of high-tech patent applications to the European Patent Office.[98]

93 https://business.bt.com/products/broadband/bt-leased-lines/
94 https://www.hyperoptic.com/business-package/
95 https://www.hyperoptic.com/map/
96 United Minds: The corporate price of high-speed broadband https://www.stokab.se/Documents/Nyheter%20bilagor/UnitedMinds_Stokab_CorporationsBroadband_2015_english.pdf
97 Proprietary research
98 Data from Eurostat 2015 (high tech employment) and 2012 (high tech patent applications)

11 Case study: Madrid

11.1 Context

Madrid is the capital city of Spain. It has a population of 3.1m. There are around 131.726 buildings in Madrid, of which 70 percent are multi-dwelling units.[99] The population density is high at 5,237 persons per square km[100].

At €31,700 per annum, GDP per capita is lower than the cities contained in this sample.[101] However, GDP per capita in Madrid is higher than other regions in Spain.

11.2 Broadband policy and regulation

In line with the EU Digital Agenda broadband targets[102], the Digital Agenda for Spain[103] aims to reach nationwide coverage of 30 Mbit/s and take up of 100 Mbit/s by at least 50% of households by 2020. The Government aims to achieve this through a market driven approach to Next Generation Access coupled with the use of targeted public support and public-private cooperation mechanisms to facilitate deployment in uneconomic areas.

The Spanish NRA (CNMC) has stated that its main objective in its regulatory approach to NGA has been to promote multiple competing infrastructures and investment in NGA. In order to facilitate the deployment of parallel, competing infrastructures, passive access regulation through duct access[104] and sharing of in-building wiring was pursued from 2009 onwards. At the same time, CNMC refrained from mandating high speed wholesale access to the incumbent operator's NGA network,[105] with the aim of incentivising alternative operators to invest in their own fibre access networks.

Following a six year period in which this ‚physical infrastructure access'-based approach was pursued, CNMC noted that infrastructure-based competition had developed, but was limited to densely populated areas, which covered around 35% of households. In its market analysis of 2017,[106] the CNMC maintained physical infrastructure access and in-building wiring as the sole remedies available for FTTH competition in very dense

99 Instituto Nacional des Estadistica (INE).
100 Madrid City Hall (http://www-2.munimadrid.es/CSE6/control/seleccionDatos?numSerie=14010100010)
101 Eurostat, 2015.
102 https://ec.europa.eu/digital-single-market/en/digital-agenda-europe-key-publications
103 http://www.agendadigital.gob.es/digital-agenda/Paginas/digital-agenda-spain.aspx
104 Applied in 2009 https://circabc.europa.eu/sd/a/f119b32f-a9ed-4c8b-a791-98869483c874/ES-2009-0961%20Acte_EN+date%20et%20nr.pdf
105 In Spain, bitstream access over FTTH/B was mandated across the national territory, but restricted to speeds of 30Mbit/s or less..
106 See summary at https://circabc.europa.eu/sd/a/0d582ae8-7c2e-4387-9ff1-75a18d2d52b0/ES-2016-1951-1952-1953%20Adopted_EN.pdf

areas including Madrid, but introduced a regulated virtual unbundling product (VULA) for access to the incumbent's FTTH/B network outside these areas.

11.3 Main operators and business models at the wholesale level

11.3.1 Business models and wholesale offers

Provision of high speed broadband in Madrid is mainly based on end-to-end infrastructure competition up to the base of the building. There are currently three operators with significant NGA infrastructure in Madrid, Telefonica the incumbent, cable operator ONO (acquired by Vodafone in 2014)[107] and Orange Spain (which acquired Jazztel in 2015)[108].

Telefonica and Orange-Jazztel's NGA deployment in Madrid is based mainly on FTTH. Telefonica's FTTH coverage in Madrid is thought to be high, while investor presentations put Jazztel's FTTH coverage in Madrid at >80% in 2015.[109] Vodafone's cable network ONO covers part of the Madrid area.

The three operators have a vertically integrated business model. Telefonica is not required to make fibre wholesale access available in Madrid. However, some wholesaling may occur on the networks of the other operators. Orange recently signed an agreement[110] with the 4th mobile operator Masmovil, to offer wholesaling over its FTTH network (including extensive coverage in Madrid). Vodafone is also party to a 'swap' agreement[111] with Orange whereby each party makes available FTTH or cable-based bitstream access to the other in certain areas where their coverage does not overlap. However, it is not known whether Madrid is included in this agreement.

11.3.2 Coverage

FTTB/H coverage in Madrid is very high and estimated at between 90 and 100 percent of homes passed.[112] Almost half of the households in Madrid can be served by the cable network. It is also notable that the coverage of the legacy copper/ADSL network

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107 http://www.vodafone.com/content/index/media/vodafone-group-releases/2014/vodafone-acquisition-ono.html

108 http://www.fiercewireless.com/europe/orange-finalises-acquisition-last-jazztel-shares

109 https://www.orange.com/en/content/download/25384/573039/version/10/file/Orange+acquires+Jazztel+-+Investor+Presentation+EN+-+vDEF2+-+disclaimer.pdf

110 http://www.economiza.com/2017/01/10/masmovil-aumenta-desde-hoy-su-cobertura-de-fibra-orange-jazztel/

111 http://www.vodafone.com/content/index/about/policy/news/public-policy-news-releases/2014/vodafone-spain-orange-spain-fibre-sharing-agreement.html

112 Secretaria de Estado para la Sociedad de la Informacion y la Agenda Digital (http://www.minetad.gob.es/telecomunicaciones/banda-ancha/cobertura/consulta/Paginas/consulta-cobertura-banda-ancha.aspx)

has declined to 10 to 20 percent of all households. Madrid therefore provides an example of advanced migration towards very high capacity networks.

11.4 Retail superfast broadband provision

The main retail providers active in Madrid are the three operators with network investments in FTTH/B and cable (Movistar (the retail arm of Telefonica), Vodafone ONO, Orange). In addition, Masmovil, which acquired assets following the acquisition of Jazztel by Orange, also operates its own FTTH infrastructure in certain districts of Madrid, and also has access to Orange's network, enabling coverage in other areas, under an agreement signed at the end of 2016.[113]

The market share in Madrid of the leading NGA retail provider, Movistar, is approximately 46 percent.[114]

11.5 Outcomes

11.5.1 Residential

11.5.1.1 Quality

Almost all households in Madrid have access to very high capacity FTTH or cable communication infrastructures. Standard offers are available at 50Mbits and 300Mbit/s with the potential for symmetric bandwidths. This is consistent with Ookla data from 2016[115] which suggests that average download speeds in Madrid were 48,1 Mbit/s, while mobile download speeds averaged 18,8 Mbit/s – considerably higher than speeds in London and Hamburg which rely significantly on FTTC technology, but below those available in Stockholm and Paris.

11.5.1.2 Pricing

Pricing of single and double play NGA offers in Madrid is high relative to some of the other cities considered. However, prices are reasonable when quality is taken into

113 http://www.grupomasmovil.com/wp-content/uploads/2017/01/150810_Agreement_with_Orange_on_Fiber_and_ADSL_Assets.pdf http://www.grupomasmovil.com/wp-content/uploads/2016/05/Barclays_European_Telecom_Services_A_change_in_Spain_-_Masmovil_FTTH.pdf

114 CNMC - Análisis Geográfico de los Servicios de Banda Ancha y Despliegue de NGA en España. Datos Junio 2016.

115 As reported in the 2016 European Digital City Index

account. Asymmetric and symmetric offers of 300Mbit/s are widely available. 1Gbit/s offers from Adamo are available to a limited number of premises in Madrid.[116]

Company	Download (Mbit/s)	Upload (Mbit/s)		Monthly price (Euro)
Movistar	50	20		26.69
Movistar	300	300		40.74
Masmovil	50	5		30,49
Masmovil	300	300		38,75
Adamo	1000	200		28.92

11.5.1.3 Choice

Most households in Madrid have a choice between up to 3 different network operators offering high speed broadband, as well as offers from Masmovil, which has its own partial FTTH coverage as well as acting as a reseller. A more limited number of premises have access to fibre-based services from Adamo.

11.5.2 Business

11.5.2.1 Pricing

A WIK analysis of wholesale incumbent Reference Offer Ethernet charges of February 2017 revealed high pricing in Spain relative to Reference Offer charges in other countries such as Germany and the UK. Charges for 1Gbit/s connections were especially high.

	10 Mbit/s	100 Mbit/s	1 Gbit/s
Telefonica	352 Euro	578 Euro	1992 Euro

Fast ethernet prices were revised downwards in March 2017[117], but were still high relative to other benchmarks.[118]

11.5.2.2 Innovation

According to the Innovation City Index Madrid is ranked 56 in 2015 and 23rd in 2016/17.[119]

116 https://www.adamo.es/madrid/
117 https://www.cnmc.es/sites/default/files/1593865_5.pdf
118 For 5km 100Mbit/s cost €434.55 and 1Gbit/s €1,226.37
119 http://www.innovation-cities.com/innovation-cities-index-2015-global/9609

12 Case study: Paris

12.1 Context

Paris is the capital city of France. It has a population of around 2.2m and accommodates around 1.5m private households,[120] and 417,000 businesses.[121] Paris has a relatively low population density for a capital, with 997 persons per square km.[122] Nonetheless, a very high proportion 97%, are estimated to live in multi-dwelling units.[123]

At €53,578 per annum,[124] GDP per capita is slightly lower than in Stockholm, London and Hamburg. GDP per capita in Paris was however higher than GDP per capita across France as a whole.

12.2 Broadband policy and regulation

The main objective of French broadband policy in commercially viable areas (including Paris) has been to promote the widespread deployment of very high speed broadband via FTTH (ie a technologically specific policy), by incentivising all operators including alternative operators to invest (or co-invest) in FTTH access infrastructure. In this sense, the policy aims to achieve infrastructure-based competition in FTTH as far as is economically feasible.

ARCEP adopted its initial FTTH decisions in 2009-10 on the basis of a specific national law developed for this purpose. The regulatory rules concerning fibre access and co-investment apply equally to all operators installing FTTP – i.e. they are symmetric.

The regime distinguishes between high-density and lower density areas. ARCEP defined the very dense zones (which include Paris) in Decision No. 2013-1475.[125] Within the high-density areas low-density pockets are differentiated from the rest of the area.

The regime provides that that in high density areas, all operators deploying FTTH must provide access to in-building wiring at a connection point which lies at the base of each building, or at a concentration point aggregating 100 units, where buildings contain fewer than 12 residential or business units.

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120 2015, Eurostat – Private households (excluding institutional households)
121 2015, Eurostat
122 2013, Eurostat
123 Eurostat
124 2014, Eurostat
125 A list of the high-density areas can be found under: http://www.arcep.fr/fileadmin/reprise/dossiers/fibre/annexes-2013-1475-liste-communes-ztd.pdf

In less dense areas, operators deploying FTTH must deploy networks in a manner[126] which enables them to offer access to fibre terminating segments[127] at connection points which aggregate at least 1,000 households. Fibre installers must offer both 'co-investment' in the fibre terminating segment and monthly rental.

Duct access and dark fibre backhaul mandated as SMP remedies on Orange, the incumbent operator, via the market analysis process, provide an essential complement to the 'symmetric' terminating segment regulatory regime, enabling alternative operators to invest in FTTH up to the building or connection point for the terminating segment.

There are no downstream active access obligations on FTTH networks under the SMP regulatory regime. However, as one of the conditions for the merger, the French national competition authority required Numericable-SFR to offer bitstream access to its cable network for an interim period of 5 years[128] at prices which are subject to the approval of the authority and do not create a margin squeeze.

12.3 Main operators and business models at the wholesale level

12.3.1 Business models and wholesale offers

Provision of high speed broadband in the Paris region is mainly based on end-to-end infrastructure competition (duplication of fibre) up to the base of the building.

There are four operators which have extensive deployments in this area – the incumbent Orange, cable operator Numericable (which acquired FTTH/LLU provider SFR), Iliad, which operates under the ‚Free' brand, and Bouygues Telecom. The infrastructure of Orange, Iliad and Bouygues is based on point-to-multipoint or in the case of iliad point to point FTTH/B. Numericable operates a mix of Docsis 3.0 and FTTH/B infrastructure. All these operators operate mobile networks as well as fixed broadband infrastructure. In addition, Regional Initiative networks (RIPs) have been installed in certain areas.

Operators without their own ducts have made use of access to the sewers and/or access to Orange ducts, which is available on the basis of SMP regulation, in order to deploy their networks.

There is understood to be minimal wholesale broadband access provision on the Orange and Free networks in the Paris area. However, the cable operator Numericable provided bitstream access on a voluntary basis to Bouygues Telecom prior to its merger

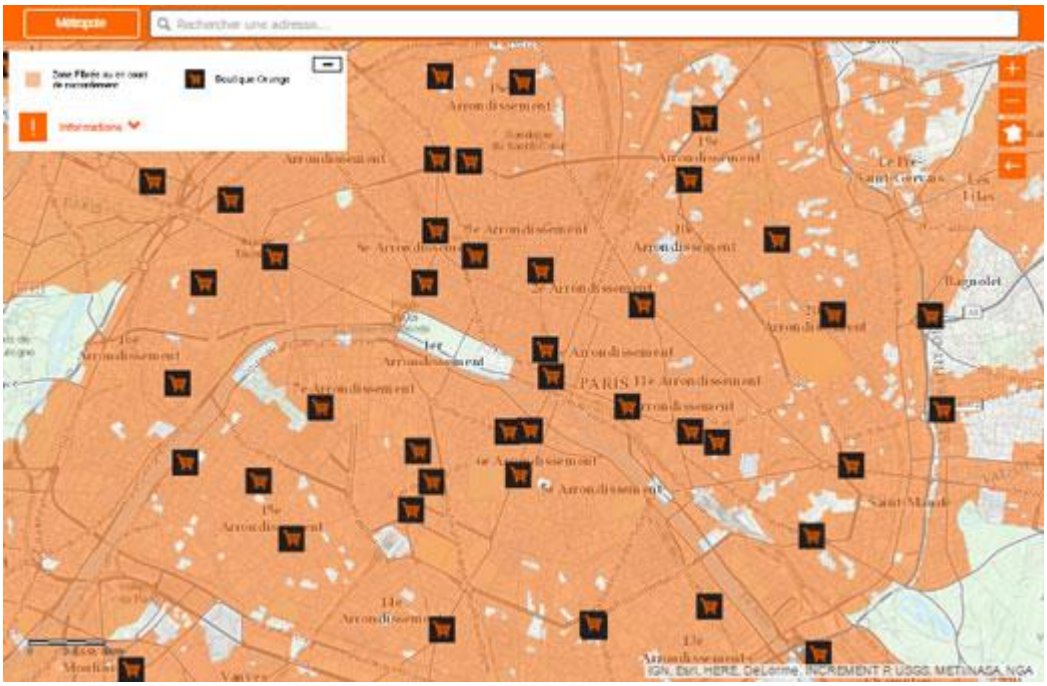
126 Through point to point fibre connections in the final segment
127 Equivalent to a fibre subloop
128 Authorite de la Concurrence approves Numericable SFR merger with conditions http://www.autoritedelaconcurrence.fr/user/standard.php?id_rub=592&id_article=2445

with SFR in 2014, and may have continued with such provision following the merger, based on obligations from the French Competition Authority.

12.3.2 Coverage

Maps provided by the four main operators suggest significant coverage within the Paris region. Incumbent Orange reported that as of March 2017, nearly 90% of Paris households were served by FTTH networks, equivalent to 1.357m homes.[129] Orange's FTTH/B coverage is shown in the picture below.

Figure 12-1: Orange coverage in the Paris area

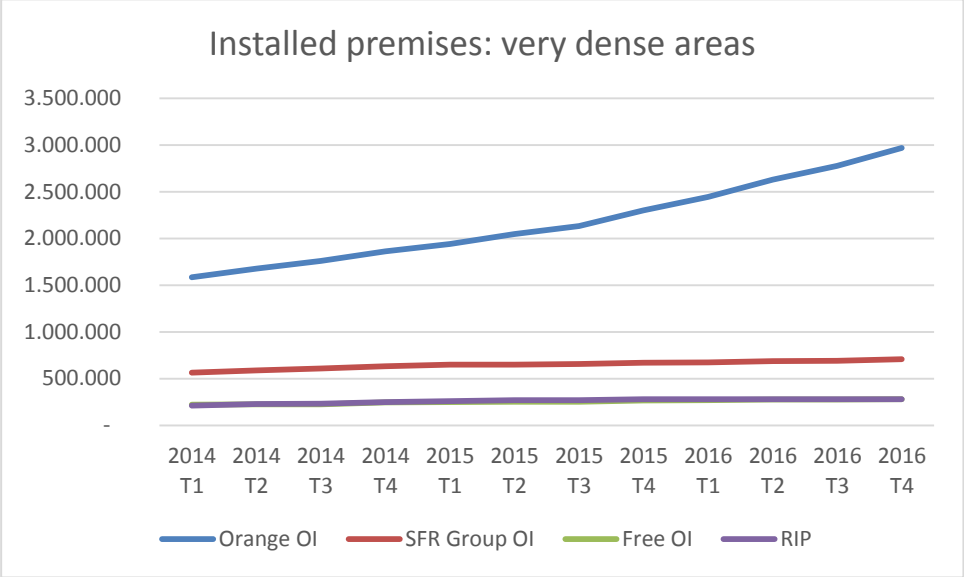


Source: Orange France

Data from the NRA ARCEP further records that within very dense areas (primarily the Paris region), the incumbent Orange had installed fibre covering nearly 3m residential and business premises at the end of 2016. The SFR Group (encompassing cable operator Numericable) had installed around 0.7m premises with FTTH/B while Free and Regional Initiative networks had each installed just under 0.3.

129 https://www.telegeography.com/products/commsupdate/articles/2017/03/21/nearly-90-of-paris-households-covered-by-ftth-networks/

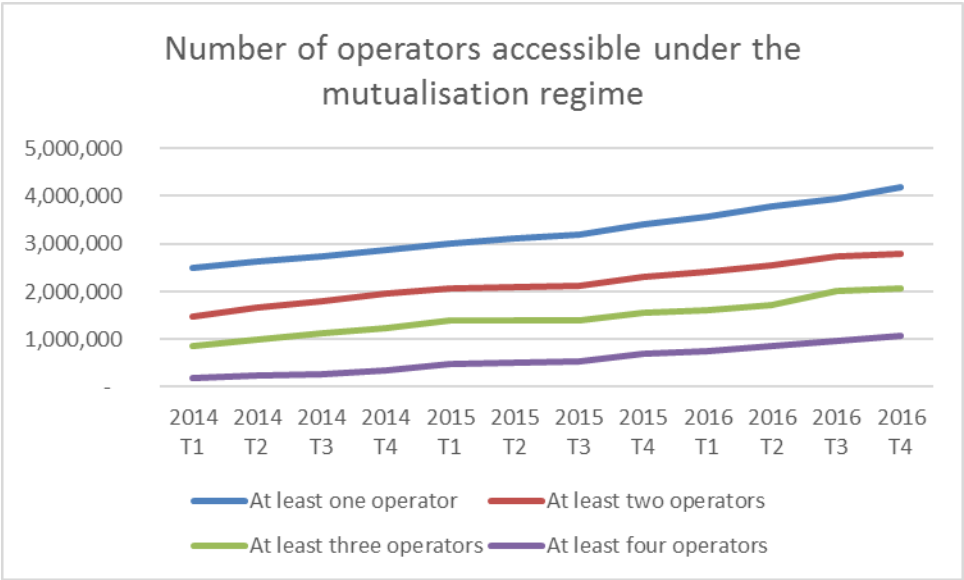
Figure 12-2: FTTH installed premises in very dense areas, France



Source: ARCEP

When access to in-building wiring (or first concentration point for buildings with less than 12 units) was taken into account, 67% of premises served with fibre in very dense areas (primarily Paris) had a choice of at least 2 operators and 49% at least 3. 26% of premises connected with fibre had a choice of at least 4 network operators.

Figure 12-3: Number of FTTH operators accessible via the mutualisation regime

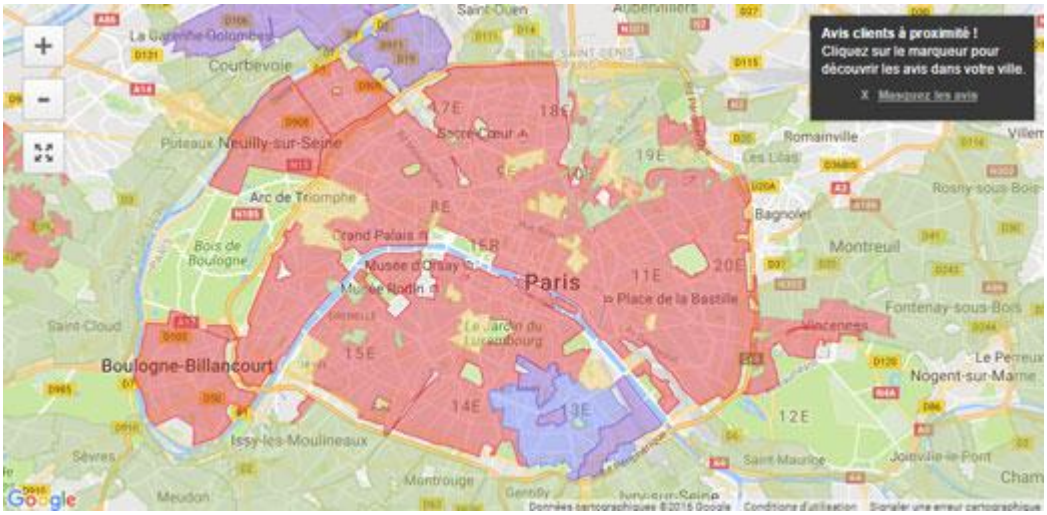


Source: ARCEP

Besides the 0.7m SFR connections, which are offered through FTTH/B, Numericable also has significant deployment through FTTLA. Although the coverage map shown does not distinguish between FTTH/B and FTTLA coverage, it is clear that through a

combination of these technologies, Numericable is able to offer speeds of 1Gbit/s or more (shown in red) to a significant majority of Paris households.[130]

Figure 12-4: Broadband coverage of Numbericable in Paris



Source: Numericable

12.4 Retail superfast broadband provision

The main retail providers active in the Paris region are the four operators with network investments in FTTH and Cable – ie Orange, Iliad, SFR-Numericable and Bouygues.

Regionalised data on market shares is not available. However, ARCEP notes in its 2016 consultation on the market review for wholesale local access that whereas at a national level the market share of the incumbent Orange increased significantly in the provision of high speed connections of above 100Mbit/s, reaching 37% in Q1 2016 (see charts below), this was mainly due to an increase in subscriptions to Orange in less dense zones. Market shares for very high speed access in very dense areas – where these operators had deployed their own end-to-end connections, were „distributed in a more equal manner".[131]

130 See http://www.ariase.com/fr/haut-debit/paris/index.html and coverage maps from Numericable http://fibreoptique.numericable.fr/carte. See also http://www.lafibreoptique.fr/paris/

131 Page 30 ARCEP public consultation markets 3a, 3b and 4 http://www.arcep.fr/uploads/tx_gspublication/bilan_et_perspectives-ADM-HD_THD-juil2016.pdf

Figure 12-5: Share of very high speed connections > 100Mbit/s between Orange and alternative operators

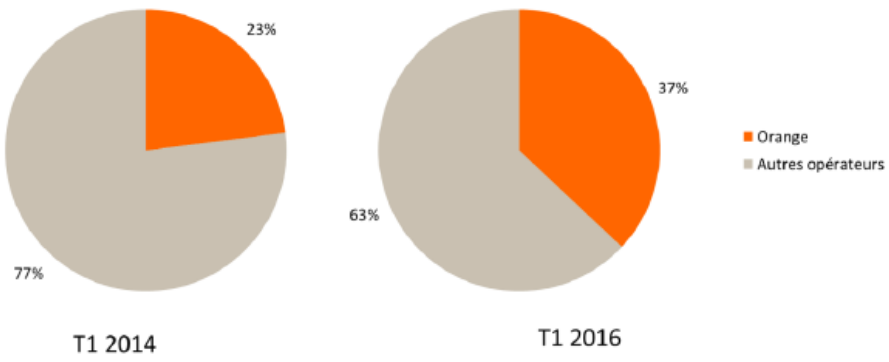


Figure 4 : Répartition des accès THD >=100 Mbit/s entre Orange et les autres opérateurs commerciaux (source : Arcep)

Source: ARCEP

12.5 Outcomes

12.5.1 Residential

12.5.1.1 Quality

A high proportion of Paris households are able to access very high speed broadband. Cable is widely available, and estimates from Orange suggest that nearly 90% of households are able to access FTTH offers.

The widespread availability of modern communication infrastructure has translated to high speeds. Ookla data from 2016[132] suggests that average download speeds in Paris were 72Mbit/s while mobile download speeds averaged 19Mbit/s. These figures are similar to Stockholm, and considerably higher than Madrid, as well as London and Hamburg, which both trail as regards actual recorded speeds.

12.5.1.2 Pricing

Offers for fast broadband in Paris are available from 100Mbit/s up to 1Gbit/s, and typically include fixed technology, TV and sometimes mobile access. Prices are low, especially considering the speeds available, and included services.

132 As reported in the 2016 European Digital City Index

Table 12-1: Sample triple play broadband offers, Paris

City	Operator	Offer	Download	Upload	Total costs € incl. VAT Minimum duration
Paris	Orange	Zen fibre	100	100	22.99
Paris	Orange	Play fibre	200	100	27.99
Paris	Orange	Jet fibre	500	200	36.99
Paris	Numericable	Box starter	200	20	22.99
Paris	Numericable	Box power	1000	60	34.99
Paris	Numericable	Box 4K power plus	1000	60	44.99
Paris	Bouygues	La fibre	1000		14.99
Paris	SFR	Starter	200	20	22.99
Paris	Free	Freebox Revolution	1000		39.99
Paris	Free	Freebox mini 4K	1000		29.99

12.5.1.3 Choice

There are a variety of fast broadband offers available if one looks across Paris as a whole. However, according to data from ARCEP, one third of households in very dense areas (including Paris) have access to only one retail provider for fibre-based services, and only one quarter have access to at least four offers.

In its 2016 consultation on the market analysis for market 3a, 3b and 4,[133] ARCEP expressed concern about increasing market shares in very high bandwidth connectivity for Orange in the residential segment as well as increased concentration in the business access market following the merger between Numericable and SFR.

12.5.2 Business

12.5.2.1 Pricing

A 2015 study on retail pricing for business access[134] suggests that retail offers for 100Mbit/s and 1Gbit/s symmetric bandwidth were in available in Paris for an average of €727 and €918 respectively, while dark fibre is available for €778 per month. These prices were comparable to London, (and slightly cheaper for 1Gbit/s), but considerably higher than those available in Stockholm. A WIK-Consult study on wholesale incumbent Reference Offer Ethernet charges as of February 2017 reveals high pricing in France

133 http://www.arcep.fr/uploads/tx_gspublication/bilan_et_perspectives-ADM-HD_THD-juil2016.pdf

134 United Minds: The corporate price of high-speed broadband https://www.stokab.se/Documents/Nyheter%20bilagor/UnitedMinds_Stokab_CorporationsBroadband_2015_english.pdf

(area type 1) relative to Reference Offer charges in the UK. Charges were also considerably above wholesale charges for dark fibre from Stokab.

Table 12-2: Symmetric business access (leased line) charges, Paris

	100Mbit/s	1Gbit/s	Dark fibre
Retail average 2015 (United Minds)[135]	€727	€918	€778
Orange wholesale RO Q1 2017 (WIK-Consult)[136]	€711	€1,337	na

12.5.2.2 Innovation

According to PwC Cities of opportunity report for 2015, Paris ranked poorly on Internet access in schools and security, but well on broadband quality and mobile speeds. Out of the five cities studied, Paris' rate of employment in the high sector and prevalence of high technology patents was higher than London, but fell behind Stockholm.[137]

135 United Minds: The corporate price of high-speed broadband https://www.stokab.se/Documents/Nyheter%20bilagor/UnitedMinds_Stokab_CorporationsBroadband_2015_english.pdf
136 Proprietary research
137 Data from Eurostat 2015 (high tech employment) and 2012 (high tech patent applications)

13 Case study: Stockholm

13.1 Context

The Stockholm region contains both mainland and several thousands of islands. It covers an area of around 216 km^2, accommodating 840,000 residents in around 450,000 buildings; 45% of these are multi-dwelling units (MDU), 19% is municipality owned.[138] Stockholm has the highest concentration of knowledge-intensive jobs in Europe (74% of working population). GDP in Stockholm is mostly driven by the service sector and amounts to 64,300 € per capita (at 2015 prices).[139]

13.2 Broadband policy and regulation

The Swedish government has a vision to make the country an information society accessible to all. In the short term, the Government has set a target for 90% of households and businesses to have access to at least 100 Mbit/s by 2020.[140] In the long term, the government considers it necessary to provide access to high-speed broadband in all of Sweden and access to reliable and high-quality mobile services. The objective of these goals is that 98% of the population should have access to broadband at a minimum capacity of 1 Gbit/s at home, as well as in the workplace, the remaining 1,9% at a minimum capacity of 100 Mbit/s, and 0,1% at a minimum capacity of 30 Mbit/s, no later than the year 2025.[141] The broadband strategy envisages a combination of private and public investments to achieve the efficient expansion of broadband infrastructure.

An integral part of Swedish broadband policy has been to separate the roles of network operators and service providers, as well as maintaining a distinct and open platform for content and applications. It is considered that such open networks will benefit end users, the market and the society. Moreover, an important role has been taken by municipal and city networks in creating competition and stimulating investment in very high capacity broadband.

The focus of NGA regulation in Sweden has historically been to promote intramodal (access-based) competition on the network of the incumbent TeliaSonera. In its original regulatory decisions for markets 4 and 5 in 2010, PTS mandated access to the FTTH network of TeliaSonera (fibre unbundling and bitstream) at cost-oriented rates which did not include any risk premium – although an uplift on the cost was

138 Wee, van der, M.; Mattsson, C.; Raju, A.; Braet, O.; Sadowski, B.M.; Nucciarelli, A. (2011), Making a success of FTTH learning from case studies in Europe, Journal of the Institute of Telecommunications Professionals.
139 Eurostat.
140 Regeringens proposition 1999/2000:86, Ett informationssamhälle för alla, (An information society for all), 29 March 2000.
141 Regeringskansliet (2016), Sverige helt uppkopplat 2025 - en bredbandsstrategi.

allowed for single-dwelling units. The context was a market in which fibre access was already well-established, mainly as a result of municipal and competitive deployments in FTTH that had occurred some time previously. However, in its most recent 2015 market analysis decision, PTS reflected the competitive dynamics from cable and municipal deployments by (i) lifting the obligation on TeliaSonera to provide bitstream access (previously under market 5/3b); [142] and (ii) permitting flexibility in the pricing of fibre unbundling,[143] subject to enhanced measures to ensure non-discrimination including Equivalence of Input and economic replicability (margin squeeze) tests.

TeliaSonera had already pursued a form of legal separation for its wholesale access unit, creating Skanova in 2008, under pressure from the regulator, which had in 2007 produced a report recommending separation.[144]

13.3 Business models and wholesale offers

There are three major infrastructure operators serving the market for fixed broadband In Stockholm:[145]

Skanova, the wholly owned subsidiary of incumbent TeliaSonera operates both a legacy copper network (partly upgraded with FTTC/VDSL) and a fibre network. Its FTTC network covers around 22% of households in Stockholm Skanova provides regulated access to unbundled fibre as well as unregulated bitstream and ethernet wholesale services to third parties as well as its downstream retail business.

In Stockholm, nearly all multi-dwelling units are connected with multifibre connections. The FTTH network of Stokab covers nearly 90% of the total households.

The cable operator ComHem, is the largest cable operator in Sweden. Its cable network is available to 78% of the population in Stockholm. It is vertically integrated and not active in the residential wholesaling market. In addition to using its own cable network, it also offers services over the Stokab fibre network .

142 PTS (2015), Beslut om fastställande av företag med betydande inflytande på marknaden för centralt tillträde till nätinfrastruktur (marknad 3b), 2015-02-19.

143 PTS (2015), Beslut om fastställande av företag med betydande inflytande på marknaden för lokalt tillträde till nätinfrastruktur (marknad 3a), 2015-02-19

144 PTS report: Improved broadband competition through functional separation June 2007 (http://www.pts.se/upload/Documents/EN/Improved_broadband_competition_through_functional_s epa ration_2007_18.pdf)

145 Other owners of fibre networks in the Stockholm region are Fiber Direkt i Sverige AB, IP-Only AB, Stadsnätsbolaget Sverige AB, Colt Technology Services AB, Sundbybergs Stadsnätsbolag AB, Sollentuna Energi och Miljö Aktiebolag, AEB Kommunikation AB, Officinen i Stockholm Aktiebolag, Tele2 Sverige AB, Tydinge Oröd Olastorps fiberförening, Utsikt Bredband AB (retrieved on May 2, 2017, from http://www.bredbandskartan.se).

The municipally owned provider Stokab provides passive infrastructure in the form of dark fibre. Based on the dark fibres rented from Stokab, multiple network providers (NPs) provide transmission capacity to end-users or to service providers (ISPs) by installing active equipment. Within the Stockholm region, both public and private NPs co-exist, each connecting different buildings.

The City of Stockholm's internal data communication network, LAN and WAN are managed by a subsidiary of Stokab, S:t Erik Kommunikation. On this communication platform, the City of Stockholm can procure services such as data communications and telephony.[146] Several private NPs also use Stokab's network including OpenNet and Zitius, and in turn provide active access to different ISPs.[147] ISPs deliver services, such as Internet, TV, telephony and others, to end users. Currently, there are more than 100 ISPs. Apart from companies that are only NPs or ISPs, there are also companies that offer both fibre network connectivity and services by using the dark fibre network of Stokab.

In addition to the telecommunications oriented market players, there are over 700 non-telecom enterprises such as banks, media and security companies which make use of Stokab's network, renting point-to-point fibres directly from Stokab and providing their own equipment or via outsourcing to an NP.[148] The ability to purchase dark fibre directly from Stokab, enables non-telecom enterprises to purchase data and IT solutions in full competition, rather than potentially needing to procure such services as part of a bundle offered with the connection.

While it focuses within the municipality of Stockholm, Stokab also offers fibre optic connections from and to networks in Enköping, Västerås, Eskilstuna, Strängnäs and Södertälje, and to several islands in the Stockholm archipelago.[149]

Real estate companies in Stockholm have played an important role in the development of broadband to tenants in multi dwelling units as they started to deploy indoor wiring in 2002.[150] They decide whether to connect their properties to a particular network provider and make agreements for the provisioning of services to the tenants. The housing companies typically adopt a policy to establish open networks, and contract an NP to function as an intermediary between the municipal network and ISPs.

146 Wee et al (2011).
147 Wee et al (2011).
148 Forzati, M. and C. Matsson (2013), Stokab, A socio-economic analysis, Acreo report: acr055698.
149 http://www.stokab.se.
150 Mölleryd, B. (2015), Development of High-speed Networks and the Role of Municipal Networks, OECD Science, Technology and Industry Policy Papers, No. 26, OECD Publishing, Paris.

13.4 Coverage

Data on broadband coverage described in Table 1 shows the availability of each of the technological solutions for broadband. In summary, 93% of households in Stockholm have access to copper-based broadband, the availability gap is mainly the result of newly built houses for which copper is no longer installed. The availability of fibre connections increased from 58% to 93% in the period 2010 – 2016. The share of the population which can access broadband over VDSL amounts to 22% and the level has been almost stable over the time. The coverage of cable connections has decreased slightly since 2015, largely due to the expansion of the fibre market.

Table 13-1: Broadband coverage in Stockholm as a share of the population, 2010 - 2016

Year	Fibre	VDSL	xDSL	Cable (Docsis 3.0)
2010	57,7%		100%	
2011	72,0%		100%	
2012	77,1%		100%	
2013	83,0%	20,7%	100%	81,8%
2014	87,7%	21,7%	100%	81,3%
2015	91,1%	24,0%	100%	78,1%
2016	92,6%	22,7%	93,4%	78,1%

Source: WIK based on http://www.statistik.pts.se/bredband.

13.5 Retail superfast broadband provision

Table 2 presents market shares of ISPs in fixed broadband market in Sweden measured by the number of subscriptions. Almost all ISPs with a considerable market share are present in Stockholm and operate on the Stokab's fibre network.

Table 13-2: Market shares in fixed broadband market in Sweden, End of 2014

ISP	Fixed broadband*	Fibre*	xDSL*	Cable*	Coverage in Stockholm**	Operation on Stokab's fibre network***
Telia	39%	28%	68%		yes	yes
Telenor (Bredbandsbolaget, Ownit)	20%	31%	18%	3%	yes	yes
ComHem	18%	4%		92%	yes	yes
Bredband 2	4%	9%		0%	yes	yes
Alltele	4%	7%	2%		yes	yes
Bahnhof	4%	8%	1%		yes	yes
Tele2	2%		6%		yes	yes
Telecom3	1%	3%				
Tyfon	1%	2%	0%		yes	yes
Net at Once	1%	1%	0%		yes	
Övriga	6%	9%	4%	4%		

Source: WIK based on *PTS (2015); **http://www.bredbandskartan.se, ***http://www.stokab.se/Vara-kunder/Operatorer/Urval-av-operatorer/

The three largest players in the fixed broadband market are Telia, Telenor and ComHem. Telenor operates the broadband providers Bredbandsbolaget, Glocalnet and Ownit. Together the largest players have a market share of 78%. Telia is the largest operator with 39% in the fixed broadband market. With a market share of 31% compared to 28%, Telenor is slightly larger than Telia in terms of broadband services delivered over fibre. Telia has closer to 70% of broadband subscriptions delivered over copper and Telenor has 18%. The cable provider ComHem operates the majority of connections available over cable networks nationally, and is the sole cable operator active in Stockholm.

13.6 Outcomes

13.6.1 Residential

13.6.1.1 Pricing

In the following Table 3, the NRA PTS reports the 2014 prices and speeds for fixed broadband for single play services of the major ISPs in Stockholm - Telia, ComHem and Bredbandsbolaget. Bredbandsbolaget is owned by Telenor, the second largest ISP in Sweden and operates on the Stokab network. In 2000, Bredbandsbolaget contracted with a real estate company in Sweden to fibre up all of their properties, including a significant footprint in Stockholm.[151]

151 Felten, B. (2015), Stokab Helps Build a Smarter Stockholm, Diffraction Analysis.

Telia's offerings reported in Table 3 have no fixed commitment period, while Bredbandsbolaget's and ComHem's offerings have a term of 12 months. The discounts are divided into different ways. Telia's offers have a discount for the first three months, when the price is 99 SEK. Bredbandsbolaget has a discount for the two highest-speed offers during the first 12 months (250/10 Mbit - 369 SEK and 1 000/100 Mbit SEK 499). ComHem has a discount for all offers during the first 12 months to a price of SEK 199. The discounts are greater for offers with higher speeds, which is most apparent in the ComHem's offerings. It should be noted that this provides a snapshot of average prices – prices are liable to change over time. In addition, the different quality levels of fibre compared with copper-based offers make direct comparisons challenging.

Table 13-3: Broadband offers of Telia, Bredbandsbolaget and ComHem for residential customers, 2014

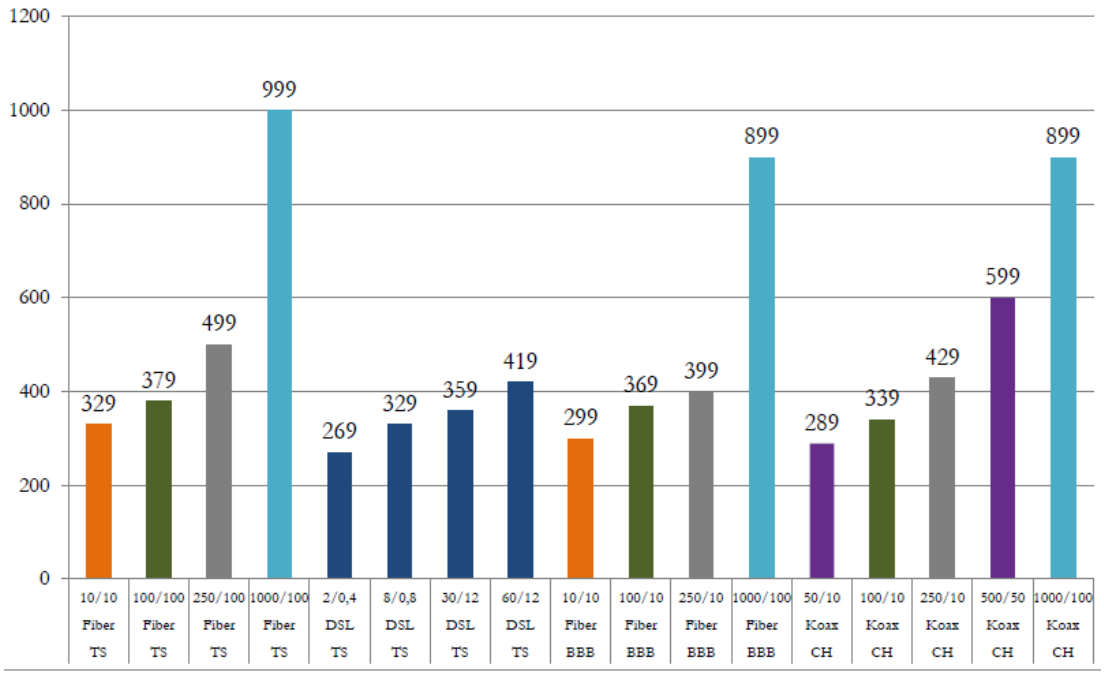
ISP	Access	Speed	1. Price excl. one-time fee and discounts	2. Price incl. one-time fee (36 months)	3. Price incl. one-time fee and discounts (36 months)	Price 2 / price 1	Price 3 / price 1
Telia	Fiber	10/10	329	329	310	100%	94%
Telia	Fiber	100/100	379	379	356	100%	94%
Telia	Fiber	250/100	499	499	466	100%	93%
Telia	Fiber	1000/100	999	999	924	100%	92%
Telia	DSL	2/0,4	269	269	255	100%	95%
Telia	DSL	8/0,8	329	329	310	100%	94%
Telia	DSL	30/12	359	359	337	100%	94%
Telia	DSL	60/12	419	419	392	100%	94%
Bredbandsbolaget	Fiber	10/10	299	307	307	103%	103%
Bredbandsbolaget	Fiber	100/10	369	377	377	102%	102%
Bredbandsbolaget	Fiber	250/10	399	407	397	102%	100%
Bredbandsbolaget	Fiber	1000/100	899	907	774	101%	86%
ComHem	Koax	50/10	289	296	266	102%	92%
ComHem	Koax	100/10	339	346	299	102%	88%
ComHem	Koax	250/10	429	436	359	102%	84%
ComHem	Koax	500/50	599	606	473	101%	79%
ComHem	Koax	1000/100	899	906	673	101%	75%

Source: PTS (2015), Ingår bredband levererat över fiber respektive koppar på samma slutkundsmarknad? National offers collected from 32 websites are shown.

Figure 13-1 shows prices according to different access technologies and speeds (excluding one-time charges and discounts). These are the national offers from Telia, Bredbandsbolaget and ComHem for residential customers. It should be noted in this context that Telia's pricing of access to the fibre-based access network is geographically differentiated.[152]

152 PTS (2015), Beslut om fastställande av företag med betydande inflytande på marknaden för lokalt tillträde till nätinfrastruktur (marknad 3a), p. 92, Dnr: 11-9306. (Decision to establish companies with significant influence on the market for local access to network infrastructure (Market 3a).

Figure 13-1: Monthly prices and speeds of fixed broadband offers for residential customers of Telia, Bredbandsbolaget and ComHem according to access technologies (excluding one-time charges and discounts), 2014



Source: PTC (2015), National offers collected from 32 websites are shown.

It is notable that the prices for copper bandwidths are high in relation to speed and when compared with fiber and cable broadband prices:

- The copper bandwidth that does not require VDSL and which is possibly comparable to fiber bandwidth is 8/0.8 Mbit/s (comparing to fiber bandwidth 10/10 Mbit/s). The price for 8/0.8 Mbit/s is SEK 329, while the average price for fiber 10/10 Mbit/s is SEK 314. ComHem has no offer to 10/10 Mbit/s. They offer 50/10 Mbit/s to a price of SEK 289.

- Telia's offerings of VDSL (30/12 Mbit/s and 60/12 Mbit/s) compete mainly with fiber offerings: 100/100 Mbit/s (Telia) and 100/10 Mbit/s (Bredbandsbolaget) and over cable (ComHem) 50/10 Mbit/s and 100/10 Mbit/s. The offer of 60/12 Mbit/s over copper has a higher price than all of the closest options. The offer 30/12 Mbit/s, SEK 359 is priced in line with Telia 100/100 Mbit/s to the price of SEK 379, Bredbandsbolaget 100/10 Mbit/s to SEK 369, and ComHem's cable offer 100/10 Mbit/s which costs SEK 339.

The following table shows more recent (May 2017) monthly and yearly average residential prices of sample ISPs which are operating on Stokab's network. The cheapest prices for a fibre connection of 100/10 Mbit/s range between 245 SEK and 339 SEK, whereas a symmetrical 100/100 Mbit/s connection costs on average 9 – 50 SEK more. The cheapest prices for a 500/100 Mbit/s fibre connection vary between

432 SEK and 539 SEK. The price increase for a 1000/100 Mbit fibre connection extends from 105 SEK to 220 SEK compared with the prices for a 500/100 Mbit/s connection. The fastest available connection (symmetric Gigabit connectivity) is provided at the monthly price of 827 – 899 SEK, on average.

Table 13-4: The cheapest average residential prices of the ISPs utilising the Stockholm City Network Stokab on monthly and yearly basis, by speed (download/upload), May 2017

ISPs utilizing Stokab	Monthly average price, SEK	Yearly average price, SEK
100/10 Mbit/s		
Universal Telekom	245	2205
Bredband 2	246	2214
T3 Bredband	249	3187
All Tele	299	3289
Telia	339	3898
100/100 Mbit/s		
Bahnhof	279	3348
Bredband 2	298	2682
T3 Bredband	299	3787
Universal Telekom	307	2763
Zitius/Qmarket	308	2772
All Tele	359	3949
500/100 Mbit/s		
Bahnhof	375	4503
Universal Telekom	432	3807
Bredband 2	424	3816
All Tele	449	4939
T3 Bredband	539	6667
1000/100 Mbit/s		
Bahnhof	480	5763
Universal Telekom	537	4833
Bredband 2	538	4842
All Tele	579	6369
T3 Bredband	749	9187
ComHem Bredband	899	10987
Telia	999	9838
1000/1000 Mbit/s		
Bredband 2	827	74440
T3 Bredband	839	10267
All Tele	899	9889

Quelle: http://abonnemang.pricerunner.se/bredband.php, retrieved on May 15, 2017, except for Bahnhof (retrieved from bahnhof.se on 26 May 2017). The prices are including VAT, without an one-time fee and without a binding time.

The residential prices based on group agreements for fibre connections in MDUs mostly have a binding time of five years and are much cheaper per household – resulting in prices than may be less than €10 rental per month for a Gigabit connection.

13.6.1.2 Quality

During the period 2010 – 2016 the quality of broadband connections in Stockholm region increased steadily. All households in Stockholm have had access to broadband connections providing up to 30Mbit/s since 2013, and the coverage of broadband connections with speed of 100 Mbit/s reached 97% in 2016 compared with 83% in 2010 (Table 5).

Table 13-5: Development of broadband speed based on population in Stockholm region, 2010 - 2016

Year	3 Mbit/s	10 Mbit/s	30 Mbit/s	100 Mbit/s
2010	100%	97%		83%
2011	100%	99%		85%
2012	100%	100%		87%
2013	100%	100%	99,9%	90%
2014	100%	100%	99,9%	92%
2015	100%	100%	100%	96%
2016	100%	100%	100%	97%

Source: WIK based on http://www.statistik.pts.se/bredband/.

The prices for different speeds and technology in Figure 13-1 and in Table 13-4 above highlight the differences in speeds according to technology:

- Copper bandwidth is offered at speeds 2/0.4 - 8/0.8 and 30/12 and 60/12 Mbit/s (VDSL).
- The minimum speed offered over fiber is 10/10 Mbit/s and maximum 1,000/100 Mbit/s.

At 72 Mbit/s and 21 Mbit/s respectively, the average actual download speeds and mobile speeds in Stockholm were the highest out of the cities included in this review, but closely approached by Paris.

13.6.1.3 Choice

There is a significant degree of choice in retail services in Stockholm, supported by the presence, in addition to network operators TeliaSoneria and ComHem, of approximately 100 operators in Stockholm using Stokab's network.

13.6.2 Business

13.6.2.1 Coverage

Copper and cable broadband coverage to business premises in Stockholm has been decreasing over time. Table 13-6 shows the decline in cable broadband availability from 78% in 2013 to to 63% in 2016. VDSL coverage has been stable for business customers, but remains at a low level of 28%. In contrast, a significant growth is shown in the fibre segment of business customers: during 2010 – 2016, of the availability of fibre to companies increased by 31% reaching 93% of all working places in Stockholm.

Table 13-6: Broadband coverage in Stockholm as a share of working places, 2010 – 2016

Year	Fibre	VDSL	xDSL	Cable (Docsis 3.0)
2010	62%		100%	
2011	79%		100%	
2012	83%		100%	
2013	86%	26%	100%	78%
2014	90%	28%	100%	77%
2015	91%	29%	99%	63%
2016	93%	28%	95%	63%

Source: WIK based on http://www.statistik.pts.se/bredband.

13.6.2.2 Quality

As for residential customers, every business customer in the Stockholm region has access to a broadband connection up to 30 Mbit/s. Furthermore, the coverage of connections to businesses in Stockholm offering 100 Mbit/s speeds increased to 96% in 2016 (Table 13-7).

Table 13-7: Development of broadband speed based on working places in Stockholm region, 2010 - 2016

Year	3 Mbit/s	10 Mbit/s	30 Mbit/s	100 Mbit/s
2010	100%	98%		
2011	100%	99%		84%
2012	100%	100%		88%
2013	100%	100%	100%	89%
2014	100%	100%	100%	92%
2015	100%	100%	100%	95%
2016	100%	100%	100%	96%

Source: WIK based on http://www.statistik.pts.se/bredband/.

13.6.2.3 Pricing

Between 2011 and 2015, Stockholm experienced a large decrease of 26% in the average price of dark fibre, to SEK 263 in 2015 from SEK 310 in 2011. A 2015 study on retail pricing for business customer access[153] indicates that Stockholm is the least expensive market compared with the other EU cities considered. In 2015, Stockholm provided business offerings of 100 Mbit/s at average price of SEK 338 which was a substantial decrease compared to SEK 551 in 2011 for the same speed connection. The average pricing for 1 Gbit/s of SEK 497 was also relatively low compared with other EU cities.

13.6.2.4 Innovation

Table 13-8: High-tech patent applications to the EPO, per million inhabitants

	Stockholm	London	Paris	Madrid	Hamburg
High-tech total	142,020	20,964	63,121	17,997	48,404
Communications technology	193,775	15,546	52,026	15,786	14,060

Source: WIK based on Eurostat.

153 United Minds (2015), The corporate price of high-speed broadband – a comparative study between five European cities, https://www.stokab.se/Documents/Nyheter%20bilagor/UnitedMinds_Stokab_CorporationsBroadband_2015_english.pdf.

Table 13-9: Technology readiness, 2014 – 2015, Scores

	Stockholm	London	Paris	Madrid	Hamburg
Internet access in schools	27	28	9	10	n.a.
Broadband quality score	25	19	27	16	n.a.
mobile broadband speed	21	18	27	20	n.a.
ICT usage	29	30	24	16	n.a.
Software development and multimedia design	12	28	22	13	n.a.
Digital security	25	19	12	13	n.a.
Total	139	142	121	88	

Source: WIK based on PwC (2015), Cities of opportunity.

13.7 Mobile

The ability to lease basic network elements including antenna sites and to connect cell towers with the fibre of Stokab has enabled mobile operators to establish themselves in the market quickly. This is evident in the deployment of 4G/LTE mobile systems in Stockholm. By agreeing to long term contracts with Stokab[154], Net4Mobility (joint venture of Telenor and Tele2) installed 4G/LTE network in Stockholm competing with the incumbents 4G/LTE network (which was the world's first). Today, four extensive 4G/LTE-networks are present in Stockholm providing a competition platform for more than 13 mobile operators.[155] The explosion in mobile data usage has in turn driven Stokab's expansion as well. In Stockholm, during 2010 – 2016 the coverage of mobile broadband services via LTE technology increased by 100% (Table 13-10).

Table 13-10: Mobile broadband coverage in Stockholm as a share of the population, 2010 - 2016

Mobile broadband coverage	2010	2011	2012	2013	2014	2015	2016
via HSPA	100%	100%	100%	100%	100%	100%	100%
via LTE	0,1%	94,7%	100%	100%	100%	100%	100%

Source: WIK based on http://www.statistik.pts.se/bredband.

The largest mobile operators Net1, Telia, Net4Mobility and Tre have full 4G mobile coverage in Stockholm by differing in their LTE licenses they own (Table 13-11).

154 Forzati, M. and C. Matsson (2013), Stokab, A socio-economic analysis, Acreo report: acr055698.
155 They are 0700, 3, AllTele, Bredbandsson, Fello, Fonia, GrönTele,, MY BEAT, Net 1, Qall, SST NET, Tele2, Telenor, Teletek, Telia (http://www.bredbandskartan.se).

Table 13-11: LTE spectrum of the largest mobile operators in Sweden

Net1	Telia	Net4Mobility	Tre
LTE 450	LTE 800 LTE 2600	LTE 800, LTE 900, LTE 1800 LTE 2600	LTE 800 LTE 2100 LTE 2600 LTE 2600 TDD

Source: PTS (2016), PTS mobiltäcknings-och bredbandskartläggning 2016