The economic benefits from deploying 1.4 GHz spectrum for a mobile broadband supplemental downlink in the MENA region

A report for Ericsson and Qualcomm

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12 October 2012

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Table of Contents

Executive Summary

This study, commissioned by Ericsson and Qualcomm, provides an independent assessment of the economic benefits which would arise from using 1.4 GHz spectrum (at 1452 to 1492 MHz)[1] to provide a supplemental downlink (SDL) for mobile broadband services in the Middle East and North Africa (MENA).

Mobile broadband traffic in the MENA region is forecast to grow rapidly over the next 10 years. It is possible that countries in the MENA region may face a spectrum shortfall unless operators undertake costly investment in network infrastructure to support this traffic growth. The 1.4 GHz frequency range, largely unused in much of the MENA region and in Europe, presents an alternative option to address this shortfall. It could be used to provide additional downlink capacity to mobile broadband services and this could reduce the costs of service provision and improve service quality.

This report assesses the economic and social benefits of deploying a 1.4 GHz SDL in seven MENA countries[2] and extrapolates the results to the region. This evidence could help inform decisions about the future use of the 1.4 GHz band in the MENA region.

What is a supplemental downlink (SDL)?

A supplemental downlink uses unpaired spectrum to enhance the downlink capability of mobile broadband networks by enabling significantly faster downloads and supporting a much greater number of users with mobile or portable wireless devices. This approach has not been used up until now in mobile networks because it required new technology (sometimes termed carrier aggregation technology). Supplemental downlink and carrier aggregation are now enabled in the HSPA+ and LTE-Advanced standards[3].

The technology allows the bonding of the usual downlink with a *supplemental* downlink channel(s), in a different band, into a single wider downlink channel as shown in Figure 1[4]. This provides an efficient way of using spectrum because consumption of rich content and other data heavy applications is asymmetric. There is much more traffic on the downlink than on the uplink over mobile broadband networks.

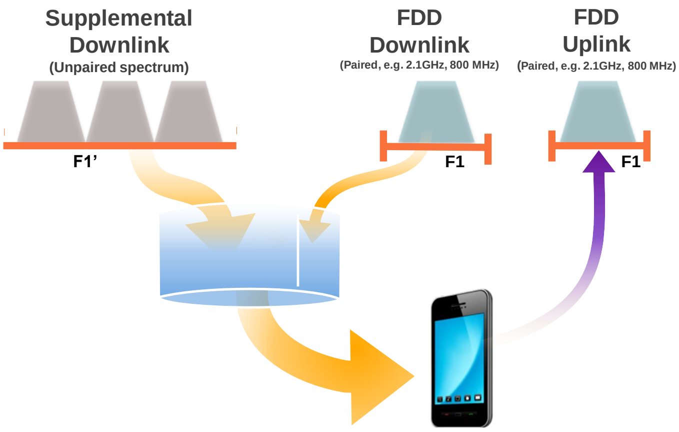
[1] This frequency range is sometimes referred to as L band.

[2] The seven countries are divided into two groups – high income countries (Qatar, Saudi Arabia, UAE) and middle income countries (Algeria, Egypt, Jordan, Morocco).

[3] Carrier aggregation across bands is supported in HSPA+ R9 (and beyond) and LTE R10 (and beyond) standards, but each specific bands combination has to be defined in 3GPP.

[4] Example of HSPA+ R10 with a 3 + 1 inter-band downlink carrier combination.

Figure 1: A supplemental downlink.



Source: Qualcomm, HSPA+ enhancements in Release 9 (and beyond)

A supplemental downlink is not just a theoretical possibility. In the US AT&T plans to implement the supplemental downlink technology in its LTE network using spectrum at 700 MHz coupled with paired spectrum AT&T already holds[5]. In Europe, ECC Report 188[6] conducted an impact assessment of the future harmonised use of the 1.4GHz band[7] and concluded that a mobile broadband SDL would generate the highest economic and social benefits of the candidate applications for the band. In September 2012, CEPT started the regulatory work to harmonise the 1.4 GHz band for a SDL[8]. An ECC Decision including the technical rules for harmonised use of the band is expected by September 2013. It is therefore possible that we will see harmonised use of the 1.4 GHz band for a mobile SDL across European countries partially from 2013 and fully from 2015. In France, Orange will conduct an SDL trial in partnership with Ericsson and Qualcomm in early 2013[9].

The role and demand for mobile broadband

In high income MENA countries the fixed network has provided affordable broadband access to the internet, largely through upgrades to the copper access network to provide DSL-based broadband. In these countries mobile broadband has, so far, largely acted as a complement to fixed broadband. Now mobile broadband is rapidly becoming more important as users demand Internet-based services on the move as well as at home and in the office. In addition mobile broadband is now the cost-effective way to deliver the broadband Internet to rural communities in most cases.

[5] http://hraunfoss.fcc.gov/edocs_public/attachmatch/FCC-11-188A1.pdf

[6] Currently under public consultation: http://www.cept.org/ecc/tools-and-services/ecc-consultation

[7] http://www.cept.org/ecc/groups/ecc/wg-fm/fm-50

[8] See Minutes of the 75th WG FM Meeting. Note: in CEPT, SDL is referred to as Mobile/Fixed Communication Networks (MFCN) Supplemental Downlink (MFCN SDL).

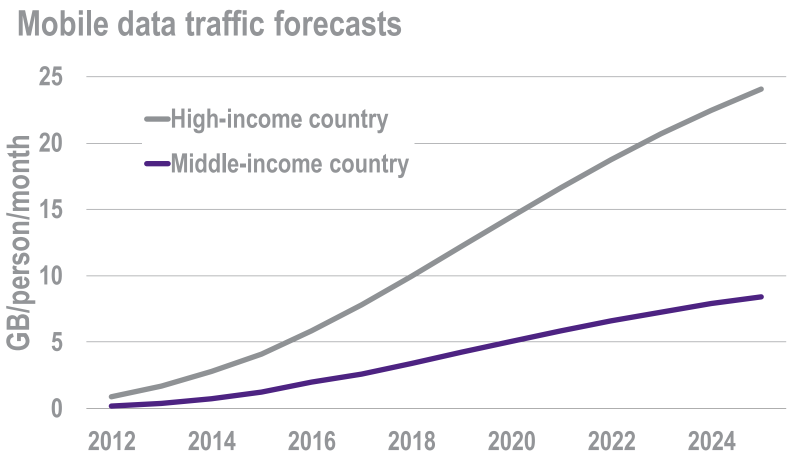
[9] http://www.orange.com/en/press/press-releases/press-releases-2012

In middle income countries mobile broadband will be even more important. It will be the only network that provides high levels of coverage, and affordable and usable services for many people[10]. This is because:

- The copper network has limited reach. Broadband over the copper network may not serve many households, particularly those in rural areas.
- Mobile broadband is more affordable than fixed broadband. This reflects the fact that pre-pay mobile broadband connectivity is available at low cost and global suppliers will focus on producing low-cost network equipment and devices for mobile broadband – a development which the countries of North Africa now have an opportunity to exploit.
- Mobile broadband devices, such as smartphones and tablets, offer an easier way of using the broadband Internet than traditional PCs. While full digital literacy is still required for an effective workforce to use PCs, the level of literacy required for basic use of the broadband Internet is much reduced.
- Mobile broadband devices facilitate shared use of Internet services and applications in a way which fixed broadband PCs do not. Such sharing is effective in spreading an appreciation of the value of using the internet. This is, in effect, a form of viral marketing, which should stimulate broadband Internet take-up.

These factors will clearly stimulate rapid traffic growth in the MENA region. The forecasts we use for the region are based on those produced by third parties and are shown in Figure 2.

Figure 2: Mobile data traffic forecasts 2012-2025



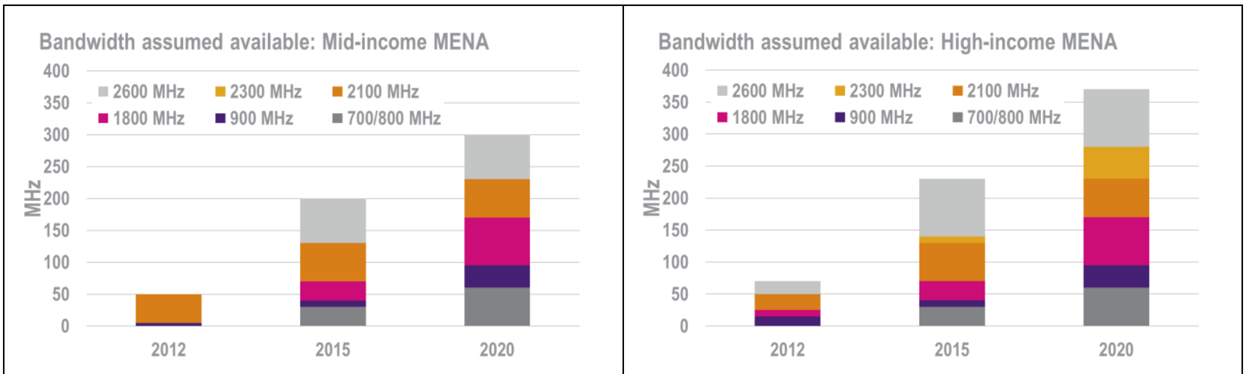
Source: Plum Consulting, Cisco, UN

10 McKinsey (2012) found that Morocco's internet ecosystem is being held back by the cost of broadband access; lack of internet infrastructure particularly in rural areas and low digital literacy particularly among the senior population. http://www.mckinsey.com/Client_Service/High_Tech/Latest_thinking/Impact_of_the_internet_on_aspiring_countries

Is there sufficient spectrum to meet the forecast demand growth?

We have assumed that governments in MENA countries will release over 250 MHz of harmonised spectrum for mobile broadband over the next 8 years, as shown in Figure 3.

Figure 3: Assumed spectrum release for mobile broadband up to 2020



Source: Plum Consulting, Qualcomm

Source: Plum Consulting

We have tested whether a spectrum shortfall could occur in the study countries over the period to 2020[11]. To do this we have modelled spectrum demand and supply in urban, suburban and rural areas in each country. The results are summarised in Table 3-2 which shows the locations where there is a forecast spectrum shortfall in 2020 by a tick – no shortfall is indicated by a cross[12].

Spectrum shortfalls are more likely in urban than in suburban and rural areas because this is where demand peaks occur and there are fewer base stations per capita in urban areas. The different country results in suburban and rural areas reflect country differences in the density of base stations in these areas and in the proportions of the population that live in urban, suburban and rural areas.

Even where there is no spectrum shortfall use of the 1.4 GHz band could reduce network deployment costs relative to use of higher frequency bands (e.g. 1.8GHz - 2.6 GHz) in coverage limited areas.

[11] The modelling assumptions are given in Appendices C and D.

[12] Graphics showing the spectrum demand and supply balance for all years up to 2025 for each country can be found in Appendix C.

Table 1: Locations where there is a spectrum shortfall in 2020

		Is there spectrum shortfall in 2020?		
Country type	Country	Urban areas	Suburban areas	Rural areas
High-income	KSA	✓	✓	✓
	Qatar	✓	×	×
	UAE	✓	×	×
Medium-income	Algeria	✓	✓	✓
	Egypt	✓	✓	✓
	Jordan	✓	×	×
	Morocco	✓	✓	×

Notes: Urban area = Population density greater than or equal to 2000 people per sq km
Suburban area = Population density greater than 200 people per sq km and less than 2000 people per sq km
Rural area = Population density less than 200 people per sq km

What are the benefits of a supplemental downlink at 1.4 GHz?

We have quantified two principal benefits of an SDL at 1.4 GHz:

- **Reduced costs**: deployment leads to avoided costs of investment in additional base station and backhaul infrastructure. Once mobile broadband demand exceeds network capacity, networks can be expanded by deploying a 1.4 GHz SDL on existing base station sites rather than building new base station sites. This is more cost efficient by a factor of five. The scale of this benefit depends primarily how soon other spectrum is made available for mobile broadband use and how quickly demand for mobile broadband grows in each MENA country
- **Better service quality**: deployment leads to improved services – in particular better in-building coverage, higher downlink speeds and ability to support a greater number of users. The 1.4 GHz SDL when paired with low frequency spectrum behaves like sub-1 GHz spectrum in terms of propagation characteristics. So a 1.4 GHz SDL offers better in-building coverage than spectrum allocated for mobile broadband use at 2.1 or 2.6 GHz

Our estimates show that **the use of 1452-1492 MHz for a supplemental downlink for mobile broadband could generate economic benefits worth as much as $26 billion for the MENA region**[13].

Other significant benefits which are not quantified include contributions to productivity improvements and broadband-enabled solutions. These can come from areas such as healthcare, education, agriculture, e-commerce and e-government. For example, access to the broadband internet

- Increases productivity by allowing more efficient solutions to business processes, better supply chain management and more efficient delivery of existing services
- Stimulates innovation and the development of new services and applications

[13] This the net present value of the economic benefits for the period from 2015 to 2025, assuming the 1.4 GHz SDL is deployed in the period 2015-2020. Values are calculated for the following countries – Algeria, Egypt, Jordan, Morocco, Qatar, Saudi Arabia and UAE.

- Facilitates greater access to information. The internet has revolutionised the way information is accessed and stored, which enables improvements at all stages in the value chains of the economies of the MENA countries
- Enhances overall living standards by improving delivery of and access to social services such as healthcare, education and government services.

The use of an SDL at 1.4 GHz also supports the achievement of national ICT plans[14]. The 1.4 GHz band can play an important role in the provision of high speed broadband access, thus reducing the requirement for public subsidies.

Finally using 1.4 GHz for SDL can help promote competition and stimulate innovation in the mobile broadband and content markets. Limited availability of spectrum below 1GHz means that in many countries, operators will have little or possibly even no low frequency spectrum to provide mobile broadband services. The availability of additional spectrum at 1.4 GHz will enable players to compete more aggressively in the supply of high speed mobile broadband and multimedia content. Increased competition is likely to result in lower prices for consumers. It is also likely to result in more mobile broadband capacity to experiment new business models.

What regulatory changes are required?

In Europe, CEPT is currently harmonising the 1.4 GHz band for SDL. This plan will provide significant economies of scale in consumer devices and infrastructure equipment production. To capitalise on this opportunity, governments and regulators in MENA are recommended to:

- Review the current use of the 1.4 GHz band in their country
- Identify alternative spectrum for the small number of systems that may be using the band.
- Harmonise and release the 1.4 GHz band for SDL.

[14] Many MENA countries (e.g. Egypt, Qatar, Morocco) have launched national broadband or ICT plans. These plans typically include targets such as universal broadband access, increased Internet penetration, and creating jobs and promoting investment in the ICT sector.

1 Introduction

1.1 The purpose of the study

This study, commissioned by Ericsson and Qualcomm, provides an independent assessment of the economic benefits which would arise from using 1.4 GHz spectrum (at 1452 to 1492 MHz)[15] to provide a supplemental downlink (SDL) for mobile broadband services in the Middle East and North Africa (MENA).

Mobile broadband traffic in the MENA region is forecast to grow rapidly over the next 10 years. It is possible there will be a shortage of spectrum to support this traffic growth unless additional measures are taken. Notably the 1.4 GHz frequency range is largely unused in much of the MENA region. It could be used to combat any shortage by providing additional downlink capacity to mobile broadband services. This could:

- Increase mobile broadband network capacity at a lower cost than building additional infrastructure
- Reduce the cost of providing coverage in rural areas and in buildings in urban areas
- Offer better service quality, through higher data rates and faster downloads as a result of the additional capacity and coverage provided.

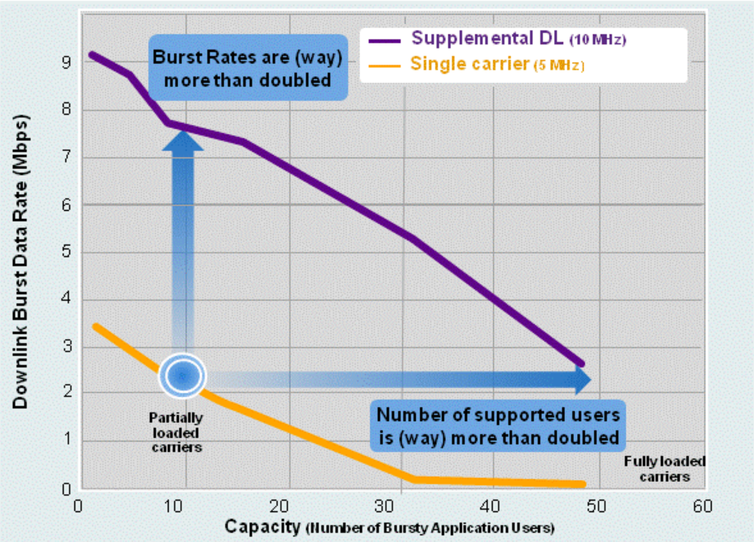
The purpose of this report is to provide evidence on the nature and scale of these benefits so as to help inform decisions about the future use of the 1.4 GHz band in the MENA region.

1.2 How does a supplemental downlink work?

A network implementing a SDL uses a wider channel for the downlink than for the uplink, by aggregating the usual downlink with a *supplemental* downlink channel. Using an additional downlink channel enables faster download speeds for mobile or portable wireless devices and support for a greater number of users, as shown in Figure 1-1.

[15] This frequency range is sometimes referred to as L band.

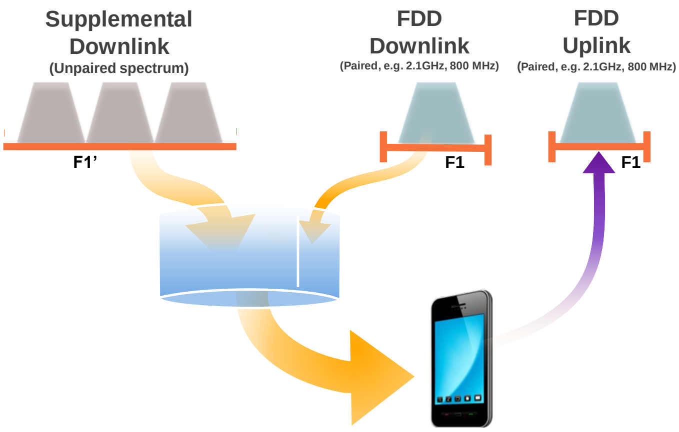
Figure 1-1: Results of simulation of performance of a HSPA+R9 supplemental downlink (SDL) network for bursty applications.



Source: Qualcomm

This approach requires new technology sometimes termed carrier aggregation technology. The technology allows the bonding of spectrum in different bands into a single wider downlink channel Figure 1-2[16] illustrates. This provides an efficient way of using spectrum because consumption of video and other data heavy applications over mobile broadband networks is asymmetric – there is much more traffic on the downlink than on the uplink.

Figure 1-2: A typical supplemental downlink configuration.



Source: Qualcomm, HSPA+ enhancements in Release 9 (and beyond)

[16] Example of HSPA+ R10 with a 3 + 1 inter-band downlink carrier combination.

1.3 The scope of the study

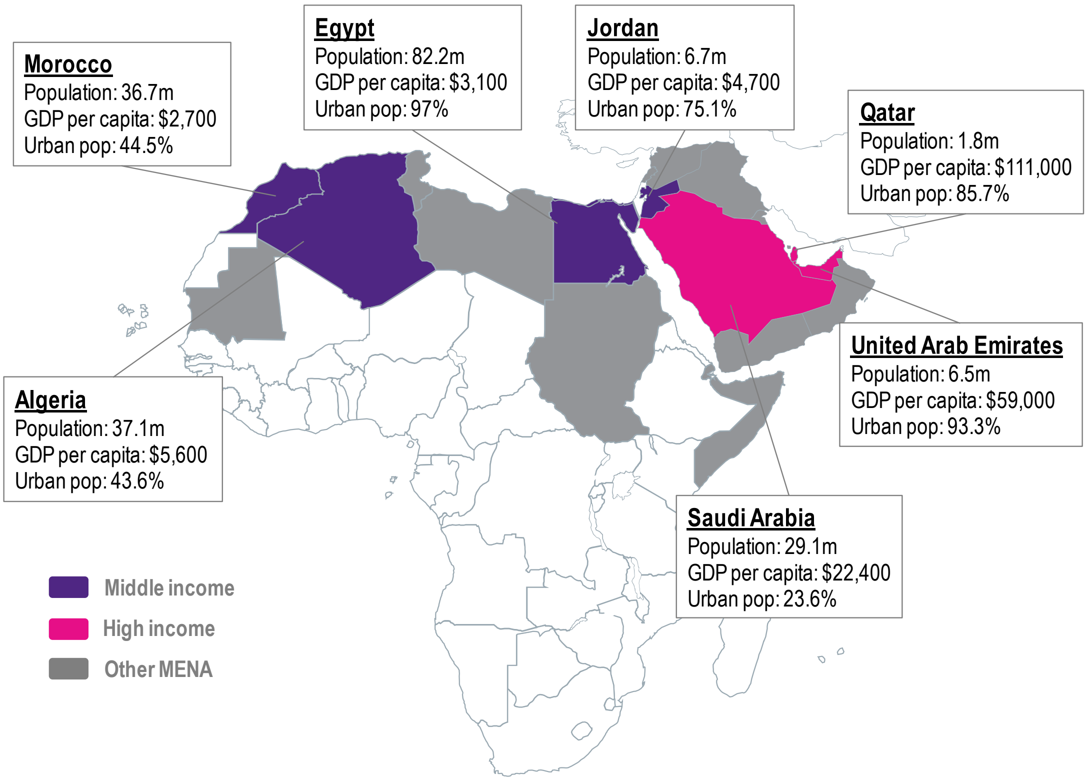
In this report we assess the economic and social benefits of deploying a 1.4 GHz SDL in the seven MENA countries indicated in Figure 1-3. The results for these countries are then extrapolated to the region.

The seven study countries divide into two groups:

- High income countries: Qatar, Saudi Arabia (KSA), and the United Arab Emirates (UAE) (with GDP per capita levels between $22,000-$111,000 which are comparable to those in Western Europe)
- Middle income countries[17]: Algeria, Egypt, Jordan and Morocco (with GDP per capita of between $2,700 and $5,600)

These income differences are reflected in similar differences in the adoption and use of telecommunications services. The countries also vary considerably in terms of population size and population density both of which have a bearing on our assessment of the economic value of an SDL at 1.4 GHz.

Figure 1-3: The seven study countries



Source: Plum Consulting, IMF, Gridded Population of the World

[17] Based on GNI per capita as classified by the World Bank, http://data.worldbank.org/about/country-classifications. The income data is at http://data.worldbank.org/indicator/NY.GNP.PCAP.CD

While there are high levels of mobile penetration and coverage in all of the study countries, mobile ARPUs are much higher in the high income countries. So too is the proportion of mobile subscribers with broadband access (see Table 1-1).

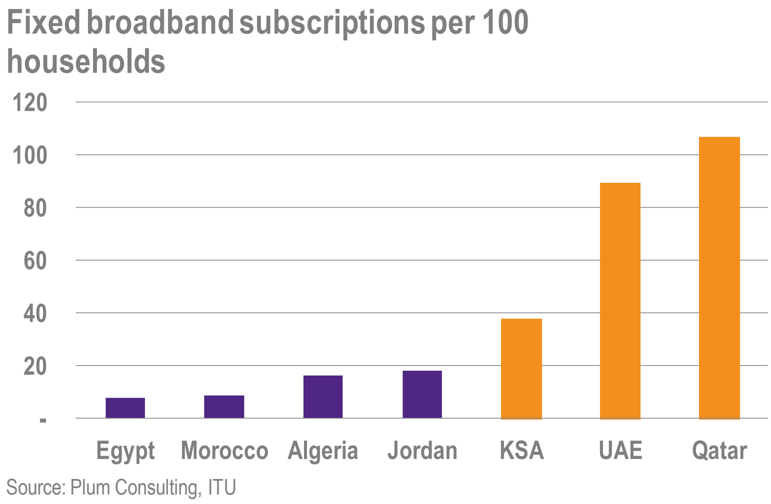
Table 1-1: Key mobile statistics for the study countries

Country	Mobile subscribers per 100 population, 2010	Mobile coverage, 2010 or latest available	Mobile subs with broadband access per 100 pop, 2010	Mobile ARPU (US$ per month), 2010
Middle income				
Algeria	92	81.5%	NA	7.4
Egypt	87	99.7%	6.4	5.2
Jordan	107	99.0%	2.4	12.2
Morocco	100	98.4%	4.8	8.0
High income				
Qatar	132	100%	73.5	44.1
Saudi Arabia	188	99.1%	41.7	19.4
UAE	145	100%	58.4	38.2

Source: ITU

The level of fixed broadband penetration is also related to GDP per capita, with high income countries having much higher levels of take-up than the middle income countries (see Figure 1-4). Mobile broadband is therefore likely to have somewhat different roles in the two groups of countries. In middle income countries it is likely to be the main means of accessing the internet for many households whereas in high income countries it is likely to be more of a complement to fixed broadband.

Figure 1-4: Fixed broadband subscriptions per 100 households



1.4 Report structure

The remainder of the report is structured as follows:

- Section 2 discusses the importance of mobile broadband in the MENA region and the likely growth in mobile data traffic
- Section 3 assesses the spectrum supply that could be available to support this traffic growth
- Section 4 discusses the potential role of a 1.4 GHz SDL
- Section 5 presents our estimates of the economic benefits of an SDL at 1.4 GHz in the MENA region. Supporting material for the modelling of benefits is given in Appendices A to D.

2 The importance of mobile broadband in the MENA region

2.1 The broadband Internet and economic development

The use of the broadband Internet is now central to economic and social development around the world. As the United Nation's Broadband Commission for Digital Development concludes[18] "*broadband infrastructure and services contribute to economic growth and job creation*" and should therefore be a policy priority. In the Arab region, internet usage, and in particular broadband Internet access, is still limited, and steps are required by governments to ensure that all citizens in the region can fully benefit from the potential of information and communication technologies (ICTs)[19].

2.1.1 Economic impacts

High levels of broadband penetration stimulate economic growth by providing connectivity to the internet. For example, access to the broadband internet

- Increases productivity by allowing more efficient solutions to business processes, better supply chain management and more efficient delivery of existing services
- Stimulates innovation and the development of new services and applications
- Improves access to information. The internet has certainly transformed the way information is accessed and stored, which enables improvements at all stages in the value chains of the economies of the MENA countries
- Enables restructuring of value chains, changing what services are offered and to whom they are offered.

There is a positive relationship between broadband penetration and GDP per capita growth. A recent ITU report estimates that for Arab states broadband penetration growth of 10% boosts GDP per capita growth by 0.18% to 0.21%.[20]

Broadband is widely recognised by many governments as enabling job creation. Jobs are created through direct employment in the network construction and telecoms equipment manufacturing, but more importantly through enhancing productivity and innovation in all sectors of the economy. A recent study in the US found that a one-billion dollar investment in wireless infrastructure a year would create approximately 12,000 jobs in that year[21].

For middle or low income countries broadband can also play a vital role in alleviating poverty by improving productivity and extending geographic reach of markets particularly for small farmers and

[18] http://www.broadbandcommission.org/Documents/Broadband_Challenge.pdf, 25 October 2011

[19] ITU (2012). ICT adoption and prospects in the Arab region. http://www.itu.int/dms_pub/itu-d/opb/ind/D-IND-AR-2012-PDF-E.pdf

[20] ITU (2012). Impact of broadband on the economy. Broadband Series, April 2012. http://www.itu.int/ITU-D/treg/broadband/ITU-BB-Reports_Impact-of-Broadband-on-the-Economy.pdf

[21] Pollack (2011). The jobs impact of telecom investment. EPI Policy Memorandum, 31 May 2011. http://w3.epi-data.org/temp2011/EPI_PolicyMemorandum_185%20%282%29.pdf

businesses. Broadband access can benefit famers by providing better access to information such as weather forecasts, crop prices and new sowing techniques.

Broadband Internet also facilitates the development of new financial services such as m-banking and online payments. These provide increased access to financial services for many people in low income countries where such services are often scarce and conventional transactions are costly. In Latin America, a study by Fundacion Telefonica found that increased access to financial services can help reduce social inequality and alleviate poverty[22]. For businesses and governments such services also help boost efficiency by lowering costs of doing business while creating more secure and reliable means of conducting transactions.

As the examples above illustrate there are substantial economic benefits associated with broadband Internet. Plum's recent study on the benefits of spectrum for mobile broadband in Sub-Saharan Africa highlights the importance of mobile broadband for economic development. We estimated that the release of digital dividend and 2.6 GHz spectrum in 2015 could increase overall GDP by $82 billion by 2025, potentially adding up to 27 million jobs and lifting 40 million people out of poverty[23].

A number of governments in MENA countries have launched initiatives to stimulate investment in broadband networks and improve access to broadband. For instance Egypt's National Telecom Regulatory Authority announced a new national broadband plan 'eMisr'[24] in 2011 which included targets for mobile coverage (98% 3G coverage by 2015 and 90% 4G/LTE coverage by 2021) and for mobile penetration (8 million mobile broadband subscribers by 2015 and 14 million by 2021). It is estimated that achieving 2015 targets will create 6,650 to 17,500 direct jobs on average per year, and will result in an incremental cumulative contribution to GDP of US$ 4.17 billion.

Qatar's National ICT Plan[25] set out the following goals: to double the ICT sector's contribution to GDP (to US$ 3 billion) and double the ICT workforce (to 40,000). This would involve providing high-speed broadband access to 95% of households and businesses, and achieving 90% Internet adoption.

For Morocco, the key priorities under its 'Maroc Numeric 2013'[26] strategy are to encourage investment in ICT, increase Internet penetration, develop domestic IT sector and facilitate e-government provision. The plan is expected to generate an additional US$3 billion in GDP and create 26,000 new jobs by 2013[27].

2.1.2 Social development impacts

As well as promoting economic development, broadband Internet access stimulates social development by substantially improving the delivery of social services such as health care and education. This is especially true of rural areas in middle income countries like Algeria, Egypt, Morocco and Jordan.

[22] http://www.fundacion.telefonica.com/en/prensa/noticias/detalle/30_06_2009_esp

[23] http://www.plumconsulting.co.uk/pdfs/Plum_Dec11_Benefits_of_spectrum_for_MBB_in_SSA.pdf

[24] http://www.tra.gov.eg/emisr/Presentations/Plan_En.pdf

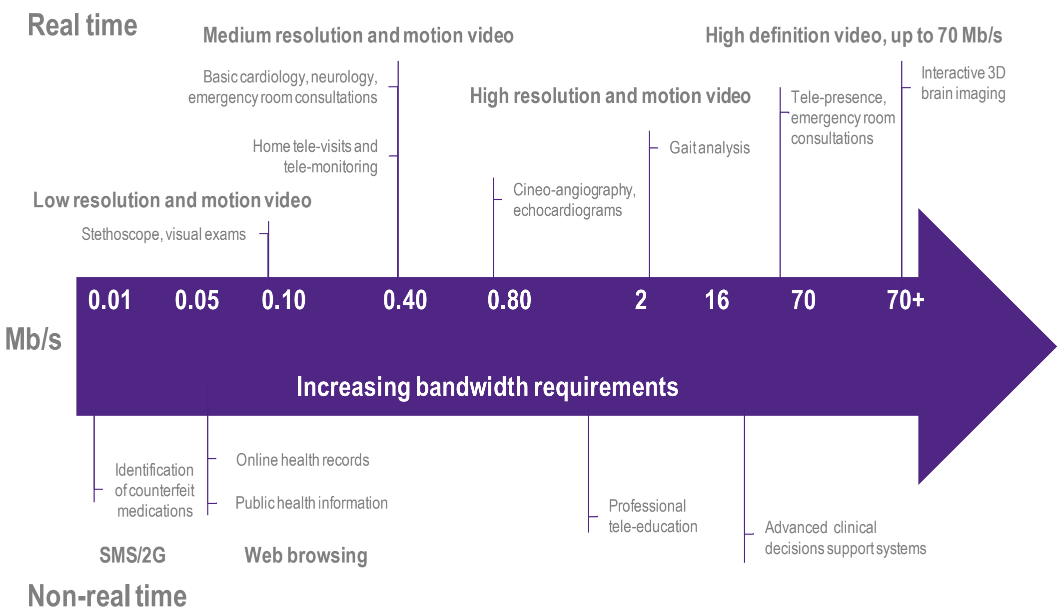
[25] http://www.ictqatar.qa/sites/default/files/documents/Qatar's_National_ICT_Plan_English.pdf

[26] http://www.mnf.ma/index.php

[27] http://www2.balancingact-africa.com/news/en/issue-no-476/computing/morocco-targets-wide/en

Healthcare is a major concern for all governments and takes up a big slice of GDP for many countries, particularly in the MENA region[28]. The availability of broadband and the development of e-health services such as telemedicine and mobile healthcare systems should deliver substantial benefits which include improved services and response times, cost savings and better elderly care and quality of life. Figure 2-1 shows the range of healthcare services possible with broadband access. These new services can help increase the efficiency of government spending on healthcare.

Figure 2-1:



Source: ITU-UNESCO

Education is another sector where mobile broadband is transforming the way services are delivered and received. The Internet not only opens up new possibilities for improving teaching and learning processes but also helps make education more accessible and better distributed across society.

With mobile broadband and technology-enabled learning solutions, learning will no longer be constrained by time, location and collaboration. For instance students can access materials outside the classroom and teachers can make use of new Internet-enabled tools such as discussion boards, live webcasts, podcasts, wikis, blogs and customisable course management platforms. These are designed to complement and enhance learning experiences for both children and working adults[29].

McKinsey predicts that the mobile education sector will be worth US$70 billion[30] by 2020 with the fastest growth coming from developing regions[31]. The market for Middle East and Africa is projected to grow 50% from 2011 to an estimated US$1 billion in 2020. Beyond the direct economic potential, these developments in education could lead to wider socio-economic impacts such as greater

[28] According to the World Health Organisation, spending on healthcare in MENA region is projected to increase 62% from 2005-2025.

[29] OECD (2011). The economic impact of Internet technologies

[30] This consists of $38 billion from m-education products and services and $32 billion from sales of devices.

[31] McKinsey (2012). Transforming learning through mEducation.

productivity, increased employment prospects, improved social mobility and improved overall living standards[32].

Broadband Internet can also help facilitate creative solutions to developmental issues. For example in Egypt a recent brainstorming event[33] for software developers and designers produced innovative solutions to water and sanitation problems. These included:

- A mobile and web-based application for more equitable water distribution, enabling farmers to remotely control irrigation
- An application for irrigation optimization and water saving in agricultural production, using smart mobile devices to enhance collection of field data
- A concept addressing water saving in industrial line production, using data visualization and SMS and web updates on water consumption.

Broadband internet access can also help to enrich the lives of those who live in rural communities in various ways. Social networking sites facilitate interaction with distant family members, friends, business associates, employees and employers. E-government solutions can help improve the accessibility, efficiency and convenience of public services by removing the need for users to be physically present at government offices. For example the Egyptian Government Services Portal[34] and Saudi e-Government National Portal[35] provide a centralised gateway which citizens can submit complaints, pay bills and access a wide range of government-related information and services.

E-commerce, while still a relatively niche activity, is seen as a key growth area in the MENA region[36]. The growing number of Internet users is reflected in the emergence of e-commerce platforms, innovative new products, services and business models. Examples include online shopping sites (Nahel.com, Maktoob.com), group buying sites (e.g. GoNab!t.com, Hmizate.ma) and online classified listings (Marocannonces.com). Not only do these platforms facilitate greater access to goods and services, but they also open new avenues for income generation and employment opportunities for rural communities.

Furthermore, in societies with distinct social and gender roles, broadband Internet can certainly be helpful to societies and individuals to increase participation in the knowledge economy by providing improved access to Government functions, education and work opportunities.

2.2 The role of mobile broadband

In high income countries:

- The fixed network has provided affordable broadband access to the internet, largely through upgrades to the copper line access network to provide DSL-based broadband
- Mobile broadband has, so far, largely acted as a complement to fixed broadband.

[32] World Bank (2008). The Road Not Traveled: education reform in the Middle East and Africa. http://siteresources.worldbank.org/INTMENA/Resources/EDU_Flagship_Full_ENG.pdf

[33] http://www.waterhackathon.org/

[34] http://www.egypt.gov.eg/English/Home.aspx

[35] http://www.saudi.gov.sa/wps/portal

[36] Booz & Co. Leaving cash behind: the rise of electronic payments in the MENA region. http://www.booz.com/media/uploads/Leaving_Cash_Behind.pdf

Now mobile broadband is rapidly becoming more important in these countries as users demand Internet-based services on the move as well as at home and in the office. For example Internet traffic over mobile networks is now growing about three times faster than Internet traffic over the fixed networks[37]. In addition mobile broadband is now the cost-effective way to deliver the broadband Internet to rural communities in most cases.

In middle income countries mobile broadband will even more important. This is because it will often be the only network that provides high levels of coverage, and affordable and usable services for many people[38]. In particular:

- The copper network has limited reach. In a high-income country the copper network passes virtually all households and enables a cost-effective upgrade to fixed broadband. But this is not the case in the middle income countries of the MENA region, where broadband over the copper network may not serve many households, particularly those in rural areas.
- Fixed broadband raises significant issues of affordability. The rental required to recover the costs of fixed broadband and basic voice telephony services in the EU is typically $30 per month. Such a fixed monthly commitment is beyond the means of many low income households in the MENA region
- Mobile broadband on the other hand offers good prospects of affordable broadband. This is because pre-pay mobile broadband connectivity is available at low cost[39] and low cost devices will be available. It is now clear that the BRIC[40] markets will be dominated by mobile rather than fixed broadband. This means that global suppliers will focus on producing low-cost network equipment and devices[41] for mobile broadband – a development which the countries of North Africa now have an opportunity to exploit.
- Mobile broadband devices, such as smartphones and tablets, offer an easier way of using the broadband Internet than traditional PCs. Figure 2-2 lists the ways this occurs. While full digital literacy is still required for an effective workforce to use PCs, the level of literacy required for basic use of the broadband Internet is much reduced.
- Mobile broadband devices facilitate shared use of Internet services and applications in a way which fixed broadband PCs do not. Such sharing is effective in spreading an appreciation of the value of using the Internet. It is, in effect, a form of viral marketing, which should stimulate broadband Internet take-up.

[37] According to Cisco, the CAGR for fixed Internet traffic is 32% compared to 92% for mobile data for the period 2010 to 2015.

[38] McKinsey (2012) found that Morocco's internet ecosystem is being held back by the cost of broadband access; lack of internet infrastructure particularly in rural areas and low digital literacy particularly among the senior population. http://www.mckinsey.com/Client_Service/High_Tech/Latest_thinking/Impact_of_the_internet_on_aspiring_countries

[39] The cost of supplying fixed broadband is driven by connection costs while the cost of mobile broadband is driven by traffic volumes with few fixed costs

[40] Brazil, Russia, India and China

[41] Already Indian supplier Datawind has announced the development of a tablet which will retail at less than ZAR1000. The next logical step is to provide it with mobile broadband connectivity and drive the price down further through global production.

Figure 2-2: Market innovations are lowering requirements for basic digital literacy

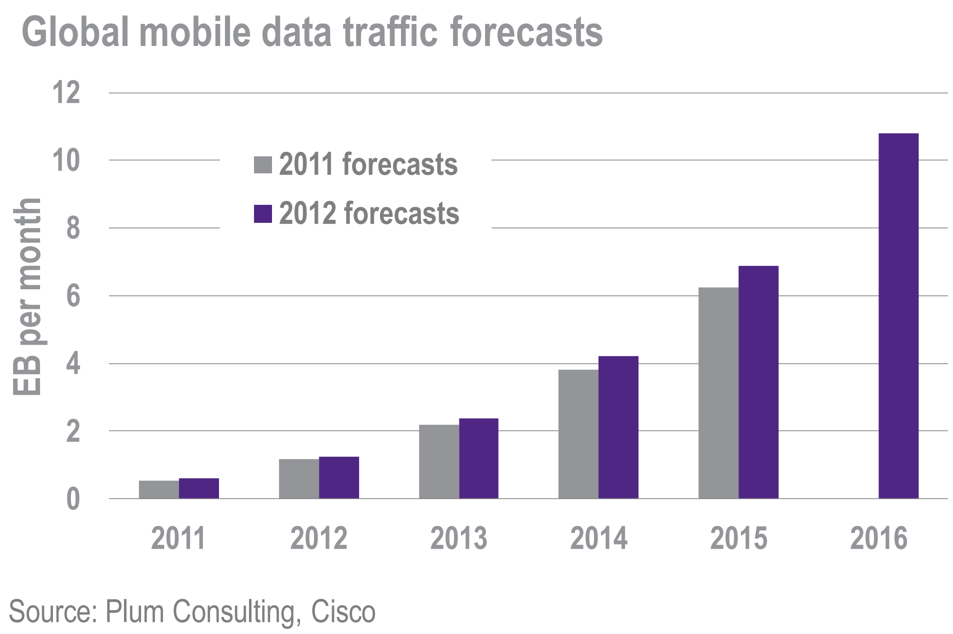
PCs:
- Complex but important for some ICT at work
- Keyboard and browser based
- Fixed broadband can be challenging to set up

Smart phones and tablets:
- Simple (complexity concealed)
- Touch screen and Apps based
- (Mobile) communications included

2.3 Demand for mobile broadband

Global demand for mobile broadband is predicted to grow 18-fold over the next five years according to Cisco's latest forecasts[42] – from 0.6 to 10.8 Exabytes[43] per month. Figure 2-3 illustrates. Moreover as actual usage has exceeded earlier forecasts predictions have been increased. Last year Cisco predicted global demand of 6.3 EB per month in 2015. This year the prediction is 6.9 EB per month.

Figure 2-3: Global demand for mobile broadband



What is driving this significant increase in demand for mobile broadband? We have identified four main drivers:

- The rapid take-up of inherently portable smartphones and tablets. These are now becoming more affordable in low and middle income countries with the development of devices which retail at less

[42] *Cisco Visual Networking Index – Global Mobile Data Traffic Forecast Update, 2011-2016*, Cisco, February 2012

[43] An Exabyte is 10^{18} bytes or 1000 million Gigabytes

than $50[44]. These devices typically generate far more data than conventional 3G mobile phones. For example in 2011 a typical smartphone generated 35 times more mobile data traffic than the typical basic feature cell phone.[45]

- A move to higher download speeds with the rollout of LTE networks. A typical 4G device operates at download speeds of 5 to 10 Mbps while a typical 3G device operates at download speeds below 1 Mbps. In 2011 a 4G device generated on average 28 times the traffic of a non-4G device.[46]
- The falling unit cost of carrying mobile data, as mobile operators deploy radio access technologies with higher spectrum efficiency, and as more spectrum is released
- Rapid growth in applications and content tailored specifically to mobile devices. The move to video-based mobile content continues[47] and there is a general trend towards cloud-based applications for mobile devices.

These developments will clearly stimulate rapid traffic growth in the MENA region. Cisco does not present forecasts for the region separate from those for the rest of Africa. But we know:

- High income countries in the MENA region have incomes similar to if not higher than those in Western Europe.
- From analysis of the data traffic volumes published by individual operators[48] that mobile data traffic levels per subscriber are often higher than in Western Europe

Hence in our modelling we have conservatively assumed traffic growth in the high income countries of the MENA region will be the same as is forecast for Western Europe. For middle income countries in the MENA region we have assumed traffic growth will be the same as is forecast for Central and Eastern Europe (CEE) (see Figure 2-4). While income levels in the CEE are higher than in the middle income MENA countries, we expect mobile data demand in the latter to be higher than would be indicated by income alone. This is because mobile broadband connectivity and devices will be more affordable than fixed broadband connections and PCs. This is likely to result in higher adoption and use of mobile broadband.

[44] For a low cost tablet see http://zeenews.india.com/business/gadgets/gadgets-news/datawind-launches-tablet-pc-at-rs-3-000_46610.html

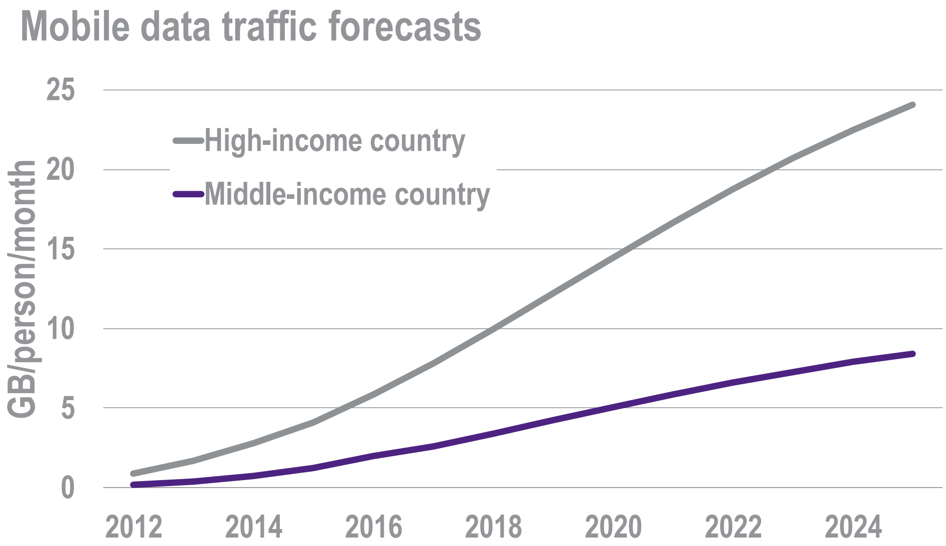
[45] *Cisco Visual Networking Index – Global Mobile Data Traffic Forecast Update, 2011-2016*, Cisco, February 2012

[46] *Cisco Visual Networking Index – Global Mobile Data Traffic Forecast Update, 2011-2016*, Cisco, February 2012

[47] With Cisco predicting that the proportion of video content downloaded to mobile devices will rise from 50% to 70% over the next five years

[48] *Mobily admits to LTE spectrum shortfall*, 27 January 2012, http://www.samenacouncil.org/samena_daily_news.php?news=25256

Figure 2-4: Mobile data traffic forecasts underpinning the modelling



Source: Plum Consulting, Cisco, UN

3 Spectrum supply in MENA countries

3.1 Introduction

The downlink spectrum currently available to mobile operators and used to provide broadband services[49] in the study countries is shown in Table 3-1. The high income countries typically have more spectrum available in more bands than the middle income countries. In this section we discuss how much additional spectrum might be made available for mobile broadband and whether this is likely to be sufficient to support forecast traffic growth at reasonable cost and quality of service.

Table 3-1: Downlink spectrum available for mobile broadband in urban areas – 2012 (MHz)

	900 MHz	1800 MHz	2.1 GHz	2.3 GHz	2.6 GHz	Total
KSA	0	10	45	10 (TDD)	20 (TDD)	55 + 30 TDD
Qatar	10	0	30	0	0	40
UAE	15	0	25	0	20	70
Algeria	0	0	0	0	0	0
Egypt	10	0	30	0	0	40
Jordan	0	0	30	0	0	30
Morocco	5	0	45	0	0	50

Notes: Frequencies are paired (i.e. FDD) unless otherwise indicated as TDD. It is assumed that 50% of TDD spectrum is used in the downlink. Most frequencies assigned at 900MHz and 1800 MHz are used for voice services.

3.2 Possible sources of additional spectrum

Possible sources of additional spectrum for mobile broadband in the MENA region include[50]:

- Spectrum not yet released to mobile services in the 900 MHz, 1800 MHz and 2100 MHz bands. These are the core mobile bands in many countries including all of Europe. In addition to release of this spectrum, we expect that operators in the MENA will start to deploy mobile broadband technology in the 900 MHz and 1800 MHz bands[51] (i.e. refarming the spectrum licensed to them) further increasing the spectrum capacity made available for mobile broadband.
- The 800 MHz (790-862 MHz) and 2.6 GHz bands which are in the process of being released in Europe. The spectrum authorities in MENA countries are only just starting to release the 800 MHz and 2.6 GHz bands.

[49] We assume that deployment of 3G or 4G technology is required to provide mobile broadband services.

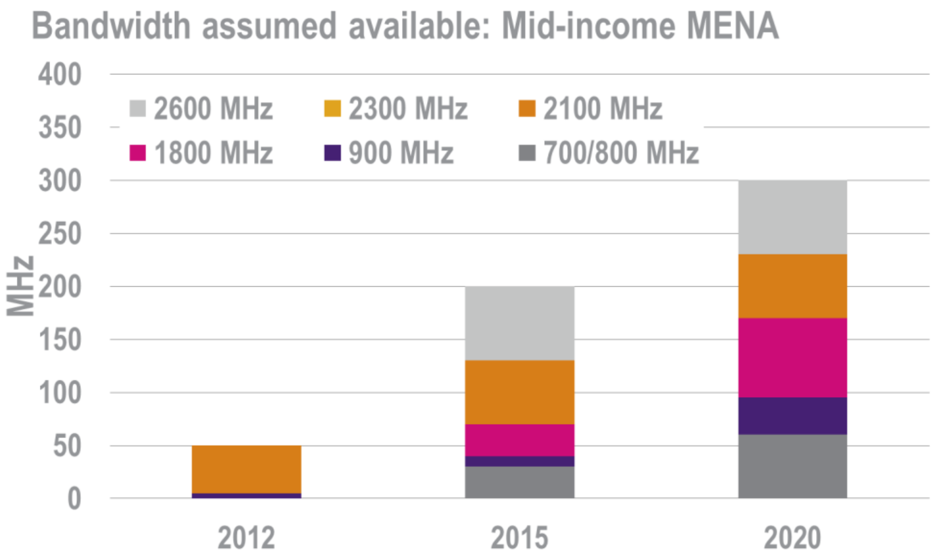
[50] In the longer term the 3.5 GHz band may start to be used, though this is a lower priority than the other bands because it is best suited to provide localised rather than wide area capacity.

[51] Using 3G and 4G technology respectively

- Spectrum at 2.3 GHz which is now being released in some countries (most notably in Russia, India and China) and for which there is readily available equipment. Only a few MENA countries have started to make this spectrum available.
- The 700 MHz band which was allocated to mobile services in Region 1 (i.e. Europe, the Middle East and Africa) at the 2012 ITU World Radiocommunication Conference (WRC) subject to final confirmation at the 2015 ITU WRC. It seems unlikely this spectrum will be used commercially for mobile broadband before 2015 in MENA.

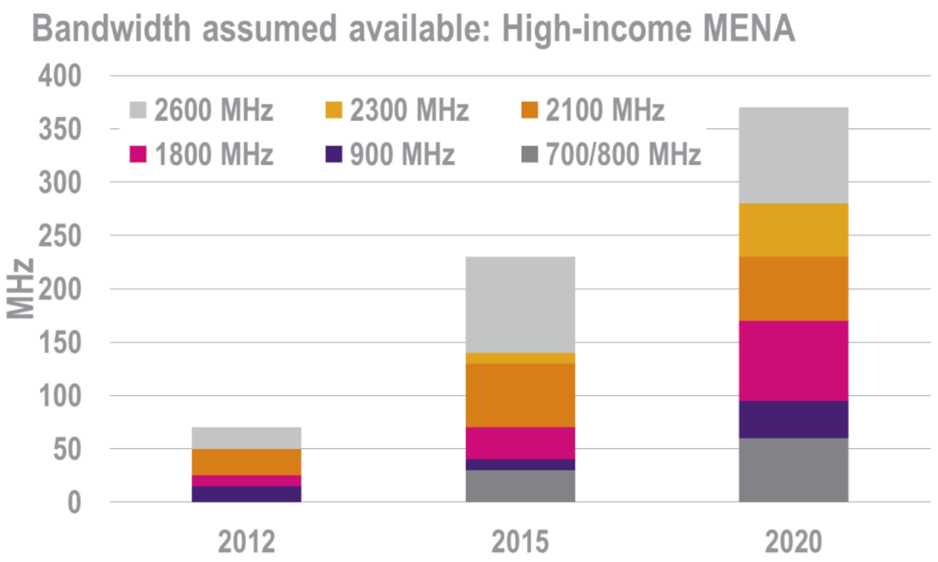
Release of these bands will inevitably take time particularly as some existing users may need to be migrated (e.g. broadcasters or public sector users). For the purposes of our modelling we have taken into account country specific factors in determining a profile for the future availability of spectrum for mobile broadband services. We assume additional spectrum is released and operators refarm 2G mobile services at 900 MHz and 1800 MHz to 3G and 4G technology respectively. Most of these changes are assumed to occur in the period 2015 to 2020. (The details are shown in Appendix A.) Overall the amount of spectrum available for mobile broadband could increase around five fold in high income countries and six fold in middle income countries over the period to 2020. See Figure 3-1 and Figure 3-2.

Figure 3-1: Bandwidth assumptions for middle income MENA countries



Source: Plum Consulting, Qualcomm

Figure 3-2: Bandwidth assumptions for high income MENA countries



Source: Plum Consulting

In the longer term beyond 2020, other bands may also be used, but this is uncertain. Rather than include other bands from 2020 in our modelling, we have only counted the benefits of the 1.4 GHz SDL for the period 2015 to 2020. In other words we have assumed that after 2020, there is no spectrum shortfall any of the study countries. This means our benefit estimates are likely to be conservative.

3.3 The prospects of a spectrum shortfall in the MENA region

We have tested whether a spectrum shortfall – when the ratio of spectrum demand to spectrum supply exceeds 100% – is likely to occur in the study countries over the period to 2020[52]. To do this we have modelled spectrum demand and supply in urban, suburban and rural areas in each country. The results are summarised in Table 3-2. Locations where there is a spectrum shortfall in 2020 are indicated by a tick. No shortfall is indicated by a cross[53].

[52] The modelling assumptions are given in Appendices C and D.

[53] Graphics showing the spectrum demand and supply balance for all years up to 2025 for each country can be found in Appendix C.

Table 3-2: Locations where there is a spectrum shortfall in 2020

Country type	Country	Is there spectrum shortfall in 2020?		
		Urban areas	Suburban areas	Rural areas
High-income	KSA	✓	✓	✓
	Qatar	✓	✗	✗
	UAE	✓	✗	✗
Medium-income	Algeria	✓	✓	✓
	Egypt	✓	✓	✓
	Jordan	✓	✗	✗
	Morocco	✓	✓	✗

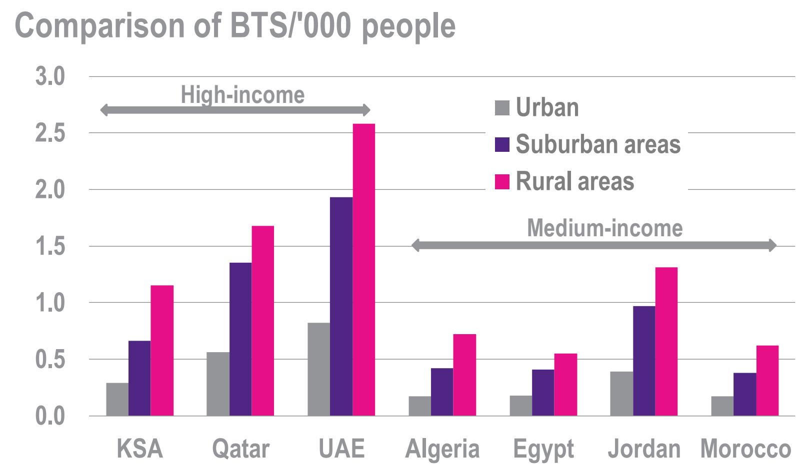
Notes:
Urban area = Population density greater than or equal to 2000 people per sq km
Suburban area = Population density greater than 200 people per sq km and less than 2000 people per sq km
Rural area = Population density less than 200 people per sq km

As expected a spectrum shortfall is more likely in urban than in suburban and rural areas because this is where busy hour traffic peaks are greatest and where there are fewer base stations per capita in urban areas. Whether there is a spectrum shortfall in suburban and rural areas depends largely on the combined effect of the number of base stations per capita and the proportion of the population that live in these areas. The current situation in the study countries in respect of these factors is shown in Figure 3-3 and Figure 3-4. The way in which they affect the possibility of a spectrum shortfall is as follows:

- The higher the number of base stations per head, the greater the network capacity, and the lower the likelihood of a spectrum shortfall (assuming all else is equal)
- The lower the share of population living in suburban or rural areas, the lower the demand for a given level of infrastructure, and so the reduced likelihood of a spectrum shortfall in suburban and rural areas.

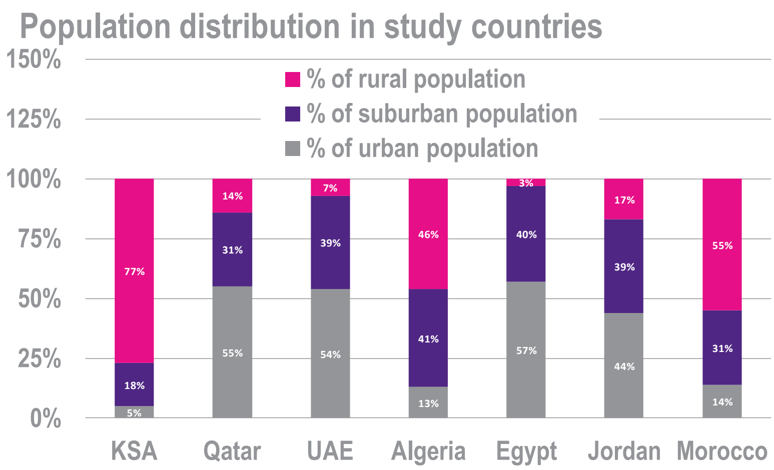
For example within their respective country groups Jordan, Qatar and UAE have high levels of Base Transceiver Station (BTS) infrastructure per capita and low shares of population living in suburban and rural areas. Hence there is no spectrum shortfall in suburban and rural areas. By contrast in KSA, Egypt and Algeria there is a much lower ratio of BTS per capita and a large proportion of the population live in suburban and rural areas. Hence a spectrum shortfall occurs in all areas of these countries.

Figure 3-3: Comparison of BTS per 1000 people in study countries (2012)



Source: Plum Consulting, ABI Research, Wireless Intelligence, GPW

Figure 3-4: Population distribution



Source: Plum Consulting, GPW

3.4 Conclusions on spectrum shortfalls in the MENA region

Overall there is a strong likelihood that supply of spectrum in the MENA region will not be sufficient to enable operators to meet mobile broadband demand over the next 10 years without considerable investment by operators in new BTSs and associated backhaul infrastructure. This would be expensive, and as a result raise end user prices for mobile broadband and constrain economic and social development in the region.

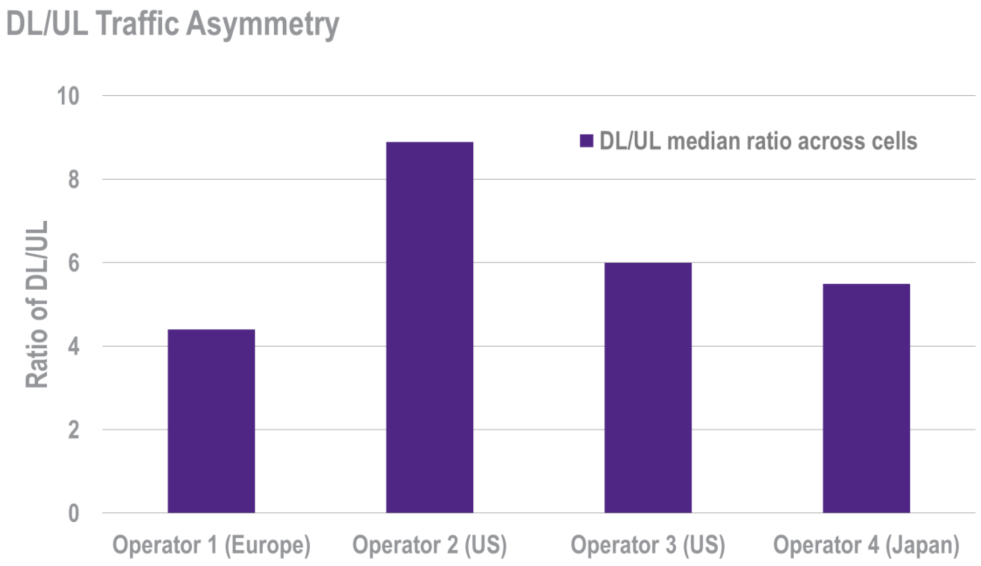
4 The potential role of a 1.4 GHz SDL

4.1 The 1.4 GHz SDL provides significant downlink capacity

The 1.4 GHz band offers 40 MHz of downlink capacity that could help to alleviate the spectrum shortfall identified in the study countries. A 1.4 GHz SDL is especially useful for mobile broadband because mobile data traffic is already highly asymmetric with much more data in the downlink than the uplink as shown in Figure 4-1. Moreover this asymmetry is growing as the video proportion of mobile data traffic grows. Using forecasts of the mix of traffic produced by Allot and Cisco we have estimated that the current ratio of downlink to uplink traffic is around 6:1 and that this could rise to 10:1 over the next five years[54].

The ratio between downlink to uplink capacity is around 2:1, which implies a significant imbalance between the downlink to uplink traffic ratio and the downlink to uplink capacity ratio when relying solely on paired spectrum. A supplemental downlink provides only downlink capacity and would therefore help meet the growing demand for downlink traffic.

Figure 4-1: Mobile downlink (DL) traffic as a multiple of uplink (UL) traffic[55]



Source: Plum Consulting, Qualcomm

[54] Economic study of the benefits from use of 1452-1492 MHz for a supplemental downlink for enhanced multimedia and broadband services, Plum for Ericsson and Qualcomm, June 2011. http://www.plumconsulting.co.uk/pdfs/Plum_June2011_Benefits_of_1.4GHz_spectrum_for_multimedia_services.pdf

[55] The data is based on measurements in live networks. Median value is shown.

4.2 The SDL is moving from a concept into reality

Supplemental downlink and carrier aggregation capability is now enabled in the HSPA+ and LTE-Advanced standards[56]. Implementation of a supplemental downlink in actual networks has not yet occurred. However, in the US AT&T plans to implement the supplemental downlink technology in its LTE network using spectrum at 700 MHz, coupled with paired AWS spectrum which AT&T already holds[57].

In Europe, ECC Report 188[58] conducted an impact assessment of the future harmonised use of the 1.4GHz band[59] and concluded that a mobile broadband SDL would generate the highest economic and social benefits of the candidate applications for the band. In September 2012 CEPT started the regulatory work to harmonise the 1.4 GHz band for a SDL[60]. An ECC Decision including the technical rules for harmonised use of the band is expected by September 2013. It is therefore possible that we will see harmonised use of the 1.4 GHz band for a mobile SDL across European countries partially from 2013 and fully from 2015. In France, Orange will conduct an SDL trial in partnership with Ericsson and Qualcomm in early 2013[61]. A possible implementation timetable is shown in Figure 4-2. This would mean that equipment would be available for use in the MENA region by 2015.

Figure 4-2: An implementation timeline for a 1.4 GHz SDL

4.3 There is potential for a global market

Spectrum authorities have allocated the 1.4 GHz band for broadcasting, and in particular DAB services in numerous countries outside Europe. This includes MENA countries. But DAB services are currently not operating in the 1.4 GHz band in any country. Hence if a European allocation for an SDL at 1.4 GHz is adopted, there is the potential for this allocation to be taken up in many other countries. Figure 4-3 shows the countries where this would be possible. Taken together with European support this gives significant potential for economies of scale in equipment production and service development to be realised. This should mean that affordable equipment will be available to MENA countries from 2015.

[56] Aggregation across bands is supported in HSPA+ R9 (and beyond) and LTE R10 (and beyond) standards, but each specific combination of bands has to be defined in 3GPP.

[57] http://hraunfoss.fcc.gov/edocs_public/attachmatch/FCC-11-188A1.pdf

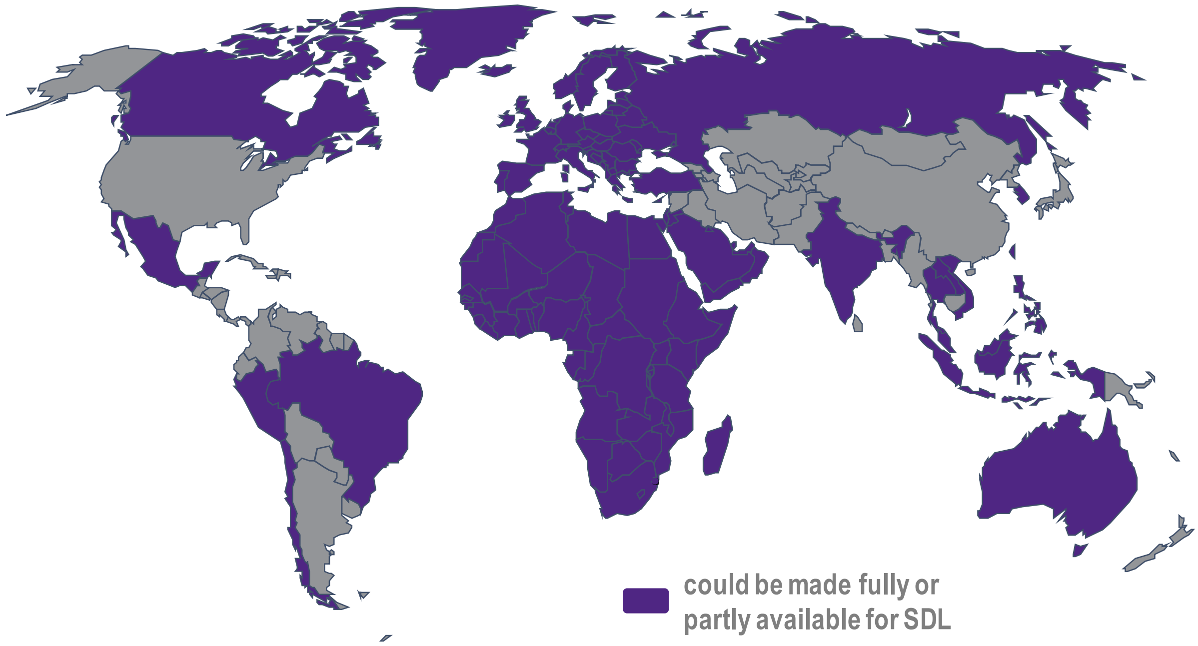
[58] Currently under public consultation: http://www.cept.org/ecc/tools-and-services/ecc-consultation

[59] http://www.cept.org/ecc/groups/ecc/wg-fm/fm-50

[60] See Minutes of the 75th WG FM Meeting. Note: in CEPT, SDL is referred to as Mobile/Fixed Communication Networks (MFCN) Supplemental Downlink (MFCN SDL).

[61] http://www.orange.com/en/press/press-releases/press-releases-2012

Figure 4-3: Map of potential availability of 1.4 GHz band for SDL on a global basis



Source: Plum Consulting, September 2012

4.4 Conclusions on the potential use of a 1.4 GHz SDL

The use of 1.4 GHz band spectrum for an SDL is a good way to expand mobile broadband network capacity in a cost-effective manner in the near term (e.g. 2015 to 2020) while waiting for other spectrum to be released for mobile broadband use. But what are the economic benefits of doing this and are they sufficient to justify use of 1.4 GHz band spectrum in this way in the MENA region? These questions are addressed in the next section.

5 Economic benefits of the SDL at 1.4 GHz

5.1 Introduction

In this section we report the results of our modelling of the economic benefits from use of the 1.4 GHz band for a mobile SDL in the MENA region. Two types of benefit are estimated, namely:

- **Reduced costs**: deployment leads to avoided costs of investment in additional base station and backhaul infrastructure. Once mobile broadband demand exceeds network capacity, networks can be expanded by deploying a 1.4 GHz SDL on existing base station sites rather than building new base station sites. This is more cost efficient by a factor of five. The scale of this benefit depends primarily on how quickly demand for mobile broadband grows in each MENA country and how soon additional spectrum is made available for mobile broadband use
- **Better service quality**: SDL deployment leads to improved services – in particular better in-building coverage and higher downlink speeds. The 1.4 GHz SDL when paired with low frequency spectrum behaves like sub-1 GHz spectrum in terms of propagation characteristics. So a 1.4 GHz SDL offers better in-building coverage than spectrum allocated for mobile broadband use at 2.1 GHz or 2.6 GHz

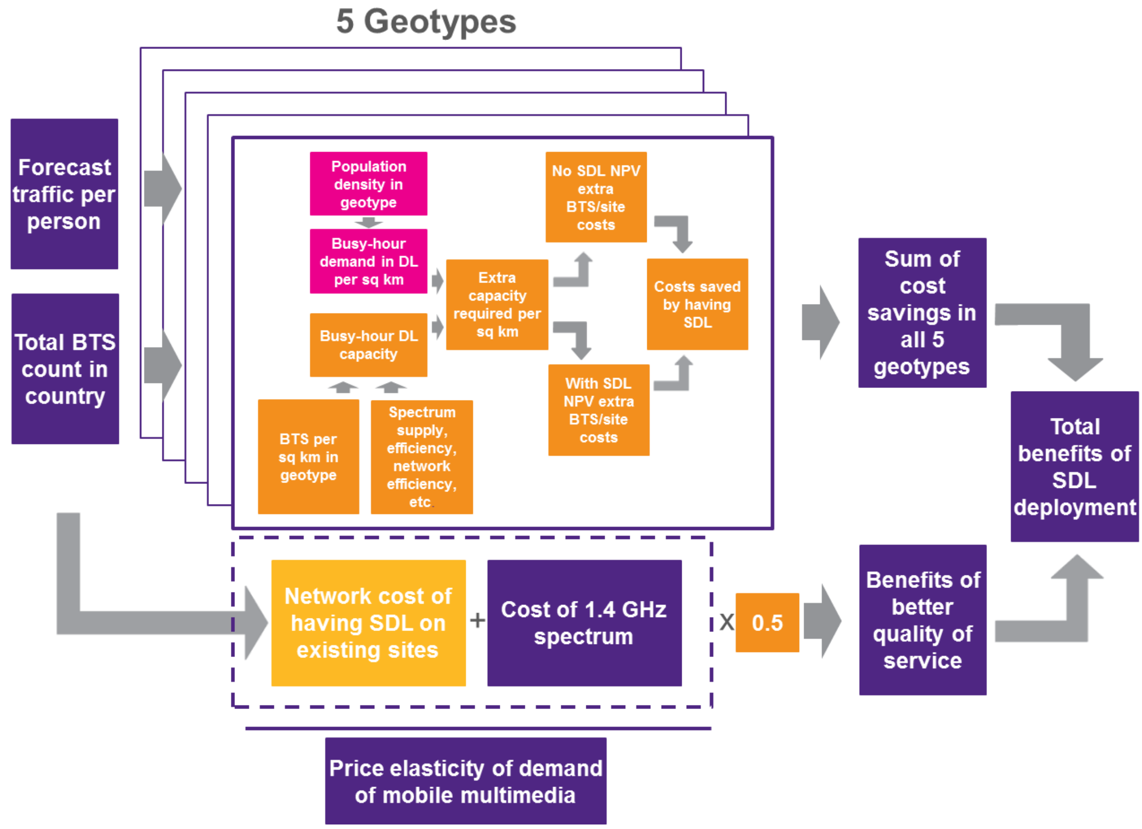
The avoided costs from deploying a 1.4 GHz SDL mean there will be lower prices than would otherwise be the case, whereas the quality of service benefits will be reflected in greater consumer satisfaction with the service. These benefits are additive and independent of each other.

There are also other benefits from SDL deployment which we do not quantify. The propagation characteristics of a 1.4 GHz SDL, when paired with sub-1 GHz spectrum, mean that it can provide mobile broadband to all ***rural customers*** currently receiving 2G mobile services without the need for additional base stations. This should stimulate economic and social development in the rural areas of the study countries where there is unlikely to be any fixed broadband. These benefits, which are discussed in Section 2.1.2, are additional to those estimated in this chapter.

5.2 Estimates of the economic benefits in the study countries

Figure 5-1 provides a graphical description of our approach to modelling the net present value of the benefits of additional network capacity provided by the 1.4 GHz band in the seven study countries.

Figure 5-1: Approach to estimating economic benefits of 1.4 GHz SDL



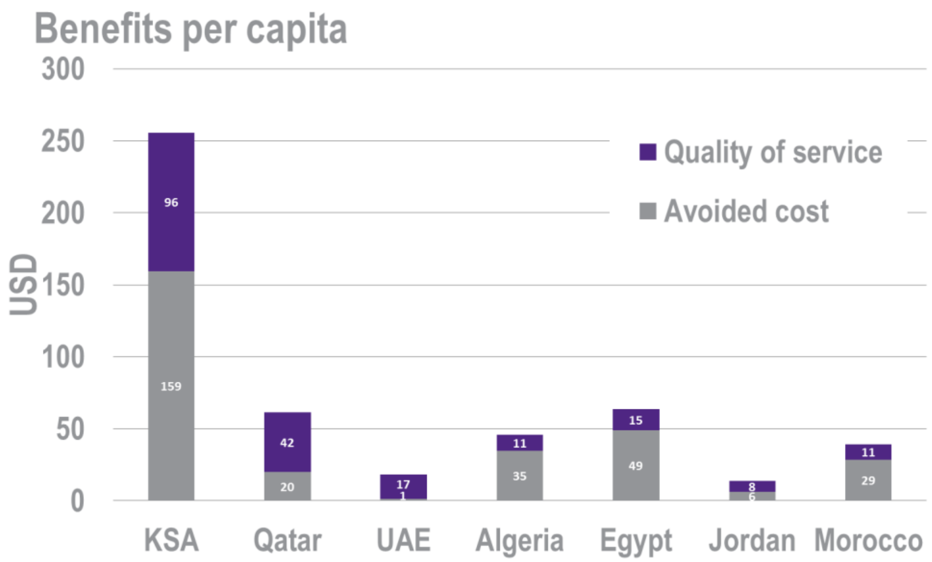
The key assumptions that underpin the modelling are as follows:

- The 1.4 GHz band spectrum is used for mobile SDL from 2015 in MENA countries
- The release of other spectrum in each study country is as specified in Appendix A
- The growth in mobile broadband traffic in each study country is as specified in Figure 2-4
- The number of mobile network operators in each country remains at current levels
- In each country 1.4 GHz SDL is used with paired spectrum below 1 GHz to enhance mobile broadband capacity, in-building coverage and data speeds
- Mobile operators continue to add base station sites to their networks up to 2015. Thereafter when demand for mobile broadband exceeds capacity the mobile operator upgrades existing base stations with a 1.4 GHz SDL rather than using the more expensive option of building additional base stations.
- Once the additional capacity from the SDL upgrades is used up, the mobile operator deploys new base stations which are more cost effective. We estimate that, by 2015, a new base station which uses the 1.4 GHz SDL might offer at least 20% more downlink capacity for only 9% greater cost, when compared with a new base station without an SDL.
- Net present values are calculated over a 10-year period from 2015 using a 10% pa discount rate.

See Appendices B to D for more details. Appendix D also gives the detailed results by country.

Figure 5-2 gives the net present value of the benefits per capita from deploying a 1.4 GHz SDL to support demand for spectrum over the period 2015 to 2020. The results vary greatly by country. Countries with larger areas and larger populations tend to benefit more from the 1.4 GHz SDL. This is not simply a scale effect. In three of the countries – Algeria, KSA and Morocco – it also reflects the lower population densities in these countries and the high cost of providing good quality mobile broadband services to a dispersed population. Egypt has a high population (and high population density) but relatively low numbers of base stations and so high benefits are obtained because the 1.4 GHz SDL allows considerable savings in infrastructure costs that would otherwise need to be installed to support the forecast traffic growth.

Figure 5-2: Benefits per capita



Source: Plum Consulting

5.3 Benefits for the overall MENA region

We have aggregated the benefits to the MENA region as a whole by first matching the economic and geographic characteristics countries in the region to the study countries and then grossing up by GDP.

For the purposes of this study the MENA region is defined to include the following countries: Algeria, Bahrain, Djibouti, Egypt, Iraq, Jordan, Kuwait, Lebanon, Libya, Mauritania, Morocco, Oman, Qatar, Saudi Arabia, Somalia, Sudan, Syria, Tunisia, United Arab Emirates and Yemen. Table 5-1 shows country groupings.

Table 5-1: MENA country groupings

Study country	"Similar" other countries in the region
KSA	Oman
Qatar, UAE	Bahrain, Kuwait
Algeria, Egypt, Jordan, Morocco	Djibouti, Iraq, Lebanon, Libya, Mauritania, Somalia, South Sudan, Sudan, Syria, Tunisia and Yemen.

The net present value of the benefits using 1.4 GHz for a supplemental downlink for mobile broadband in MENA region is estimated to be US$26 billion. The results are presented in Table 5-2: . The quantified benefits of 1.4 GHz translates into $1.94/MHz/pop which is around half the European value of $3.90/MHz/pop (€2.71) calculated in our study for Europe.

Table 5-2: Benefits of 1.4 GHz spectrum for SDL in MENA region

Countries in MENA region	Benefits (US$ bn)
Group 1 (KSA, Oman)	8.85
Group 2 (Qatar, UAE, Bahrain, Kuwait)	0.34
Group 3	17.18
Overall(1)	26.37

Note: (1) Somalia and South Sudan not included as data not available.

Appendix A: Spectrum for the MBB downlink by country

A.1 KSA

Urban spectrum

Band (MHz)	2012	2015	2020	2025
700/800	0	30	60	60
900	0	10	35	35
1800	10	30	75	75
2100	45	60	60	60
2300	10	10	50	50
2600	20 (TDD)	70 + 20 (TDD)	70 + 20 (TDD)	70 + 20 (TDD)
Total	**55 FDD + 30 TDD**	**200 FDD + 30 TDD**	**300 FDD + 70 TDD**	**300 FDD + 70 TDD**

Suburban/rural spectrum

Band (MHz)	2012	2015	2020	2025
700/800	0	30	60	60
900	0	10	35	35
1800	10	30	75	75
2100	45	60	60	60
2300	0	0	0	0
2600	0	0	0	0
Total	**55 FDD**	**130 FDD**	**225 FDD**	**225 FDD**

A.2 Qatar

Urban spectrum

Band (MHz)	2012	2015	2020	2025
700/800	0	30	40	40
900	10	10	35	35
1800	0	20	75	75
2100	30	60	60	60

Band (MHz)	2012	2015	2020	2025
2300	0	0	50	50
2600	0	80	80 + 20 (TDD)	80 + 20 (TDD)
Total	**40 FDD**	**200 FDD**	**280 FDD + 70 TDD**	**280 FDD + 70 TDD**

Suburban/rural spectrum

Band (MHz)	2012	2015	2020	2025
700/800	0	30	40	40
900	10	10	35	35
1800	0	20	75	75
2100	30	60	60	60
2300	0	0	0	0
2600	0	0	0	0
Total	**40 FDD**	**120 FDD**	**210 FDD**	**210 FDD**

A.3 UAE

Urban spectrum

Band (MHz)	2012	2015	2020	2025
700/800	0	30	60	60
900	15	15	35	35
1800	0	20	75	75
2100	25	60	60	60
2300	0	0	50	50
2600	20	70	70 + 20 (TDD)	70 + 20 (TDD)
Total	**60 FDD**	**195 FDD**	**300 FDD + 70 TDD**	**300 FDD + 70 TDD**

Suburban/rural spectrum

Band (MHz)	2012	2015	2020	2025
700/800	0	30	60	60
900	15	15	35	35
1800	0	20	75	75
2100	25	60	60	60

Band (MHz)	2012	2015	2020	2025
2300	0	0	0	0
2600	0	0	0	0
Total	**40 FDD**	**125 FDD**	**230 FDD**	**230 FDD**

A.4 Algeria

Urban spectrum

Band (MHz)	2012	2015	2020	2025
700/800	0	30	45	60
900	0	10	30	30
1800	0	30	75	75
2100	0	60	60	60
2300	0	0	0	0
2600	0	0	70	70
Total	**0**	**130**	**280**	**295**

Suburban/rural spectrum

Band (MHz)	2012	2015	2020	2025
700/800	0	30	45	60
900	0	10	30	30
1800	0	30	75	75
2100	0	60	60	60
2300	0	0	0	0
2600	0	0	0	0
Total	**0**	**130**	**210**	**225**

A.5 Egypt

Urban spectrum

Band (MHz)	2012	2015	2020	2025
700/800	0	30	45	60
900	10	10	30	30
1800	0	30	75	75

Band (MHz)	2012	2015	2020	2025
2100	30	60	60	60
2300	0	0	0	0
2600	0	70	70	70
Total	**40**	**200**	**280**	**295**

Suburban/rural spectrum

Band (MHz)	2012	2015	2020	2025
700/800	0	30	45	60
900	10	10	30	30
1800	0	30	75	75
2100	30	60	60	60
2300	0	0	0	0
2600	0	0	0	0
Total	**40**	**130**	**210**	**225**

A.6 Jordan

Urban spectrum

Band (MHz)	2012	2015	2020	2025
700/800	0	30	60	60
900	0	10	35	35
1800	0	30	75	75
2100	30	60	60	60
2300	0	0	0	0
2600	0	70	70	70
Total	**30 FDD**	**200 FDD**	**300 FDD**	**300 FDD**

Suburban/rural spectrum

Band (MHz)	2012	2015	2020	2025
700/800	0	30	60	60
900	0	10	35	35
1800	0	30	75	75
2100	30	60	60	60

Band (MHz)	2012	2015	2020	2025
2300	0	0	0	0
2600	0	0	0	0
Total	**30 FDD**	**130 FDD**	**230 FDD**	**230 FDD**

A.7 Morocco

Urban areas

Band (MHz)	2012	2015	2020	2025
700/800	0	30	45	60
900	5	10	30	30
1800	0	30	75	75
2100	45	60	60	60
2300	0	0	0	0
2600	0	70	70	70
Total	**50**	**200**	**280**	**295**

Suburban/rural areas

Band (MHz)	2012	2015	2020	2025
700/800	0	30	45	60
900	5	10	30	30
1800	0	30	75	75
2100	45	60	60	60
2300	0	0	0	0
2600	0	0	0	0
Total	**50**	**130**	**210**	**225**

Appendix B: Approach to benefits estimation

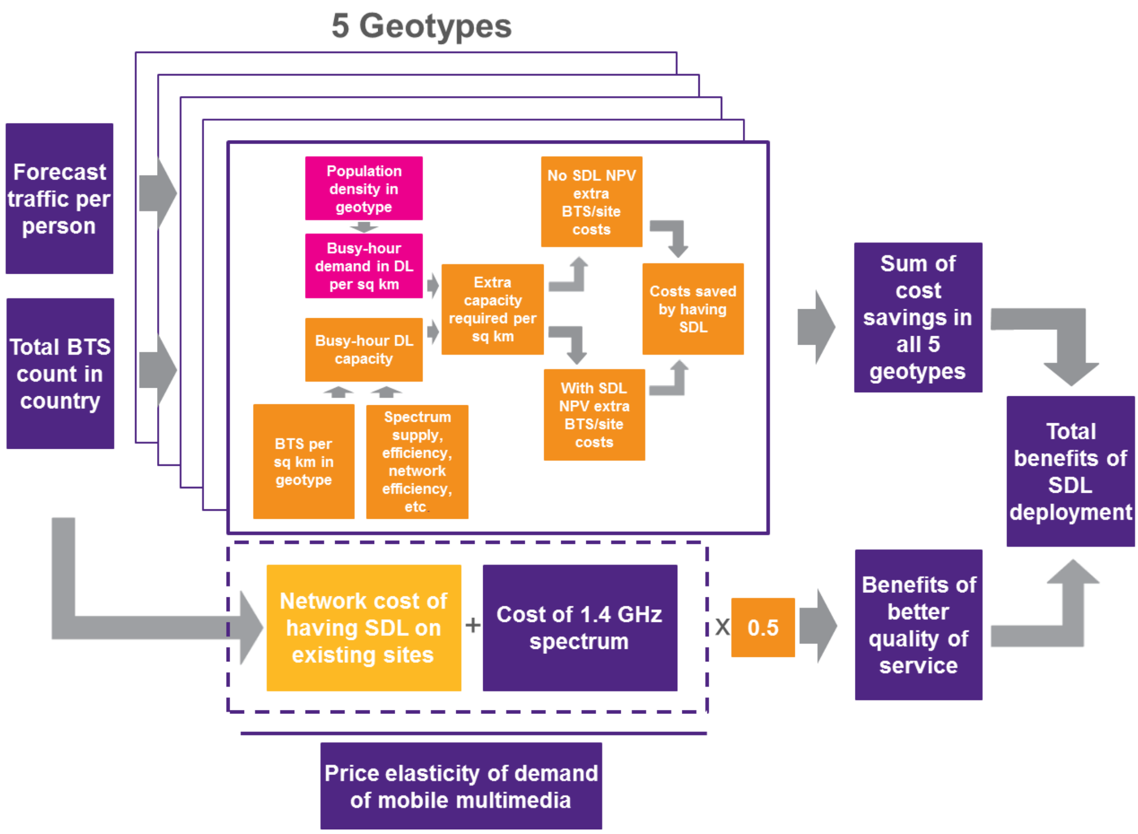
B.1 Overview

Figure B-1 illustrates how we make estimates of economic benefits of 1.4 GHz SDL deployment. There are two components to the benefits:

i. The costs avoided by upgrading existing base stations rather than building new ones (top half the diagram)

ii. The benefits of better quality of service in terms of (primarily) in-building coverage (bottom half of the diagram).

Figure B-1: Method of estimating benefits from SDL deployment at 1.4 GHz



Source: Plum Consulting

B.2 Avoided cost calculations

The steps in the calculations are as follows.

Step 1: We define the geotypes in terms of population density as per Table B-1. Then the area in square kilometres of each geotype for each country is calculated. We use the Gridded Population of the World (GPW) database for the latter.

Table B-1: Geotype definition

EAA genotypes		Proposed MENA geotypes	
Label	Pop/sq km lower limit	Label	Pop/sq km lower limit
Hotspot	100,000	Dense urban	30,000
Dense urban	30,000	Urban 1	8,000
Urban	8,000	Urban 2	2,000
Suburban	200	Suburban	200
Rural	0	Rural	0

Step 2: For each geotype, we estimate the population density per square kilometre. We project population growth at 2% per annum and apportion to this projected population to each geotype using the GPW database. We then divide the population by the total land area of the geotype.

Step 3: For each geotype, we estimate the traffic per square kilometre. To do this we estimate:

– The GB per month over time for the whole country using Cisco's VNI 2012 and hence the GB per month per head of population for the whole country

– The GB per month per square kilometre for each geotype using the population density of Step 2. We assume that the GB per month per pop does not vary across geotypes

– Gbps in the busy hour assuming 10% of traffic per day is in the busy hour

Step 4: We estimate total BTS in each country in the base year and project forward using observed growth rates to 2014. After that the number of base stations is driven by the model.

Step 5: For each geotype, we estimate the base stations per square kilometre over time. To distribute the base stations over the geotypes we assume that the ratio of BTS per pop between geotypes is the same as that used in the European 1.4GHz study. In particular we assume that the BTS per pop for rural areas is twice that in non-rural areas. This is consistent with the studies we have done elsewhere – e.g. South Africa.

Step 6: We calculate the traffic capacity per square kilometre for each geotype using:

– The number of base stations per square kilometre from Step 5

– Utilisation factors for the 12 Mbps end user experience

– Spectrum efficiency as for the European 1.4 GHz study

– The spectrum scenarios for each country

Step 7: We compare the traffic capacity per square kilometre from Step 6 with the traffic demand per square kilometre from Step 3. Note that we modelled downlink capacity only. This is the binding constraint

Step 8: Where demand is greater than network capacity, we add infrastructure for each geotype. There are two scenarios here:

– Scenario 1 in which there is no 1.4 GHz SDL and base stations are added

– Scenario 2 in which, initially, a 1.4 GHz SDL is deployed to expand capacity. So capacity is first increased by upgrading existing BTS with the 1.4 GHz SDL and then by adding additional base stations (with the 1.4 GHz SDL) until capacity matches traffic demand.

We count the number of new base stations and upgrades for each scenario up to 2020. After that date we assumed that operators will have access to other, more cost efficient, spectrum for increasing network capacity

Step 9: We calculate the net present cost of adding a base station under Scenario 1, of a 1.4 GHz SDL upgrade and of an additional BTS under Scenario 2

Step 10: We multiply the NPCs of Step 9 by the additional infrastructure required in Step 8 to get the additional infrastructure costs and then calculate the difference between the two scenarios. This is the avoided cost per square kilometre by geotype.

Step 11: We repeat Steps 2 to 10 for all geotypes and aggregate the cost savings to get the NPV of the avoided cost benefit for the country.

B.3 Improved quality of service benefits

Deploying a 1.4 GHz SDL leads to better in-building coverage and higher speeds in urban areas. This shifts the demand curve for mobile data upwards and to the right and generates significant additional economic benefits in terms of increased consumer surplus. The formula we have used to do estimate the quality of service benefits is:

0.5 x [NPV of costs of SDL deployment on existing BTS + Value of the 1.4 GHz spectrum]/**e**

The cost of SDL deployment comes from Steps 8 and 9 of the avoided cost mode. The values for e, the absolute elasticity of demand, and the spectrum values are derived in Appendix C.

However, estimates of consumer surplus are highly dependent on the assumed shape of the demand curve. The subsections below examine the cases of linear and constant elasticity demand curves and indicate that the proposed approach is conservative.

B.3.1 Linear demand curve

Figure B-2 shows a linear demand curve; although the demand curve is linear, elasticity varies along the curve. Elasticity is 1 in the middle of the curve, more elastic to the left of this and inelastic to the right. If the demand curve is defined as:

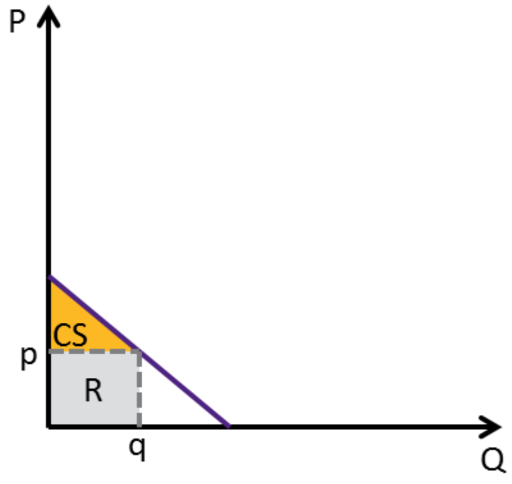
$$q = A - bp$$

Where q is quantity, p is price and A and b are constants. Consumer surplus (CS) is given by:

$$CS = \frac{q^2}{2b} = \frac{qp}{2e} = \frac{R}{2e}$$

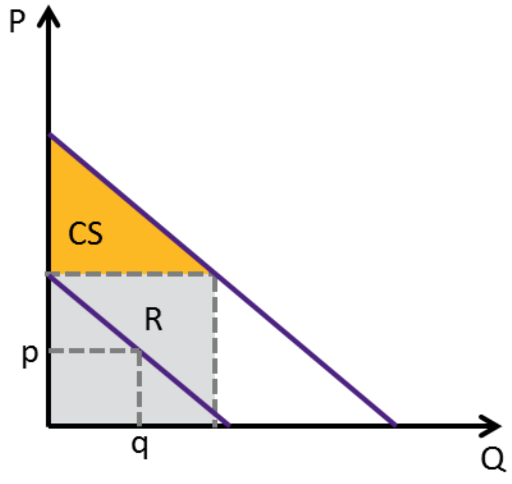
Where e is the absolute value of the price elasticity of demand and R is revenue.

Figure B-2: Linear demand curve



To estimate a change in consumer surplus you need to estimate the change in revenue and the change in elasticity. Figure B-3 and Figure B-4 illustrate how the elasticity assumption affects the size of the change in consumer surplus (for an assumed constant change in revenue).

Figure B-3: Same elasticity of demand



In Figure B-3 the elasticity is assumed to be the same as in Figure B-2, in this case the change in consumer surplus is given by:

$$\Delta CS = \frac{R_2}{2e_1} - \frac{R_1}{2e_1} = \frac{\Delta R}{2e_1}$$

Figure B-4: Same price

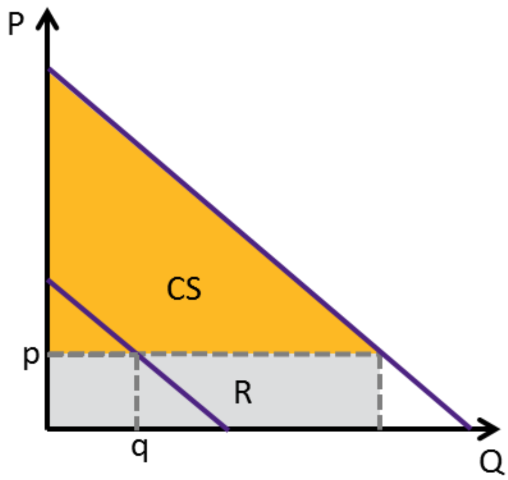


Figure B-4 illustrates an example in which the change in revenue is the same as in Figure B-3; however the elasticity is allowed to vary and the price is held constant. Here the outward shift in the demand curve means the elasticity (at the same price) falls. As demand increases the good is increasingly seen as a necessity and demand becomes inelastic. In this case the change in consumer surplus is given by:

$$\Delta CS = \frac{R_2}{2e_2} - \frac{R_1}{2e_1}$$

As e_2 is less than e_1 the change in consumer surplus is greater than in Figure B-3. An approximate estimate of the change in consumer surplus when $p_1 = p_2$ and Δq is small is given by the following formula:

$$\Delta CS = \frac{\Delta R}{e_1}$$

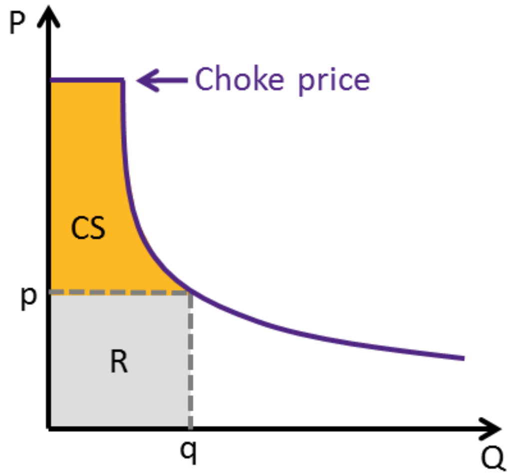
Therefore by assuming the elasticity is constant (as in Figure B-3) when the situation is in fact more like that in Figure B-4 the change in consumer surplus is underestimated. Arguably Figure B-4 better reflects the situation for mobile broadband where coverage and capacity enhancements are provided at little or no extra price.

B.3.2 Constant elasticity demand curve

Although the linear demand curve allows changes in consumer surplus to be easily calculated it may not be an accurate approximation of reality. There is also a risk that this assumption may result in overestimates of consumer surplus. This is because as the linear demand curve shifts out, the choke price (i.e. the price at which demand falls to zero) can increase unrealistically and result in significant increases in consumer surplus.

A constant elasticity demand curve, with specified choke price, as illustrated in Figure B-5, may give a more accurate reflection of demand.

Figure B-5: Constant elasticity demand curve



The equation for the consumer surplus with a constant elasticity demand curve and a choke price is[62]:

$$CS = R\left[\frac{1-\left(\frac{p_{choke}}{p_1}\right)^{-(e-1)}}{e-1}\right]$$

The change in consumer surplus can be derived as:

$$\Delta CS = CS_1\frac{\Delta R}{R_1}$$

And if we assume that the choke price is a fixed multiple of the current price, i.e. $p_{choke} = c.p_1$, then consumer surplus is as follows:

$$\Delta CS = \left[\frac{1-c^{-(e-1)}}{e-1}\right].\Delta R$$

If the elasticity is one, then:

$$\Delta CS = \ln(c).\Delta R$$

B.3.3 Implications for the MENA analysis

Table B-2 shows the change in consumer surplus, as a multiple of a change in revenue, for different assumptions about the demand curve. We show values for elasticities of -0.5 and -1 as these are used in our modelling. For the constant elasticity demand curve values for several ratios of the choke price to the current price, c, are shown.

[62] When the elasticity is one, the formula is $CS = R.\ln(\frac{p_{choke}}{p_1})$

We have not found any evidence on the size of the ratio of the choke price to the current price for mobile broadband services. Crandall et al (2002)[63] estimate that for broadband services in the US it is 3 times the current price. Although some individuals may be willing to pay many times the current price they will not be representative of the whole population. Therefore we propose testing the impact of a choke price of between 3 and 5 times the current price.

Table B-2: Change in consumer surplus under different assumptions

ΔCS			Elasticity, e	
			0.5	1
MENA analysis	Linear – constant elasticity assumed		ΔR	0.5ΔR
Demand curve	Linear – constant price		2ΔR	ΔR
	Constant elasticity	C=3	1.46ΔR	1.1ΔR
		C=5	2.5ΔR	1.6ΔR

The first line of the table shows the estimated change in consumer surplus for the approach used in this study. The other three rows give estimates based on other assumptions. As can be seen by comparing the results in the first row with those in the other three rows the approach we have taken is conservative under a reasonable set of assumptions.

[63] Robert Crandall, Robert Hahn and Timothy Tardiff (2002). The benefits of broadband and the effects of regulation. Chapter 13 in Robert Crandall and James Alleman (eds) Broadband: how should we regulate high-speed internet access? Washington, D.C.: Brookings Institution Press.

Appendix C: Modelling assumptions

The three classes of assumptions that are used in the modelling of the benefits of SDL deployment in this study are as follows:

- Common model assumptions are assumptions that are all country-level models share
- Regional model assumptions are those that are common across each of the two groups of countries – high-income and low-income
- Individual country's assumptions are assumptions that are specific to each study country

This appendix reports the first two sets of assumptions. Country specific assumptions and results are reported in Appendix D.

C.1 Common model assumptions

There are three main categories of assumptions that are shared by all individual country models: these are geotype classification assumptions, network and spectrum assumptions and infrastructure cost assumptions. Table C-1 shows the definition of each geotype in terms of the lower population density limit.

Table C-1: Definitions of geotypes for MENA region

Geotype label	Lower limit of population density per sq km
Dense urban	30,000
Urban 1	8,000
Urban 2	2,000
Suburban	200
Rural	0

The common, basic network and spectrum assumptions are stated in Table C-2. Values for parameters that directly affect the overall capacity in the network are identical to those in Plum's 2011 report for Ericsson and Qualcomm on the benefits of the 1.4 GHz band in Europe[64]. The only new variable introduced in this study is the year, after which operators stop their network build-out. This is taken to be 2014 to reflect the mobile companies' expectation of the release of significant chunks of new spectrum in the medium term, which will enable them to support a much higher level of traffic demand without the need for additional radio network equipment.

[64] http://www.plumconsulting.co.uk/pdfs/Plum_June2011_Benefits_of_1.4GHz_spectrum_for_multimedia_services.pdf

Table C-2: Network and spectrum assumptions

Parameter	Value used	Source
Percentage of traffic in busy hour	10%	Plum 2011 study for Ericsson and Qualcomm
Percentage of traffic in the downlink 2012 2015 2020 2025	 86% 89% 90% 90%	Plum 2011 study for Ericsson and Qualcomm
Percentage utilisation of capacity for reasonable quality of service for end user	60%	Plum 2011 study for Ericsson and Qualcomm
Sectors per BTS	3	
Spectrum efficiency (bps/Hz) 2010 - 2012 2012 - 2021 2022 and after	 0.35 0.35 – 1.25 1.25	Plum 2011 study for Ericsson and Qualcomm
Year on year change in spectrum efficiency between 2012 and 2022 (bps/Hz)	0.05	Plum's estimate
Downlink 1.4 GHz spectrum available for SDL (MHz)	40	Plum 2011 study for Ericsson and Qualcomm
Target user experience speed (Mbps)	12	Qualcomm
Final year of BTS volume growth	2014	Plum's estimate

Similarly, infrastructure costs in the current study are also assumed to be the same as those previously used in the modelling for Europe in Plum's study for Ericsson and Qualcomm.

Table C-3 show the values that have been used in the models for these input variables.

Table C-3: Infrastructure cost assumptions

Network cost type	Value used	Source
Annual discount rate	10%	Plum 2011 study for Ericsson and Qualcomm
CAPEX per band - cost of each set of antennas (€ '000)	30	Plum 2011 study for Ericsson and Qualcomm
CAPEX of SDL equipment (€ '000)	30	Plum 2011 study for Ericsson and Qualcomm
OPEX as % of CAPEX	12%	Plum 2011 study for Ericsson and Qualcomm
Site establishment cost (€ '000)	150	Plum 2011 study for Ericsson and Qualcomm
Site rental per year (€ '000)	30	Plum 2011 study for Ericsson and Qualcomm

C.2 Regional demand assumptions

Based on considerations of their social and economic characteristics, the seven study countries have been divided into two groups: high-income countries and low-income countries. The three countries in the high-income group are the Kingdom of Saudi Arabia (KSA), Qatar and the United Arab Emirates. The four remaining countries – Algeria, Egypt, Jordan and Morocco – belong to the low-income group.

The main distinctions are the future availability of spectrum in urban areas and the levels of mobile traffic to be assumed for the modelling period. We expect spectrum availability in urban areas to be more limited in low-income countries. In total, the KSA, Qatar and the UAE are expected to have between 70 MHz and 90 MHz more downlink spectrum for use in the provisioning of mobile broadband service in 2020, than Algeria, Egypt, Jordan and Morocco. Detailed spectrum allocations in each geotype for the study countries are tabulated in Appendix A.

For the high-income countries, forecasts of per-capita mobile traffic used in the calculation of additional capacity required mirror those implied by Cisco's 2012 VNI[65] numbers for Western Europe. Although, the estimates are derived from data for Western Europe, we have used these numbers since they are consistent with near-term traffic statistics[66] published by some operators in the study countries. In the case of the low-income countries, per-capita traffic estimated based on Cisco's 2012 VNI numbers for Central and Eastern Europe is used in the models. The main reason for the use of these projections is that these traffic levels are in line with the capacity that can be provided given the level of network investment in the countries.

Table C-4 and Table C-5 show the values of the forecasts for the modelling period.

Table C-4: Per-capita data usage in high-income study countries

Year	Monthly per-capita data consumption (GB/month)	Source
2012	0.9	Plum's estimate based on Cisco 2012 VNI numbers for Western Europe
2015	4.1	
2020	14.4	
2025	24.1	

Table C-5: Per-capita data usage in low-income study countries

Year	Monthly per-capita data consumption (GB/month)	Source
2012	0.2	Plum's estimate based on Cisco 2012 VNI for Central and Eastern Europe
2015	1.2	
2020	5.0	
2025	8.4	

65 http://www.cisco.com/en/US/solutions/collateral/ns341/ns525/ns537/ns705/ns827/white_paper_c11-520862.html

66 http://www.samenacouncil.org/samena_daily_news.php?news=25256

C.3 Value of 1.4 GHz spectrum

In Plum's previous study on the benefits of 1.4 GHz spectrum for Europe, spectrum value was estimated based on auction values and reserve prices. In particular the upper bound was based on our analysis of recent sub-1 GHz spectrum auctions while the lower bound was based on auctions for bands above 1 GHz[67].

For the seven MENA study countries we adopt a similar methodology to derive appropriate benchmark values for 1.4 GHz spectrum. There have been several spectrum auctions in MENA countries but quite a few are multi-band auctions and detailed results are not publicly available[68]. We have included MENA spectrum auctions where the data is available, but our analysis is based on auctions from 2003 onwards for frequency bands used for provision of mobile services[69].

As the MENA region is more diverse than Europe in terms of economic development and GDP per capita, we derive two sets of values – high income versus low and middle income countries[70] – to estimate the values of spectrum that will be used in our analysis. Table C-6 and Figure C-1 show the average values (US$/MHz/pop) in several frequency groupings for high and low/middle income countries[71]. In all we look at 93 auction data points consisting of 70 for high income countries and 23 for low/middle income countries.

Table C-6: Average auction results, 2003 onwards (US$/MHz/pop)

Frequency band	No. of data points in all countries	All countries	High income countries	Low/middle income countries
Sub-1 GHz	24	0.57	0.67	0.10(1)
Digital dividend	8	0.78	0.78	NA
Above-1 GHz	69	0.18	0.19	0.17
Above-1 GHz (excl 2.6 GHz)	40	0.27	0.34	0.19
2.6 GHz	29	0.05	0.06	0.02
All bands	93	0.28	0.32	0.16
All bands (excl 2.6 GHz)	64	0.39	0.49	0.17

Note: (1) only 4 data points.
Source: Plum Consulting, national regulators

[67] See Plum report http://www.plumconsulting.co.uk/pdfs/Plum_June2011_Benefits_of_1.4GHz_spectrum_for_multimedia_services.pdf

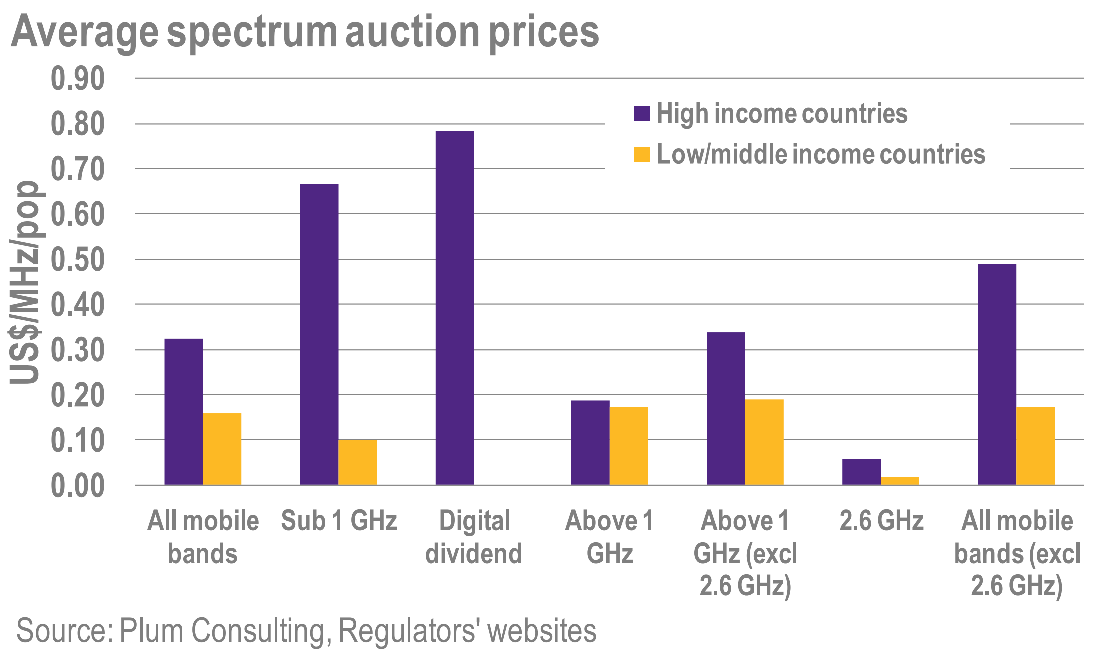
[68] E.g. the Saudi Arabia auction in March 2007 for 900 MHz, 1800 and 2100 MHz bands, and the Qatar auction in May 2008 for UHF, 900 MHz, 1800 MHz and 2100 MHz bands.

[69] These bands comprise 700 MHz, 800 MHz, 850 MHz, 900 MHz, 1800 MHz, 1900 MHz, 2100 MHz, AWS and 2600 MHz.

[70] The classification is based on World Bank's database http://data.worldbank.org/about/country-classifications/country-and-lending-groups#MENA

[71] High income countries are defined as those with GDP per capita of greater than USD PPP 25,000 at time of auction.

Figure C-1: Average spectrum value benchmarks



Before analysing the results, it is important to note effects that the 2.6 GHz auction results have on the averages in Table C-6. Firstly, the average value of 2.6 GHz spectrum is much lower (around 5 times) than other bands above 1 GHz and thus skews the overall averages downwards. Secondly, most of the 2.6 GHz auction results are from high income countries (27 out of 29) and thus skew the overall averages of high income countries downwards.

Given that the characteristics of the 1.4 GHz spectrum are closer to sub-1 GHz, 1800 MHz and 2.1 GHz bands compared to 2.6 GHz, we give more weight to the average values excluding 2.6 GHz in estimating value of 1.4 GHz for MENA countries. The following subsections examine in closer detail past auctions results from high income countries and low/middle income countries.

C.3.1 High income MENA countries

For 1.4 GHz spectrum in high income MENA countries, a high estimate would be somewhere in the region of $0.60/MHz/pop, similar to the sub-1 GHz average but lower than the average for the digital dividend spectrum in the 700/800 MHz bands. A low estimate would be $0.30/MHz/pop, similar to the above 1-GHz average excluding 2.6 GHz prices for reasons discussed above. A conservative estimate would be $0.40/MHz/pop, which is closer to the lower end of the range because:

- this is a new band for mobile multimedia services – equipment and handsets might not be as readily available as for other bands
- spectrum releases in the near future (between now and 2015) may allow operators to address their spectrum requirements earlier

Therefore the estimated value range for 1.4 GHz spectrum for high income MENA countries is $0.30-$0.60/MHz/pop with $0.40/MHz/pop as our recommended value.

C.3.2 Low/middle income MENA countries

For low/middle income countries we expect the value of spectrum in general to be lower than that of high income countries because of consumers' lower ability and willingness to pay for mobile services. This is reflected in the differences in average auction prices in Figure C-1.

Due to the smaller sample of low/middle income countries, the sub-1GHz average is not used as the high estimate for 1.4 GHz spectrum – there are only four data points and the average is lower than bands above-1 GHz. To derive the estimated value range we examine the auction data for low/middle income countries is greater detail in Table C-7.

Table C-7: Spectrum auctions in low/middle income countries

Country	Date	Band auctioned	Value/MHz/Pop (US$)
Jordan	Aug-09	2100	0.7800
Albania	Nov-10	2100	0.4555
Egypt	Jan-07	2100	0.4132
India	May-10	2100	0.3088
Macedonia	Jan-08	2100	0.2046
Brazil	Dec-10	2100	0.1926
Macedonia	Nov-08	2100	0.1773
Indonesia	Feb-06	2100	0.1417
Turkey	Nov-08	2100	0.1412
Latvia	Sep-10	900	0.1226
Chile	May-06	850	0.1020
Georgia	2008	2100	0.1004
Georgia	2007	900	0.0990
Mexico	Jul-10	AWS	0.0754
Kenya	2007	900	0.0726
Mexico	Jun-10	1900	0.0535
Nigeria	2006	1900	0.0534
Nigeria	Mar-07	2100	0.0521
Colombia	Aug-11	1900	0.0357
Kenya	2007	2100	0.0336
Chile	Sep-09	2100	0.0115
Average			0.1727

The range of values is very wide but if we exclude the Jordanian 2.1 GHz auction which is a clear outlier, a high estimate would be $0.40/MHz/pop and a low estimate would be around $0.10/MHz/pop.

For the same reasons described above we expect the conservative estimate to be closer to the lower end of the range. Therefore the estimated value range for 1.4 GHz spectrum for low/middle income MENA countries is $0.10-$0.40/MHz/pop with $0.20/MHz/pop as our recommended value.

C.4 Elasticity of demand for mobile broadband

To determine the consumer benefits from improved quality of service arising from SDL deployment at 1.4 GHz, we survey the literature on demand for telecommunications services. Most of the extant literature on demand has been on mobile services rather than mobile broadband. While the focus in this study is on mobile broadband, it is also important to recognise fixed-mobile substitution effects and that demand for mobile services is related the availability of substitutes in the country or region concerned.

Another important factor to consider is the different income and socio-demographic factors among the countries in the MENA region. The studies summarised below involve countries with varying levels of GDP. We have grouped them according to low and middle income countries (Table C-8) and high income countries (

Table C-9).

The price elasticity range for mobile services is quite wide as shown below. However price elasticity for low-middle income countries is generally higher compared to high income countries. We therefore use price elasticity values of -1.0 for the middle income MENA countries (Algeria, Egypt, Jordan, Morocco) and -0.5 for high income MENA countries (Qatar, Saudi Arabia, UAE) in our calculations of consumer benefits from improved quality of service.

Table C-8: Summary of literature for low-middle income countries

Authors	Countries	Price elasticity of demand for mobile services
Karacuka et al (2012)[72]	Turkey	-0.72 (post-paid) -0.33 (pre-paid)
Ward and Zheng (2012)[73]	China	-0.59 (1)
Gasmi et al. (2009) [74]	South Africa	-1.3 to -3.8 (voice) -1.2 to -3.2 (SMS)
Garbacz and Thompson Jr (2007) [75]	53 developing countries (GDP per capita below $8000 in year 2000)	- 1.25
Frontier Economics (2005)[76]	50 emerging markets	-0.54 (post-paid) -0.76 (pre-paid)
	21 Africa and Middle East countries (2)	-0.24 (post-paid) -0.89 (pre-paid)
Waverman et al (2005)[77]	102 low and middle income countries	-1.5

[72] Justus Haucap, Ulrich Heimeshoff and Mehmet Karauka (2011). Competition in Turkish mobile telecommunications markets: price elasticities and network substitution. Telecommunications Policy, 35, 202-210.

[73] Michael R Ward and Shilin Zheng (2012). Mobile and fixed substitution for telephone service in China. *Telecommunications Policy*, 36, 301-310.

[74] Farid Gasmi, Marc Ivaldi and Laura Recuero Virto (2009). An empirical analysis of cellular demand in South Africa. Toulouse School of Economics, Working Paper Series, 09-091. http://ideas.repec.org/p/cpr/ceprdp/7153.html

[75] Christopher Garbacz and Herbert G Thompson Jr (2007). Demand for telecommunication services in developing countries. *Telecommunication Policy*, 31, 276-289.

[76] GSMA Mobile Tax Report (2005) http://www.ictregulationtoolkit.org/en/Publication.3376.html

[77] Leonard Waverman, Meloria Meschi and Melvyn Fuss (2005). The Impact of Telecoms in Economic Growth in Developing Countries. Vodafone Public Policy Paper Series 2. http://www.vodafone.com/content/dam/vodafone/about/public_policy/policy_papers/public_policy_series_2.pdf

Table C-9: Summary of literature for high income countries

Authors	Countries	Price elasticity of demand for mobile services
Srinuan et al (2012)[78]	Sweden	-0.479 to -3.623 (mobile broadband) [(1)]
Hazlett and Munoz (2009)[79]	US	-1.12
Dewenter and Haucap (2008)[80]	Austria	-0.74 (business customers) -0.36 (consumers)
Cadman and Dineen (2008)[81]	28 OECD countries (mainly high income)	-0.43 (broadband) [(2)]
Hausman and Sidak (2007)[82]	Ireland	-0.84
Europe Economics (2006)[83]	UK	-0.3 to -0.47
Garbacz and Thompson Jr (2005)[84]	Developed countries	-0.5
Ida and Kuroda (2005)[85]	Japan	-0.564 to -0.783 (3G) -0.231 to -0.303 (2G)

Notes: (1) Price elasticity for mobile broadband higher in areas where 3 or 4 alternatives broadband options (e.g. DSL, cable, fibre) are available. Price elasticity for mobile broadband lower in rural areas where broadband infrastructures are underdeveloped. Mobile broadband considered a significant substitute for DSL in rural areas. (2) Long run elasticity.

[78] Pratompong Srinuan, Chalita Srinuan and Erik Bohlin (2012). Fixed and mobile broadband substitution in Sweden. *Telecommunications Policy*, 36, 237-251.

[79] Thomas Hazlett and Robert Munoz (2009). A welfare analysis of spectrum allocation policies. RAND Journal of Economics, 40(3), 424-454.

[80] Ralf Dewenter and Justus Haucap (2008). Demand elasticities for mobile telecommunications in Austria. *Jahrbucher fur Nationalokonomie und Statistik*, 228.

[81] Richard Cadman and Chris Dineen (2008). Price and income elasticity of demand for broadband subscriptions: a cross-sectional model of OECD countries. http://spcnetwork.eu/uploads/Broadband_Price_Elasticity.pdf

[82] Jerry A Hausman and J Gregory Sidak (2007). Evaluating Market Power Using Competitive Benchmark Prices Instead of the Herfindahl-Hirschman Index. http://papers.ssrn.com/sol3/papers.cfm?abstract_id=971114

[83] Europe Economics (2006). Economic impact of the use of radio spectrum in the UK. http://stakeholders.ofcom.org.uk/binaries/research/spectrum-research/economic_impact.pdf

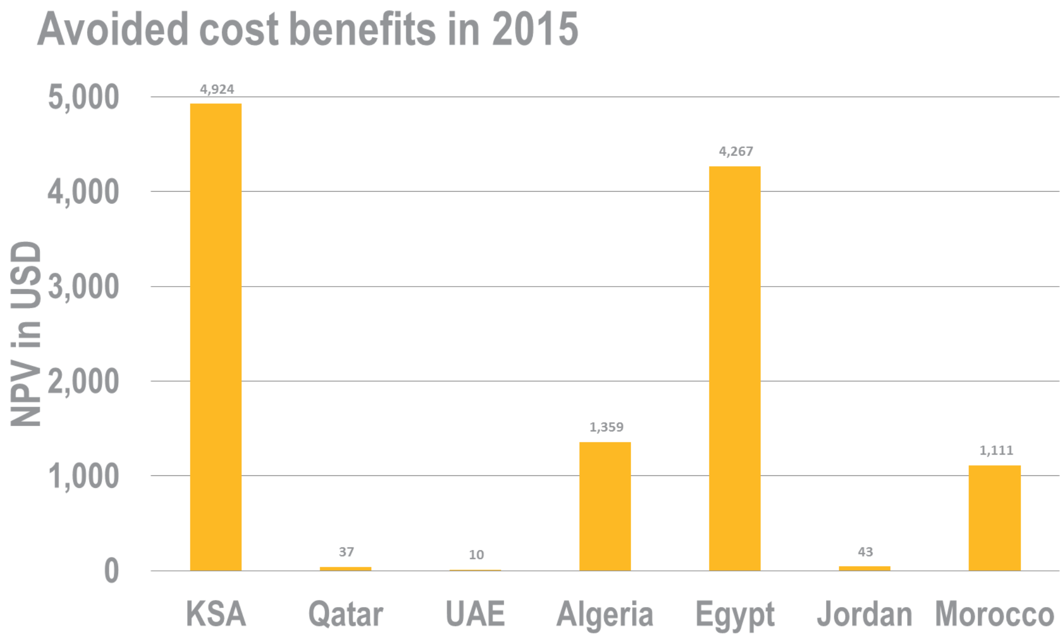
[84] Christopher Garbacz and Herbert G Thompson Jr (2005). Universal telecommunication service: a world perspective. *Information Economics and Policy*, 17, 495-512.

[85] Takanori Ida and Toshifumi Kuroda (2005). Discrete choice model analysis of mobile telephone service demand in Japan. Kyoto University. http://www.kier.kyoto-u.ac.jp/coe21/dp/81-90/21COE-DP090.pdf

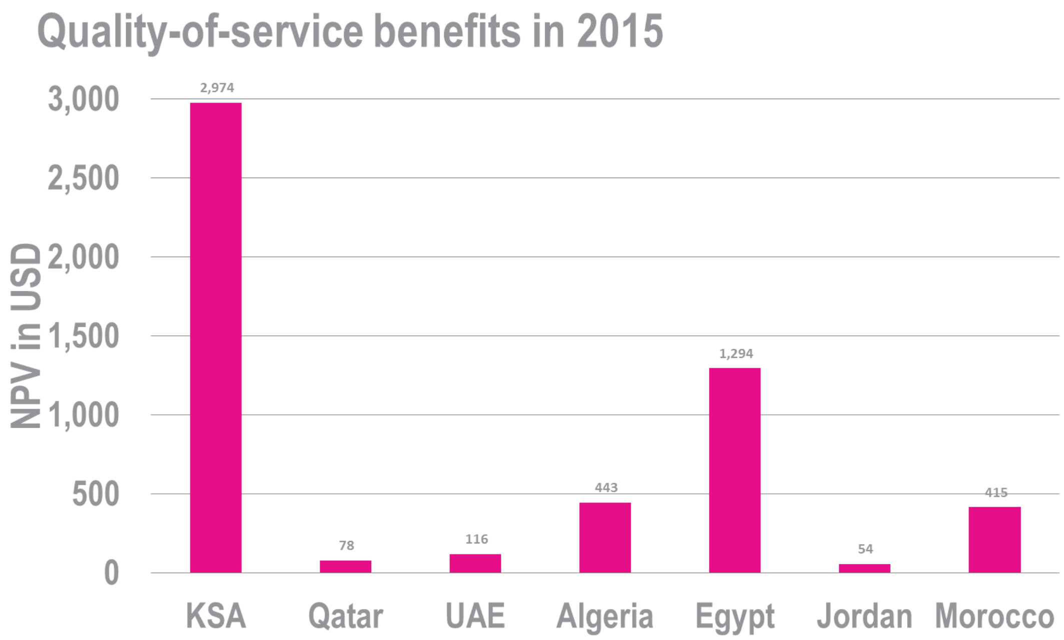
Appendix D: Country specific assumptions and results

D.1 Aggregate results

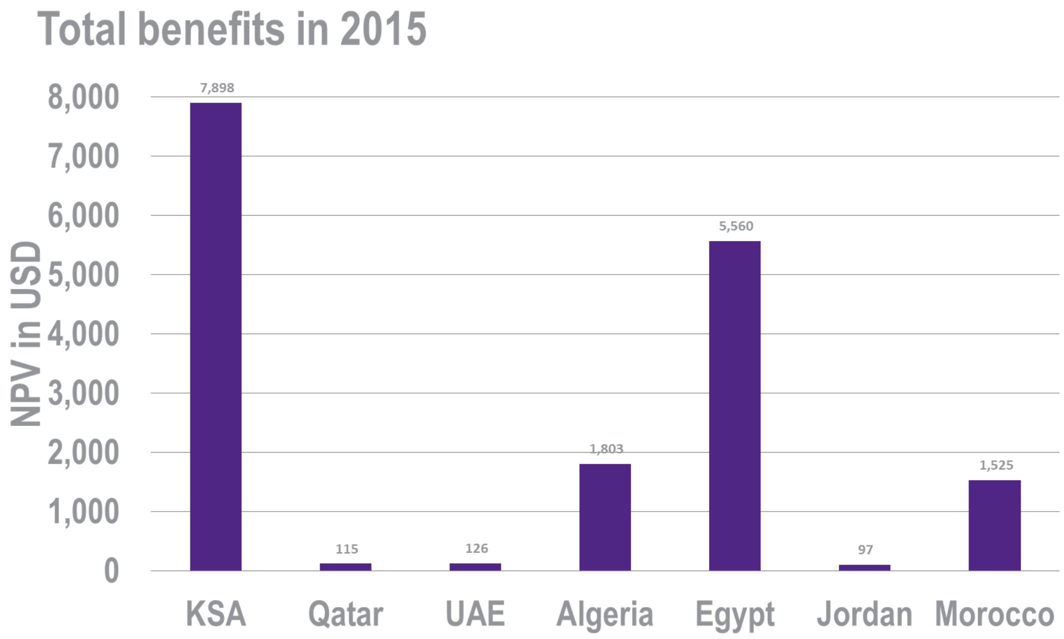
The following graphics show the total avoided costs, consumer surplus and total benefits by country. Detailed country assumptions and estimates are given in the sections below.



Source: Plum Consulting



Source: Plum Consulting



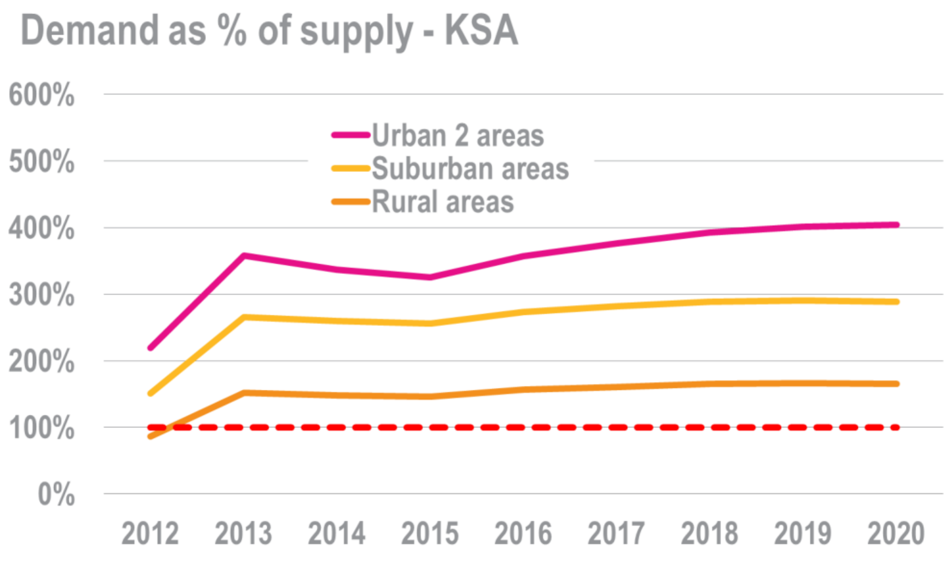
Source: Plum Consulting

D.2 Kingdom of Saudi Arabia

Table D-1: Population density and network assumptions for KSA

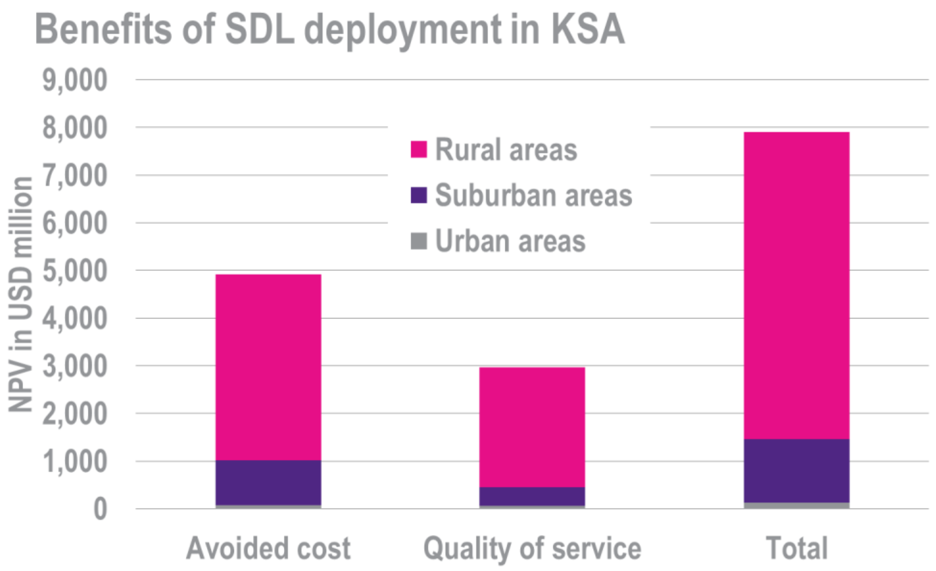
Parameter	Value used	Source
Population under mobile coverage in 2012 (million)	28.9	Plum's estimate based on Gridded Population of the World and ITU
Population growth rate per annum	2%	Plum's estimate
Total land area ('000 sq km)	2,000	Gridded Population of the World
Number of operators	3	Wireless Intelligence
Number of BTS in 2011	29,300	Plum's estimate based on ABI Research and Wireless Intelligence data
Annual growth rate of BTS volume (up to 2014)	4.8%	ABI Research

Figure D-1: Spectrum shortfall results in different geotypes in KSA



Source: Plum Consulting

Figure D-2: Breakdown of Benefits from SDL deployment in KSA



Source: Plum Consulting

Table D-2: Inputs for calculation of benefits of SDL deployment for KSA

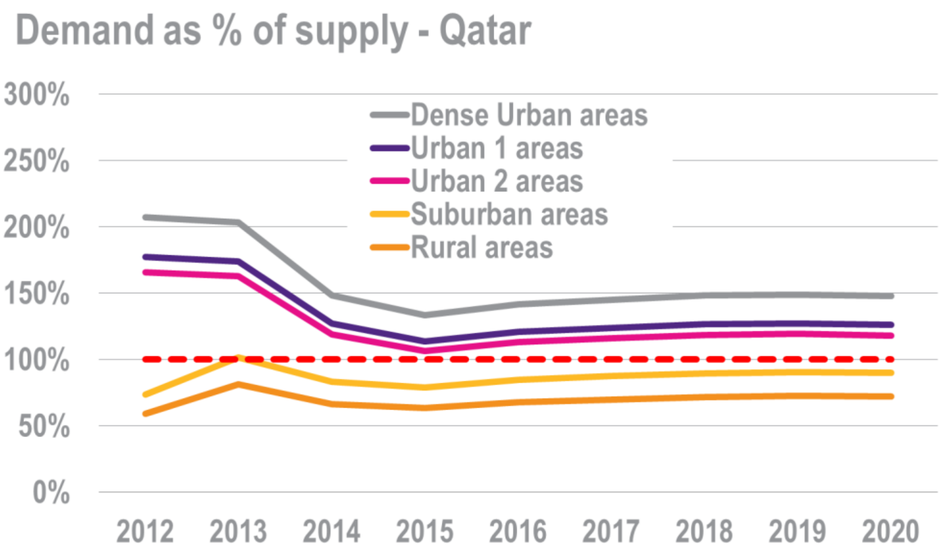
Input variable	Value used	Source
Spectrum value/MHz/pop (USD)	0.4	Plum's estimates based on auction values in the region
Spectrum value (USD m)	448	Plum's calculation
Net present cost of SDL deployment (USD m) Urban Suburban Rural	 39 301 2,185	Plum's calculation

D.3 Qatar

Table D-3: Population density and network assumptions for Qatar

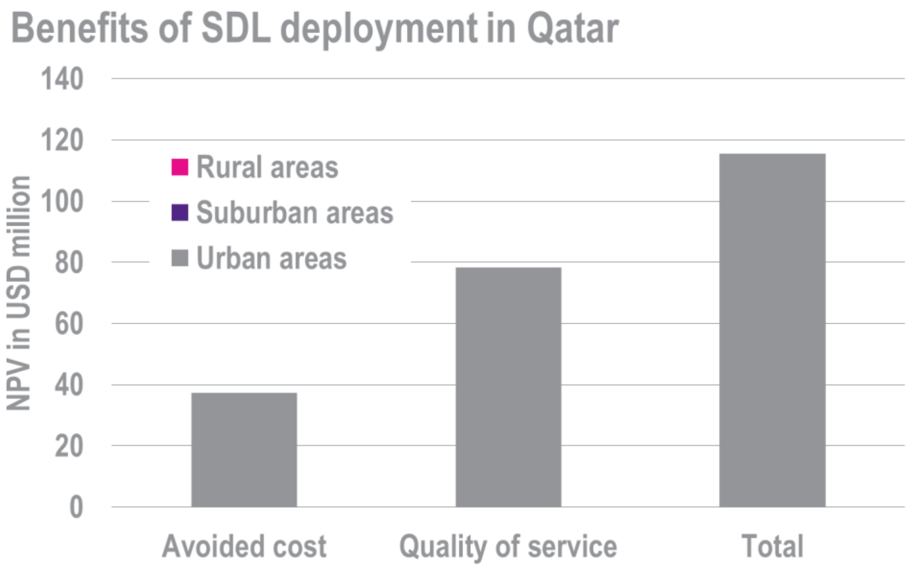
Parameter	Value used	Source
Population under mobile coverage in 2012 (million)	1.8	Plum's estimate based on Gridded Population of the World and ITU
Population growth rate per annum	2%	Plum's estimate
Total land area ('000 sq km)	12	Gridded Population of the World
Number of operators	2	Wireless Intelligence
Number of BTS in 2011	1,400	Plum's estimate based on ABI Research and Wireless Intelligence data
Annual growth rate of BTS volume (up to 2014)	17%	ABI Research

Figure D-3: Spectrum shortfall results in different geotypes in Qatar



Source: Plum Consulting

Figure D-4: Breakdown of Benefits from SDL deployment in Qatar



Source: Plum Consulting

Table D-4: Inputs for calculation of benefits of SDL deployment for Qatar

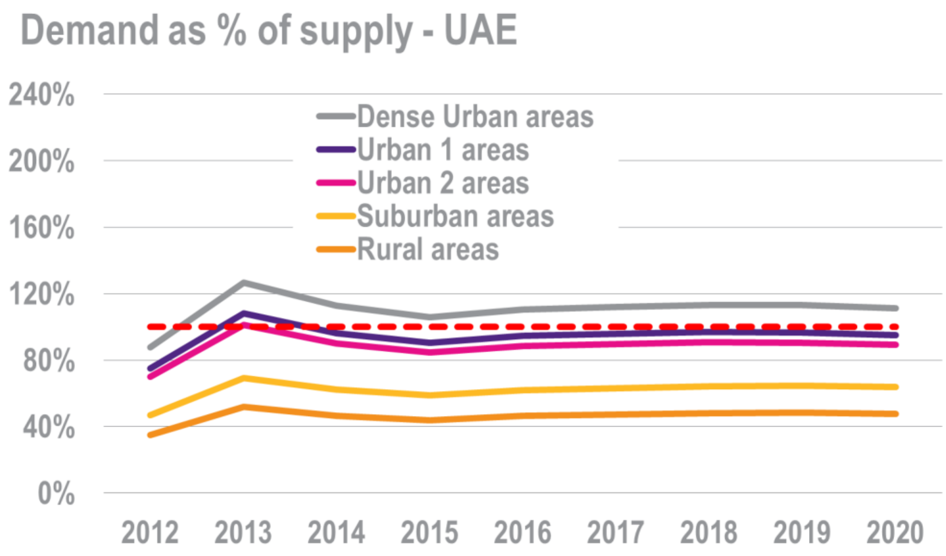
Input variable	Value used	Source
Spectrum value/MHz/pop (USD)	0.4	Plum's estimates based on auction values in the region
Spectrum value (USD m)	27	Plum's calculation
Net present cost of SDL deployment (USD m) Urban Suburban Rural	 51 0 0	 Plum's calculation

D.4 United Arab Emirates

Table D-5: Population density and network assumptions for the UAE

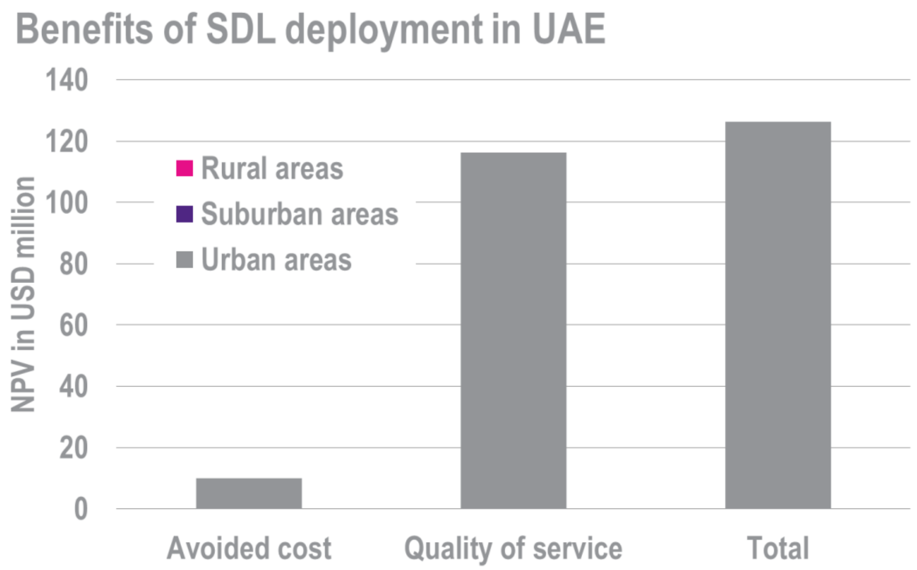
Parameter	Value used	Source
Population under mobile coverage in 2012 (million)	6.5	Plum's estimate based on Gridded Population of the World and ITU
Population growth rate per annum	2%	Plum's estimate
Total land area ('000 sq km)	78	Gridded Population of the World
Number of operators	2	Wireless Intelligence
Number of BTS in 2011	9,000	Plum's estimate based on ABI Research and Wireless Intelligence data
Annual growth rate of BTS volume (up to 2014)	5.8%	ABI Research

Figure D-5: Spectrum shortfall results in different geotypes in UAE



Source: Plum Consulting

Figure D-6: Breakdown of Benefits from SDL deployment in UAE



Source: Plum Consulting

Table D-6: Inputs for calculation of benefits of SDL deployment for the UAE

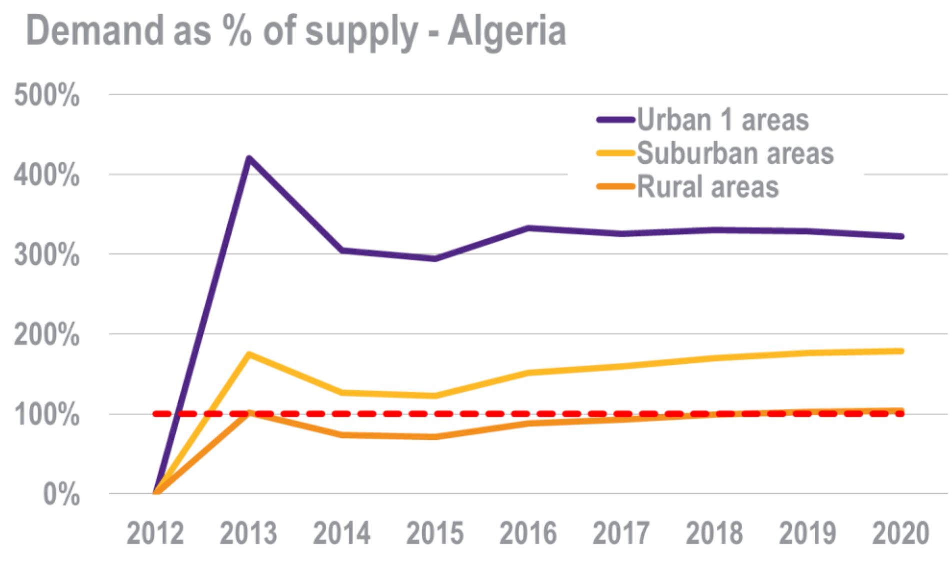
Input variable	Value used	Source
Spectrum value/MHz/pop (USD)	0.4	Plum's estimates based on auction values in the region
Spectrum value (USD m)	100	Plum's calculation
Net present cost of SDL deployment (USD m) Urban Suburban Rural	 16 0 0	 Plum's calculation

D.5 Algeria

Table D-7: Population density and network assumptions for Algeria

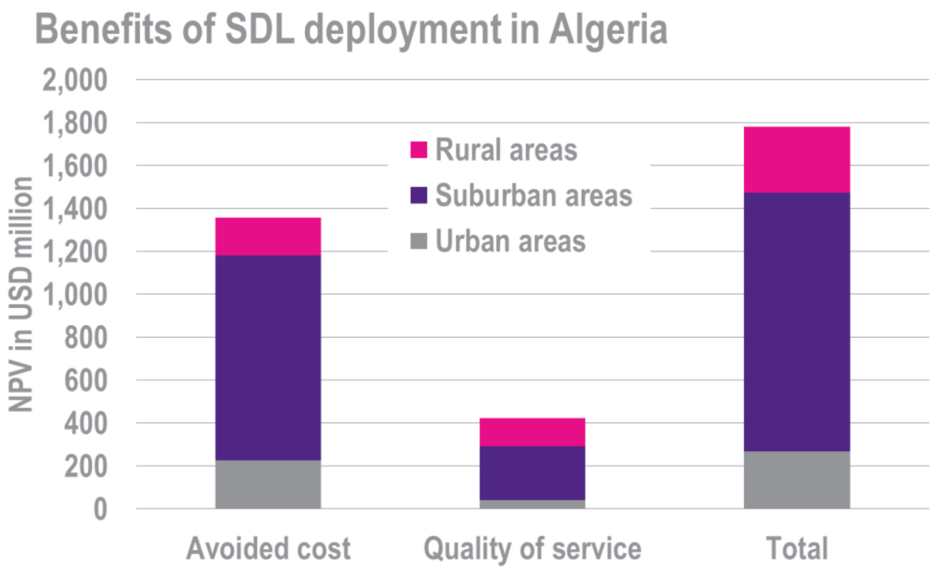
Parameter	Value used	Source
Population under mobile coverage in 2012 (million)	30.2	Plum's estimate based on Gridded Population of the World and ITU
Population growth rate per annum	2%	Plum's estimate
Total land area ('000 sq km)	2,317	Gridded Population of the World
Number of operators	3	Wireless Intelligence
Number of BTS in 2011	15,883	Plum's estimate based on ABI Research and Wireless Intelligence data
Annual growth rate of BTS volume (up to 2014)	3.7%	ABI Research

Figure D-7: Spectrum shortfall results in different geotypes in Algeria



Source: Plum Consulting

Figure D-8: Breakdown of Benefits from SDL deployment in Algeria



Source: Plum Consulting

Table D-8: Inputs for calculation of benefits of SDL deployment for Qatar

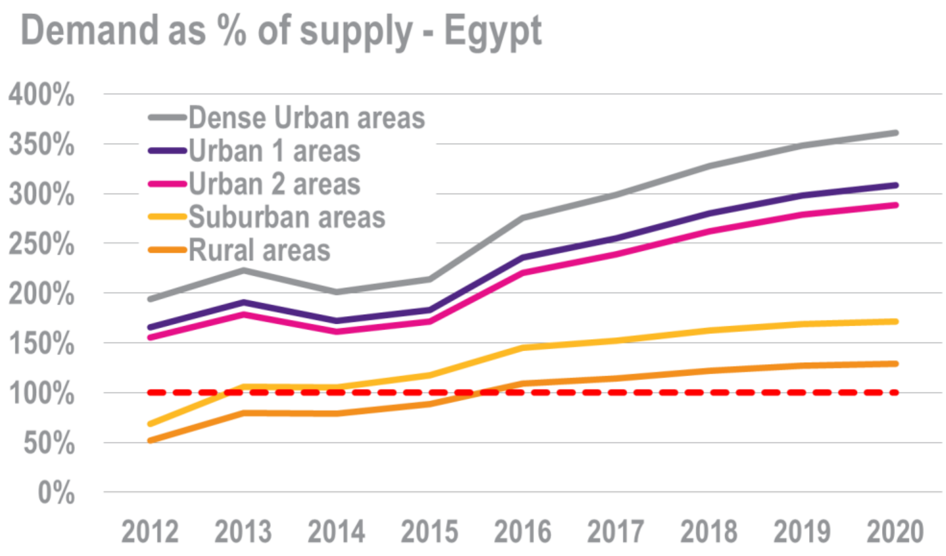
Input variable	Value used	Source
Spectrum value/MHz/pop (USD)	0.2	Plum's estimates based on auction values in the region
Spectrum value (USD m)	285	Plum's calculation
Net present cost of SDL deployment (USD m) Urban Suburban Rural	 57 418 127	 Plum's calculation

D.6 Egypt

Table D-9: Population density and network assumptions for Egypt

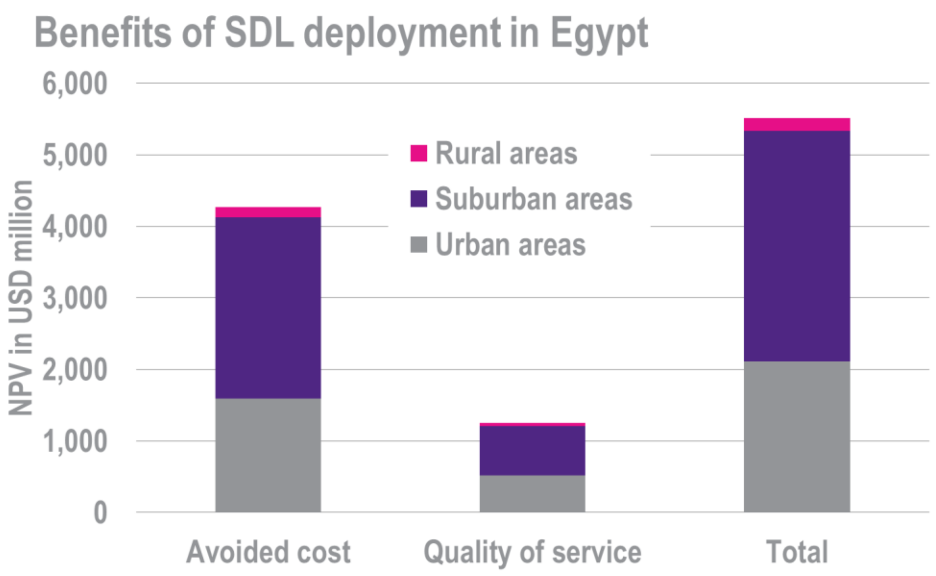
Parameter	Value used	Source
Population under mobile coverage in 2012 (million)	81.8	Plum's estimate based on Gridded Population of the World and ITU
Population growth rate per annum	2%	Plum's estimate
Total land area ('000 sq km)	980	Gridded Population of the World
Number of operators	3	Wireless Intelligence
Number of BTS in 2011	22,945	Plum's estimate based on ABI Research and Wireless Intelligence data
Annual growth rate of BTS volume (up to 2014)	5.9%	ABI Research

Figure D-9: Spectrum shortfall results in different geotypes in Egypt



Source: Plum Consulting

Figure D-10: Breakdown of Benefits from SDL deployment in Egypt



Source: Plum Consulting

Table D-10: Inputs for calculation of benefits of SDL deployment for Egypt

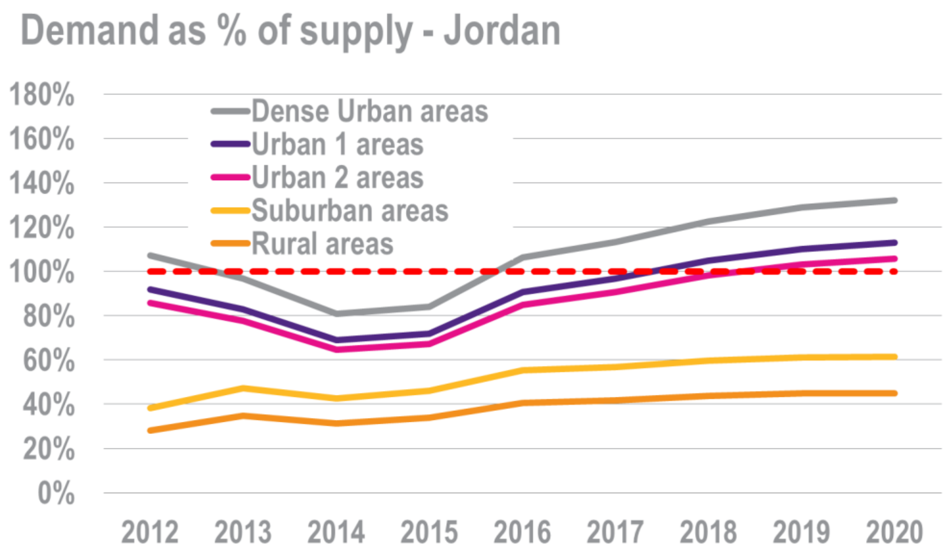
Input variable	Value used	Source
Spectrum value/MHz/pop (USD)	0.2	Plum's estimates based on auction values in the region
Spectrum value (USD m)	632	Plum's calculation
Net present cost of SDL deployment (USD m) Urban Suburban Rural	 727 1,162 85	Plum's calculation

D.7 Jordan

Table D-11: Population density and network assumptions for Jordan

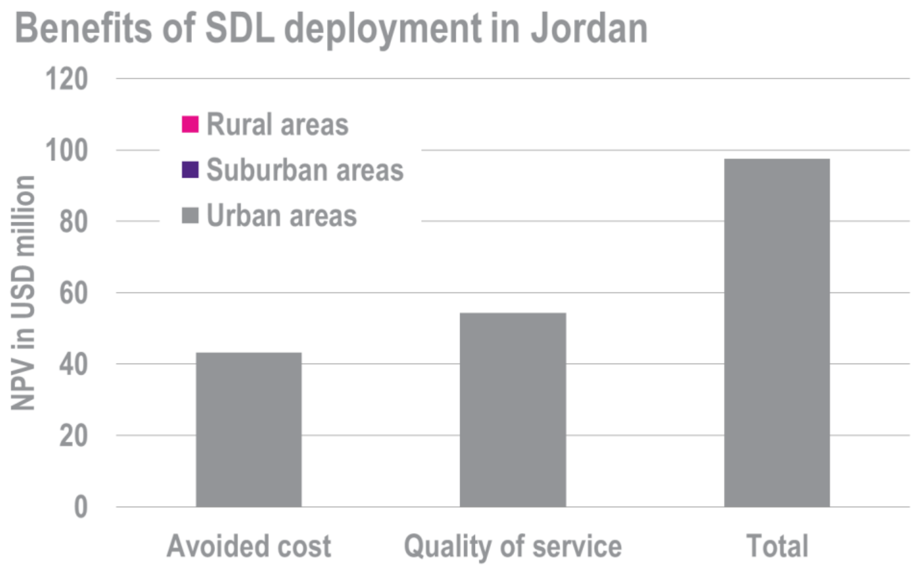
Parameter	Value used	Source
Population under mobile coverage in 2012 (million)	6	Plum's estimate based on Gridded Population of the World and ITU
Population growth rate per annum	2%	Plum's estimate
Total land area ('000 sq km)	90	Gridded Population of the World
Number of operators	3	Wireless Intelligence
Number of BTS in 2011	4,600	Plum's estimate based on ABI Research and Wireless Intelligence data
Annual growth rate of BTS volume (up to 2014)	8.9%	ABI Research

Figure D-11: Spectrum shortfall results in different geotypes in Jordan



Source: Plum Consulting

Figure D-12: Breakdown of Benefits from SDL deployment in Jordan



Source: Plum Consulting

Table D-12: Inputs for calculation of benefits of SDL deployment for Jordan

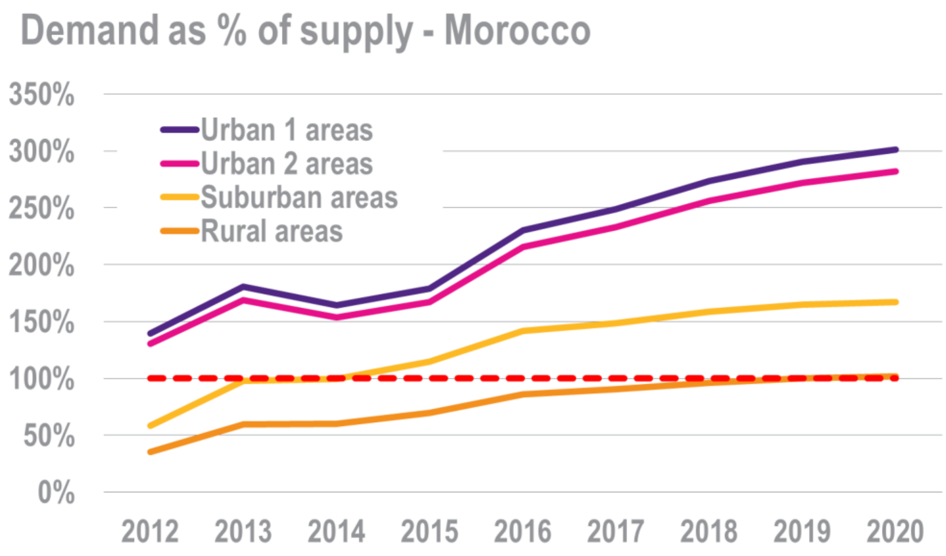
Input variable	Value used	Source
Spectrum value/MHz/pop (USD)	0.2	Plum's estimates based on auction values in the region
Spectrum value (USD m)	51	Plum's calculation
Net present cost of SDL deployment (USD m) Urban Suburban Rural	 57 0 0	Plum's calculation

D.8 Morocco

Table D-13: Population density and network assumptions for Morocco

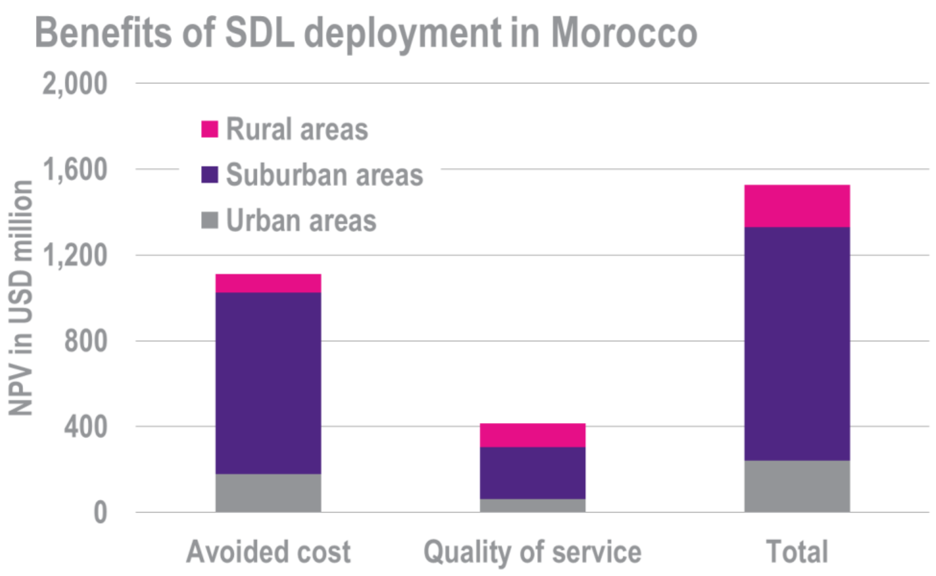
Parameter	Value used	Source
Population under mobile coverage in 2012 (million)	36.1	Plum's estimate based on Gridded Population of the World and ITU
Population growth rate per annum	2%	Plum's estimate
Total land area ('000 sq km)	673	Gridded Population of the World
Number of operators	3	Wireless Intelligence
Number of BTS in 2011	17,275	Plum's estimate based on ABI Research and Wireless Intelligence data
Annual growth rate of BTS volume (up to 2014)	10%	ABI Research

Figure D-13: Spectrum shortfall results in different geotypes in Morocco



Source: Plum Consulting

Figure D-14: Breakdown of Benefits from SDL deployment in Morocco



Source: Plum Consulting

Table D-14: Inputs for calculation of benefits of SDL deployment for Morocco

Input variable	Value used	Source
Spectrum value/MHz/pop (USD)	0.2	Plum's estimates based on auction values in the region
Spectrum value (USD m)	282	Plum's calculation
Net present cost of SDL deployment (USD m) Urban Suburban Rural	 86 398 62	 Plum's calculation