Economic benefits from making the 2.7–2.9GHz band available for mobile broadband services in Kenya

Report for the GSM Association

Final report

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Aetha Consulting Limited
Terrington House
13–15 Hills Road
Cambridge
CB2 1NL
United Kingdom

Phone: +44 (0)1223 755 575
Fax: +44 (0)20 7183 3716
Email: enquiries@aethaconsulting.com
www.aethaconsulting.com

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0 Executive summary

This report has been prepared by Aetha Consulting Limited (Aetha) for the GSM Association (GSMA) to assess the possible economic benefits that could arise from making the 2.7–2.9GHz band available for mobile broadband services in Kenya.

The availability of spectrum has become a key issue in tackling the forecast rise in global mobile data traffic, which is expected to create significant capacity constraints on mobile networks in the coming years. Part of the solution to this problem is to make more spectrum available to mobile network operators (MNOs). In this report, we examine the economic benefits of making the 2.7–2.9GHz band available to mobile services in Kenya.

We have calculated the economic benefits by considering two scenarios; one in which mobile operators have access to the 2.7–2.9GHz band and one in which they do not. The economic benefits can then be calculated by examining the cost differences between both scenarios and the resulting consumer benefits, utilising a similar approach to Aetha's previous report for the GSMA focusing on the benefits of the 2.7–2.9GHz band in Western Europe.[1]

By making the 2.7–2.9GHz band available for mobile services, it will be possible to avoid deploying a significant number of incremental mobile base station sites. When assessing the relevant cost savings accruing to mobile operators and considering the resulting benefits for consumers in Kenya (in terms of better service offerings and lower prices for mobile data services) over a 20–year period, this translates into economic benefits of approximately **USD770 million**. Whilst we have not evaluated the cost of moving existing services in detail, we understand that the 2.7–2.9GHz band is not being used extensively in Kenya and have estimated the resulting cost of moving existing users to be an order of magnitude below the value attributed to a use of the band by mobile services. This highlights the economic value of making the 2.7–2.9GHz band available to mobile services.

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1 *'Economic benefits from making the 2.7–2.9GHz band available for mobile broadband services in Western Europe'*, Aetha Consulting study for the GSM Association, 4 June 2013.

1 Introduction

The rapid take-up and usage of mobile broadband services is expected to continue with the introduction of LTE mobile technology. The challenge faced by mobile network operators (MNOs) is to provide sufficient network capacity to support this, at times, exponential growth in demand for mobile data services. For example, the latest Cisco VNI network forecast[2] suggests that mobile data traffic in the Middle East and Africa region will grow from 106PB per month in 2013 to 1490PB per month by 2018. This implies a compound annual growth rate of about 70%.

A key part of the solution is to identify new spectrum bands which can be used for mobile data services. As a result of this growing demand for spectrum for mobile services, one of the main agenda items at the next World Radiocommunications Conference (WRC-15) is to consider such new spectrum bands for mobile services.

A pilot inventory of spectrum use[3] undertaken on behalf of the European Commission identified the 2.7–2.9GHz band to be underutilised in many European Union countries. This band is also in close proximity to the existing 2500–2690MHz band, which has already been assigned to mobile operators in many countries across the world.

For these reasons, the GSMA considers the 2.7–2.9GHz band a potential candidate that can help provide the network capacity required to meet future traffic demand and wishes to better understand the economic case for making this spectrum available for mobile broadband services.

The objective of this study is, therefore, to develop an initial estimation of the economic benefits that would arise in Kenya as a result of making the 2.7–2.9GHz band available for mobile broadband services.

The remainder of this document is structured as follows:

- Section 2 provides an overview of our approach and the key assumptions used in our assessment
- Section 3 provides the results of our assessment and illustrates the impact of relevant sensitivities
- Section 4 summarises our conclusions
- Annex A provides a detailed explanation of the approach used for our economic assessment.

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2 '*Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2013-2018*', Cisco, 5 February 2014.

3 '*Inventory and review of spectrum use: Assessment of the EU potential for improving spectral efficiency*', WIK-Consult study for the European Commission, 11 September 2012.

2 Approach to the assessment of economic benefits

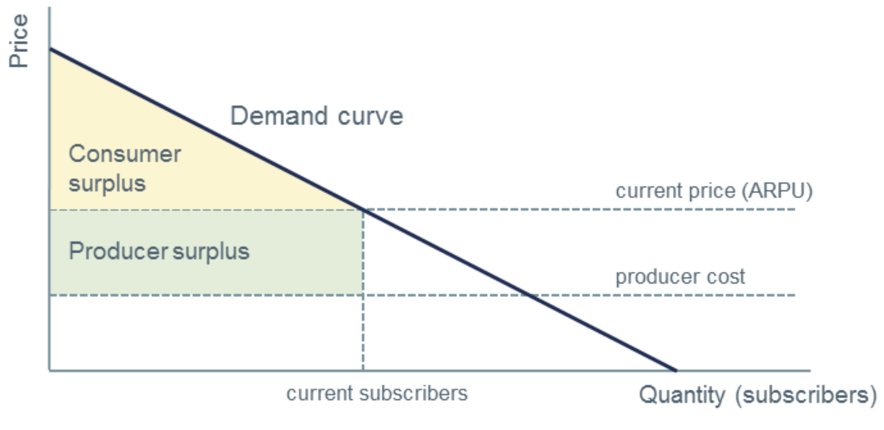
In this section, we provide an overview of the approach taken in our study to investigate the economic benefits of making the 2.7–2.9GHz band available for mobile broadband services in Kenya. Our approach estimates the benefits to consumers and producers which are derived from the availability of incremental spectrum. Our model calculates the cost savings, from access to additional spectrum, for a generic MNO in Kenya by considering the difference in network costs for this MNO between a scenario in which the 2.7–2.9GHz band is not made available for mobile use and a scenario in which the band is made available for mobile use. We then consider the impact when (part of) these cost savings are passed on to consumers, as a result of a competitive mobile market.

In general, this study applies the same principals and key assumptions as used in a previously published report for the GSMA[4] (based on a typical Western European country). However, a detailed analysis of the cost of moving existing users in the band (e.g. civilian Air Traffic Control (ATC) radars, military ATC radars or meteorological radars) is beyond the scope of this study. We have, therefore, only made a high-level indicative estimate of such costs, this is discussed in Section 4.

2.1 Approach to estimating benefits of making 2.7–2.9GHz available for mobile use

In our analysis, we estimate the economic benefits of the 2.7–2.9GHz band by assessing the changes in consumer and producer surplus resulting from an allocation of the band to mobile services. The concepts of producer and consumer surplus are illustrated in Figure 2-1 below.

Figure 2-1: Illustration of consumer and producer surplus [Source: Aetha]



If the 2.7–2.9GHz band were to be made available to MNOs, this would allow MNOs to carry more traffic on their sites. This would, therefore, decrease the need for new sites to be built in order to cope with increasing traffic levels. The availability of additional spectrum thus leads to cost savings for each MNO, as it has to build and operate fewer sites and, in addition, it can deploy the newly available spectrum at

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4 *'Economic benefits from making the 2.7–2.9GHz band available for mobile broadband services in Western Europe'*, Aetha Consulting study for the GSM Association, 4 June 2013.

comparatively lower costs on existing sites. This results in a reduction in producer costs. If current prices remained unchanged, the profit earned by the producer of the service would increase from access to additional spectrum.

However, in a competitive market, MNOs are incentivised to lower their prices in line with these cost savings in order to retain market share. We therefore assume that the realised cost savings are passed on to consumers, thereby transferring the gain in producer surplus.

The demand curve in Figure 2-1 represents the number of subscribers willing to buy mobile services at the corresponding price. The consumer surplus is approximated by the area between the demand curve and the current price of the service (which is equivalent to the current ARPU). In a scenario where more spectrum is made available, MNOs realise cost savings and these are passed on to consumers. This reduces prices in the market, thereby increasing the penetration of mobile services. The resulting difference in consumer surplus between the scenarios with and without the 2.7–2.9GHz band represents the total economic benefits of the 2.7–2.9GHz band to mobile broadband services in Kenya.

Our approach to calculating the network savings and the resulting impact on consumer surplus is discussed in more detail in Annex A.

2.2 Main modelling assumptions

In order to estimate the cost savings to mobile operators, we have developed a model that estimates the number of network elements (sites, base stations, carriers) required in different scenarios and derives the resulting network costs and associated savings from access to more spectrum. The model is based on a set of input parameters which were provided to us by the GSMA, or have been gathered internally by Aetha based on our previous project experience. In this section, we focus our discussion of the model assumptions on four key inputs which critically affect the network costs of an MNO and which are, therefore, highly relevant to calculating the estimated economic benefits of the 2.7–2.9GHz band:

- the amount of spectrum available to the generic MNO
- future traffic levels
- the unit costs of constructing and operating base stations
- the key assumptions regarding our analysis of consumer surplus.

2.2.1 Spectrum availability

The capacity of a base station site is directly related to the amount of spectrum available to the operator. Effectively, the greater the amount of spectrum an operator has available, the higher the capacity per site. This allows the operator to serve more data traffic on its existing site grid and reduces the need for new sites. Therefore, the amount of spectrum available to the generic operator is an important assumption in our model.

Within our model, we have considered both currently available bands and bands which are likely to be made available to operators in the future. We have assumed that the spectrum in these bands would be available for mobile data services (especially for LTE use) by 2021, at which point the 2.7–2.9GHz band would become available.

LTE is typically deployed in carrier sizes which are multiples of 5MHz (or 2×5MHz in the case of paired spectrum) and, today, regulators mostly make spectrum available to operators in this form. Within our model, we have estimated the cost savings for a generic operator in Kenya. We have modelled the Kenyan mobile market to have four operators, based on data from the Communications Authority of Kenya (CA) which shows that there is currently one key operator with 68% market share and another three operators with the remaining 32%.[5] We estimate the generic MNO to have access to about 1400 sites[6], and approximately a quarter of the spectrum in each band. The bands we have assumed to be available to the operator, along with the total amount of spectrum available to it are shown below in Figure 2-2.

Figure 2-2: Current and future spectrum available to generic operator [Source: Aetha]

Band	Current total spectrum available for mobile (MHz)	Expected additional future spectrum available for mobile (MHz)	Spectrum assigned to generic operator (MHz)
700MHz (paired)	-	60	20[7]
800MHz (paired)	-	60	10[7]
900MHz (paired)	70	-	20
1400MHz (supplementary downlink)	-	40	10
1800MHz (paired)	80	-	20
2.1GHz (paired)	60	-	10
2.3GHz (unpaired)	-	100	25
2.6GHz (paired)	-	140	30
2.6GHz (unpaired)	-	40	10
Total (excluding 2.7–2.9GHz)	210	440	155 (~24% of total spectrum)
2.7–2.9GHz (paired)	-	180	40
Total (including 2.7–2.9GHz)	210	620	195 (~23% of total spectrum)

As can be seen in Figure 2-2, in the scenario with the 2.7–2.9GHz band made available for mobile services the generic operator would have an additional 40MHz (2×20MHz) of paired spectrum available. We have assumed that 180MHz, of the 200MHz in the band, would be available for mobile use with the remainder being required for guard bands at the top and bottom of the band (in particular at the top of the band in order to prevent interference to and from radars operating above the band) and to create a duplex gap between the uplink and downlink parts of the band.

Another band that has not been included, but could potentially be available to MNOs is the 3.5GHz band. This would give mobile operators access to an additional 200MHz of unpaired spectrum. However, as the 2.7–2.9GHz band has better propagation properties, due to the lower frequency range it is based on, and is also adjacent to the 2.6GHz band, potentially leading to better equipment availability, it is unlikely that the 3.5GHz band would be used in preference. Hence, this band has only been included as a sensitivity to our results and is discussed further in Section 3.2.

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5 *'Quarterly Sector Statistics Report, Third Quarter of the Financial Year 2013/14'*, CA, March 2014

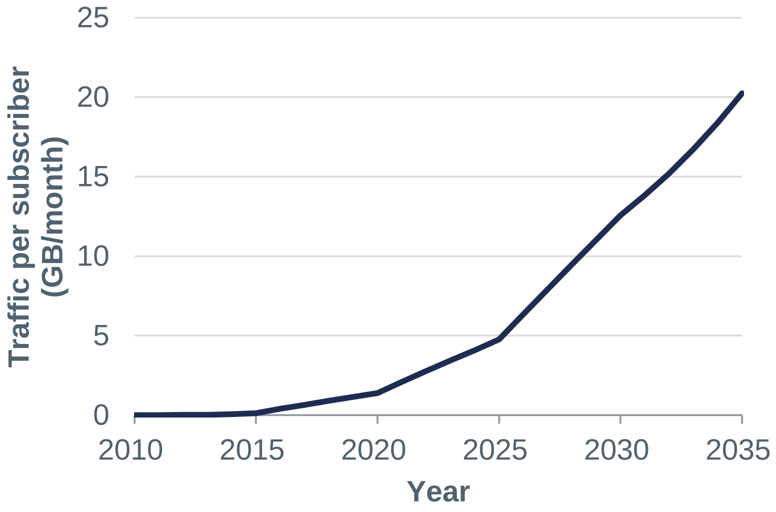
6 Estimate based on site data provided to us by the GSMA.

7 Across the 700MHz and 800MHz band, we expect the generic operator to have access to a total of 2×15MHz of low-frequency spectrum.

2.2.2 Future traffic forecast

One of the main drivers of future spectrum demand is the growing consumption of mobile data, which is expected to continue increasing in the future. In our model, we forecast the average data traffic per SIM in the Kenyan market up to 2035. Naturally, there is a large degree of uncertainty associated with such a forecast. However, in order to achieve consistency within our work, we have based our forecast on the model developed in our previous report.[8] Our previous forecast was based on data from the ITU[9] and the UMTS Forum.[10] To arrive at a forecast for Kenya, we have developed a model which assumes that, whilst the general long-term trend between countries is similar, countries are at different positions on the growth curve. In other words, we have assumed the annual growth in monthly data consumption per SIM in Kenya to follow that of a typical Western European country, albeit trailing by a constant number of years based on present-day usage levels.[11] The forecast growth is shown below in Figure 2-3 and is used in our model to determine if additional capacity (i.e. extra base stations) is required to meet future data demands. A more detailed explanation of our model logic can be found in Annex A.

Figure 2-3: Traffic forecast per SIM for generic Kenyan operator [Source: Aetha]



As the forecast traffic demand is a key assumption to our model and an important driver of spectrum demand, we have applied a sensitivity analysis to this forecast, which is discussed in Section 3.2.

2.2.3 Unit costs for base station sites

The cost of operating and building sites is based on a benchmark of operators' current costs and forecasts for a typical Western European country. This is done to ensure consistency with our previous report to the

8 '*Economic benefits from making the 2.7–2.9GHz band available for mobile broadband services in Western Europe*', Aetha Consulting study for the GSM Association, 4 June 2013.

9 '*Future Spectrum Requirements Estimate for Terrestrial IMT, Report ITU-R M.2290-0*', ITU, December 2013.

10 '*Mobile traffic forecasts 2010-2020 report*', UMTS Forum, January 2011.

11 Estimate based on site data provided to us by the GSMA.

GSMA.[12] However, we have reflected the difference in cost levels by scaling the unit costs based on differences in purchasing power parity (PPP). The resulting present-day unit costs, as well as the assumed price trends, are shown below in Figure 2-4.

Figure 2-4: Unit cost capex and opex assumptions [Source: Aetha]

Network cost element	Unit cost in 2014 (USD)	Year-on-year price trend
New site	102 018	1.5%
New frequency band on existing site - antennas	1065	-2%
New frequency band on existing site – other equipment	13 311	-2%
Site opex (per year per site)	7204	2%
Additional site opex for 2.7–2.9GHz band (per year per site)	139	2%
Backhaul capex (per site)	4303	-1%
Backhaul opex (per year per site)	1087	-

The calculation of network costs is performed in the scenario with and the scenario without the 2.7–2.9GHz band made available for mobile services. The difference between both scenarios for each year gives the network cost savings for the operator for each year from being able to use the 2.7–2.9GHz band.

2.2.4 Consumer preferences

In order to arrive at an estimate for the economic benefits of the 2.7–2.9GHz band, we also need to make key assumptions about how network cost savings impact consumer preferences.

In Section 2.2.1, we discussed how making additional spectrum available to an MNO would lead to cost savings for the operator. In a competitive market, an MNO might pass on (part of) these cost savings to its consumers, by offering lower prices and/or better services, in order to retain its market share. In our model, we have assumed that MNOs pass on their entire cost savings to consumers. This implies lower prices for mobile services which will consequently lead to a higher market penetration and a higher realised surplus per consumer.

A key input to determine the impact of these reduced prices on consumer surplus is the price elasticity of demand, which is a measure of how the willingness of consumers to buy a product varies with its price. For MNOs, if the price elasticity is large (in magnitude) this would indicate that small changes in the prices that an operator charges can result in big changes in its number of subscribers. In our model, we have assumed a demand elasticity of -0.55, the choice of this value is discussed in greater detail in Annex A.

Note that we assess the impact of the share of cost savings which are passed on in our sensitivity analysis in Section 3.2.

12 '*Economic benefits from making the 2.7–2.9GHz band available for mobile broadband services in Western Europe*', Aetha Consulting study for the GSM Association, 4 June 2013.

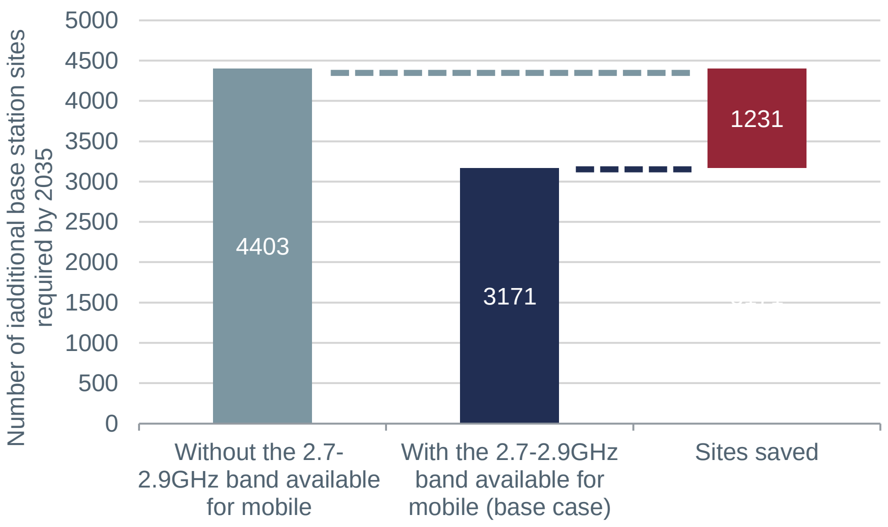
3 Results

In this section, we first outline the results of our analysis, in Section 3.1, and then test these results by means of a sensitivity analysis in Section 3.2.

3.1 Main results

The economic benefits to mobile broadband services in Kenya of being able to use the 2.7–2.9GHz band from 2021 is calculated on the basis of the network cost savings of a generic MNO which are being passed on to Kenyan consumers in the form of lower prices and/or better services. The network cost savings are due to the operator building and maintaining fewer sites, when given access to spectrum in the 2.7–2.9GHz band. The estimated number of additional sites built by the theoretical operator in the scenarios with and without the 2.7–2.9GHz band available for mobile services is summarised in Figure 3-1 below.

Figure 3-1: Additional sites built by generic Kenyan operator [Source: Aetha]



As Figure 3-1 shows, the theoretical operator would have to build an additional 4403 base station sites by 2035, if it did not have access to the 2.7–2.9GHz band. Thus, by making the 2.7–2.9GHz band available to mobile services, the number of additional base stations required is reduced by approximately 28%. In general, we note that the number of additional sites required may appear large considering the current site grid (i.e. we expect site numbers to more than double over the next 20 years). This is because the current network density, in Kenya, is significantly lower than in developed markets due to economic constraints and the more nascent nature of the mobile data market. So, the options for mobile operators to meet the capacity demands of forecast traffic are either to increase their site grids or to gain access to further spectrum.[13] Our results highlight the important role that additional spectrum bands can play in the future.

The network cost savings are assumed to be passed on to consumers in the form of lower prices, leading to an increase in consumer surplus. This increase in consumer surplus scaled to the entire country represents

13 In addition, we note that site numbers in similar low mobile data traffic markets have grown considerably in recent years. Data provided by the GSMA suggests that the total number of sites in Indonesia has grown by more than 45% in the last two years alone.

the overall economic benefits to mobile broadband services of the 2.7–2.9GHz band. In this study, we have estimated the economic benefits of the band to mobile services to be **USD770 million**.

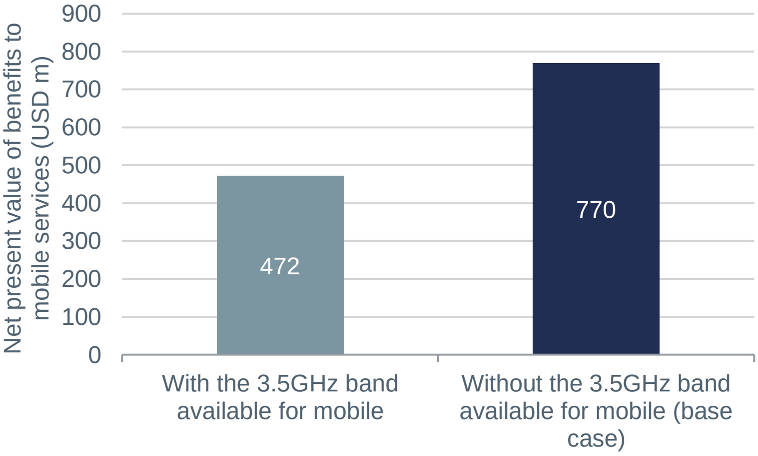
Note that this study is intended as an initial high-level assessment of the economic benefits of making the 2.7–2.9GHz band available to mobile services in Kenya. A more detailed study could improve on the accuracy of these results. In order to estimate the range of likely values for the economic benefits of the band to mobile services, we have performed a sensitivity analysis on some of the key inputs and assumptions, with the results discussed in the following section.

3.2 Sensitivity analysis

In this section, we present details of the sensitivity analysis that we have performed on the availability of substitute spectrum bands, future traffic levels and the share of cost savings passed on to consumers.

In Section 2.2.1, we discussed the importance of available spectrum bands in determining the capacity of base station sites. We have therefore examined a scenario where an additional 50MHz of spectrum in the 3.5GHz band is available to the generic MNO. This scenario is relevant as the 3.5GHz band is currently in Kenya for WiMAX which looks set to become harmonised with LTE in the near future.[14] The results of the analysis are shown in Figure 3-2 below.

Figure 3-2: Sensitivity 1 – Impact of 3.5GHz availability on economic benefits of 2.7–2.9GHz band [Source: Aetha]



As Figure 3-2 shows, the economic benefits from making the 2.7–2.9GHz band available reduce significantly from our base case value of USD770 million to approximately USD472 million, if the 3.5GHz band is also made available for mobile services.

In Section 2.2.2, we discussed the strong link between the number of incremental capacity sites and the forecast data consumption per SIM. As such, we have modelled a scenario in which the monthly data consumption per SIM reaches twice the base case levels. The results are summarised in Figure 3-3 below.

[14] *'WiMAX Advanced to Harmonize with TD-LTE in the 2.3, 2.5 & 3.5GHz bands'*, WiMax Forum, November 2013.

Figure 3-3: Sensitivity 2 – Impact of forecast traffic on economic benefits of 2.7–2.9GHz band [Source: Aetha]

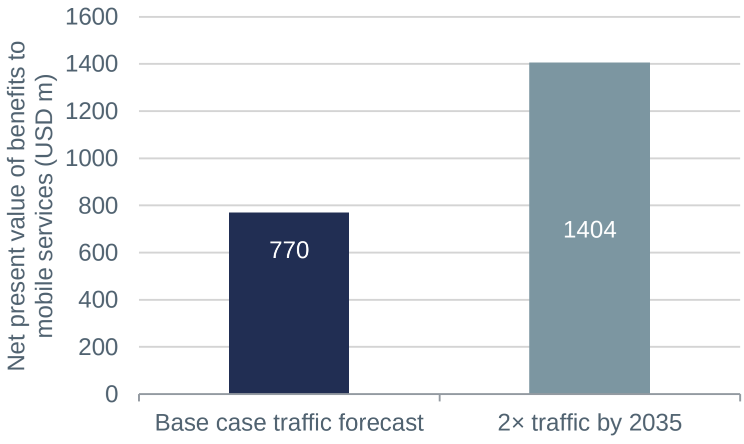
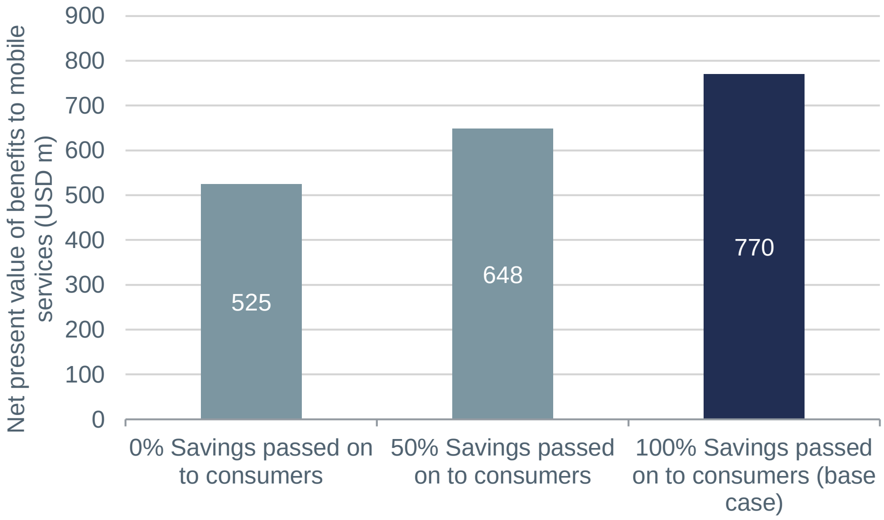


Figure 3-3 shows that if future data traffic reaches twice the value forecast in our base case, then the economic benefits of the 2.7–2.9GHz band rises, by approximately a factor of two, to approximately USD1.4 billion.

Finally, in Section 2.2.4 we also stated that we expect all of the MNO's cost savings to be passed on to its consumers, allowing the MNO to retain its market share in a competitive mobile market. Here, we have modelled two additional scenarios, one in which only 50% of the cost savings are passed on and one in which none of the cost savings are passed on to consumers.

Figure 3-4: Sensitivity 3 – Impact of MNO's percentage cost savings passed on to consumers on economic benefits of 2.7–2.9GHz band [Source: Aetha]



In Figure 3-4, we see that the maximum economic benefits of the 2.7–2.9GHz band are realised when the MNO passes on its entire cost savings to its consumers. The economic benefits decrease to approximately USD648 million and USD525 million, respectively, in the cases where 50% and none of the MNO's cost savings are passed on to its consumers. This implies that the passing on of all cost savings leads to a so-called multiplier effect of about 1.5.

4 Conclusions

This study on behalf of the GSMA provides an initial assessment of the economic benefits of making the 2.7–2.9GHz band available to mobile broadband services in Kenya.

Based on the results of our model, we expect that significant economic benefits can be gained by making the 2.7–2.9GHz band available. Our model forecasts that the number of mobile base stations a generic operator is required to build, in order to meet forecast mobile data traffic, is reduced by 28% by using the band within the period up to 2035. Based on our calculations, we have estimated the resulting economic benefits of making the 2.7–2.9GHz band available to be approximately **USD770 million**. However, our sensitivity analysis shows that under certain circumstances this value could potentially be as low as USD472 million and as high as USD1.4 billion, depending on the availability of other spectrum bands and the forecast level of traffic. Here, we would like to emphasise that within most reasonable scenarios we expect the economic benefits of the 2.7–2.9GHz band to lie close to our calculated value of USD770 million, and that the potential spread in this value is based on sensitivity scenarios with low probability but which require consideration given the timescale we are investigating.

The economic benefits, of making the 2.7–2.9GHz band available for mobile services, must be weighed against the costs of moving existing users from the band. Whilst a detailed study of such costs is beyond the scope of this report, we have conducted a high-level estimate to illustrate their order of magnitude.

According to numbers published by the Kenyan Airports Authority (KAA)[15] and the Kenyan Airforce (KAF)[16] there are 13 primary surveillance radars (i.e. radars which may operate in the 2.7–2.9GHz band) in Kenya, of which 8 are civilian and 5 are military. The potential unit costs of relocating these radars are approximately USD1.9 million and USD2.5 million for the civilian and military radars respectively, based on a BAE Systems study.[17] We used a similar assumption in our previous report[18] and have scaled the unit costs by PPP to adjust for differences in cost levels. However, it is possible that for some military radars the installation of additional filters to prevent interference could suffice, and this would cost approximately ten times less than relocation. We have estimated the percentage of military radars which only require additional filters to be 70%, which is consistent with our previous report. This gives an indicative cost for the relocation of radars operating in the 2.7–2.9GHz band of USD19 million.

Overall, it can be seen that the cost of moving existing users in the 2.7–2.9GHz band is likely to be an order of magnitude below the value arising from use of the band for mobile broadband services. Therefore, the conclusion from this study is that making the 2.7–2.9GHz band available to mobile services would provide significant economic benefits to Kenya.

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15 Estimate based on number of airports listed by KAA, available at:

https://www.kaa.go.ke/airports

16 Estimate based on number of airports listed by KAF, available at

http://kaf.mod.go.ke/?p=1296

17 *'Study into Spectrally Efficient Radar Systems in the L and S Bands'*, BAE Systems study for Ofcom, May 2006

18 '*Economic benefits from making the 2.7–2.9GHz band available for mobile broadband services in Western Europe'*, Aetha Consulting study for the GSM Association, 4 June 2013.

Annex A Detailed methodology

As discussed briefly in Section 0, the economic benefits of using the 2.7–2.9GHz band for mobile services are assessed by calculating the network savings that a generic MNO, in the Kenyan market, would gain from using the spectrum. We then convert this from a producer surplus to a consumer surplus. These steps are discussed in detail in this section, along with the key assumptions involved.

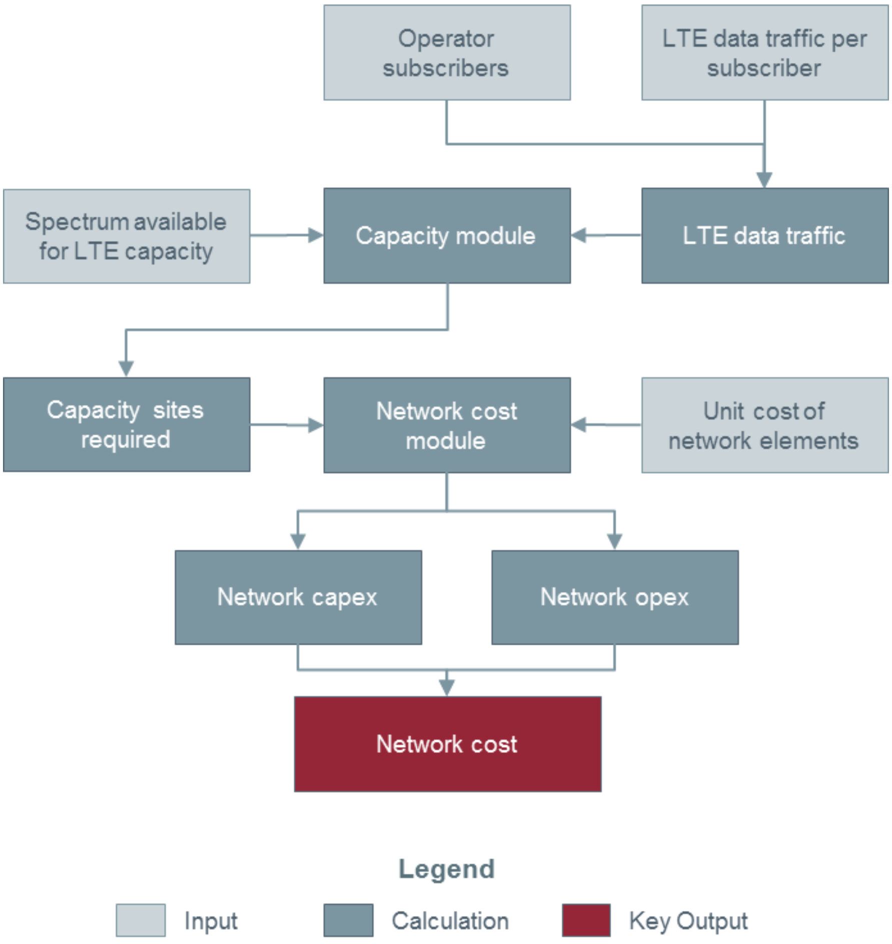
A.1 Approach to calculating the network savings of a generic MNO in Kenya

We have calculated the network cost savings of a generic MNO in Kenya, for which we have assumed the following characteristics:

- a population forecast from the World Bank (approximately 41 million in 2015 rising to 74 million in 2035)
- 4 MNOs in the country, each with equal market share
- each operator has a current site grid of 1391 sites, in order to provide sufficient coverage and carry current traffic levels.

To calculate the network cost savings for this generic MNO we consider the difference between the network costs of the company in the scenarios with and without the 2.7–2.9GHz band available for mobile services. This involves calculating the number of additional capacity sites required to carry the traffic of the generic operator in each scenario, and calculating the costs these sites would incur. An overview of the network cost calculation is shown in Figure A-1, and discussed in detail below. These costs are calculated for each year of the modelling period, from 2010 to 2035, although there will be no difference between the scenarios with and without the 2.7–2.9GHz band available for mobile services until the band would be introduced in 2021.

Figure A-1: Calculation flow of network capacity costs [Source: Aetha]



Combining the forecast population of the country with the generic operator's market share and a forecast of mobile SIM penetration gives the number of subscribers (i.e. the number of active SIMs) that the operator has each year. We have assumed that mobile penetration in Kenya increases from 69% in 2013[19], to 170% by 2032, remaining constant thereafter. The penetration rate forecast for Kenya was assumed to lag behind that of a typical Western European country, as reported previously in our study for the GSMA.[20] In other words, we have assumed the annual growth in SIM penetration for Kenya to follow that of a typical Western European country, albeit trailing by a constant number of years based on present-day penetration values.

Subscriber numbers together with a forecast of LTE traffic per subscriber gives the total traffic the generic operator is expected to carry on its network. The traffic forecast is discussed in detail below in Section A.1.1. The operator's traffic is then scaled to represent the downlink traffic in the busiest hour of the day on the busiest sector of each site, as this is the traffic that will constrain the operator and hence the traffic that the operator will dimension their network on. We have assumed the following percentages for these parameters, based on knowledge of the network measurements of various operators:

- 80% of traffic is assumed to be downlink traffic

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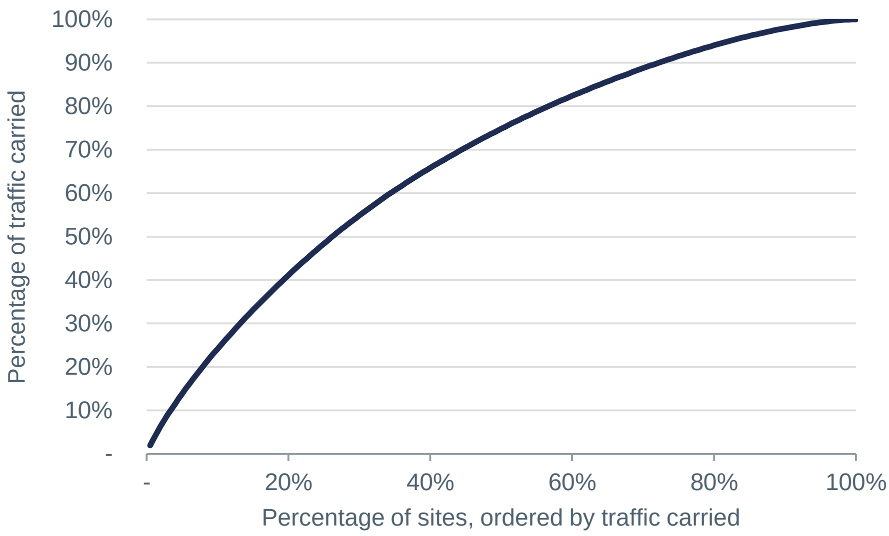
19 *'Quarterly Sector Statistics Report, Third Quarter of the Financial Year 2013/14'*, CA, March 2014

20 '*Economic benefits from making the 2.7–2.9GHz band available for mobile broadband services in Western Europe'*, Aetha Consulting study for the GSM Association, 4 June 2013.

- 10% of the daily traffic is assumed to occur in the busiest hour of the day
- 55% of a site's traffic is assumed to occur in the busiest sector of the site.

The traffic is distributed amongst the operator's sites by splitting the sites into 200 groups, with similar traffic levels within each group. The distribution used is shown below in Figure A-2 and is based on knowledge of the traffic distribution on sites of various relevant operators.

Figure A-2: Distribution of traffic over operator sites [Source: Aetha]



The spectrum available to the operator for LTE use is a key input to the capacity calculation, as it determines how much traffic each site can carry. The addition of the 2.7–2.9GHz band for mobile services from 2021 would allow the generic operator to carry more traffic on each site. The assumptions on available spectrum are given in Section 2.2.1. Also, the capacity of each sector on a site per MHz of spectrum will increase as the LTE technology is improved and used more efficiently. The assumptions on sector capacity are discussed in Section A.1.2.

The traffic, available spectrum and sector capacity inputs feed into the capacity module, which calculates how many sites and carriers are required to hold the traffic. It is assumed that the operator deploys every band other than the 2.7–2.9GHz band on each new site and deploys the 2.7–2.9GHz band (in the scenario with the band available for mobile services) separately in order to avoid the cost of new sites.

The cost of operating and building the sites is then calculated using forecasts for unit costs, as discussed in Section 2.2.3. The calculation of network costs is performed in the scenario with and the scenario without the 2.7–2.9GHz band available for mobile services. The difference in each year between both scenarios gives the network cost savings for the operator for each year from having use of the 2.7–2.9GHz band.

A.1.1 Traffic forecast

The traffic forecast is a key driver in the model as it drives the need for the generic operator to build additional sites and upgrade existing sites. We have based our forecast on two recent studies:

- An ITU publication[21] provides lower and upper bounds for future traffic, until 2020, compared to 2010 levels. It predicts traffic in 2020 to be between about 26 and 98 times the traffic in 2010. This forecast is shown below in Figure A-3.
- A UMTS Forum report[22] forecasts total global traffic until 2025, as shown below in Figure A-4.

Figure A-3: Mobile traffic forecasts towards 2020 by extrapolation [Source: ITU[21]]

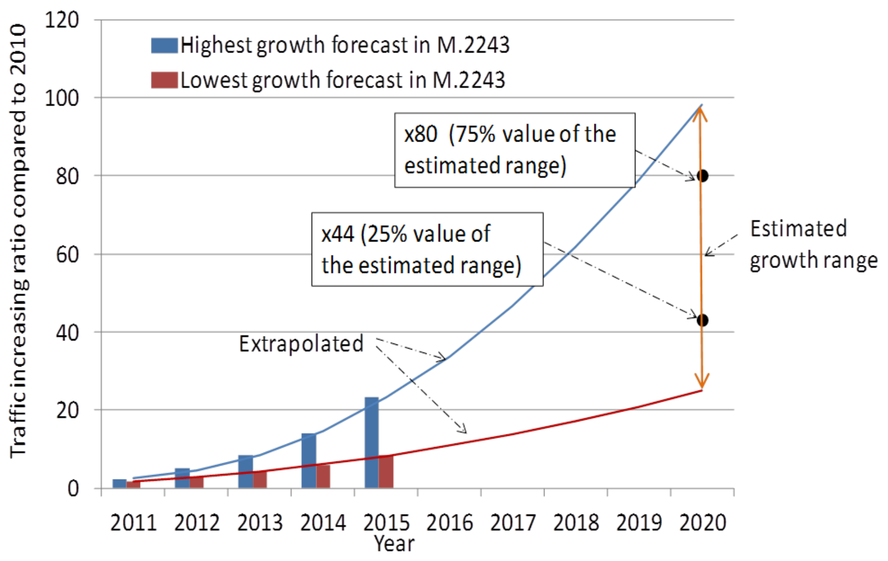
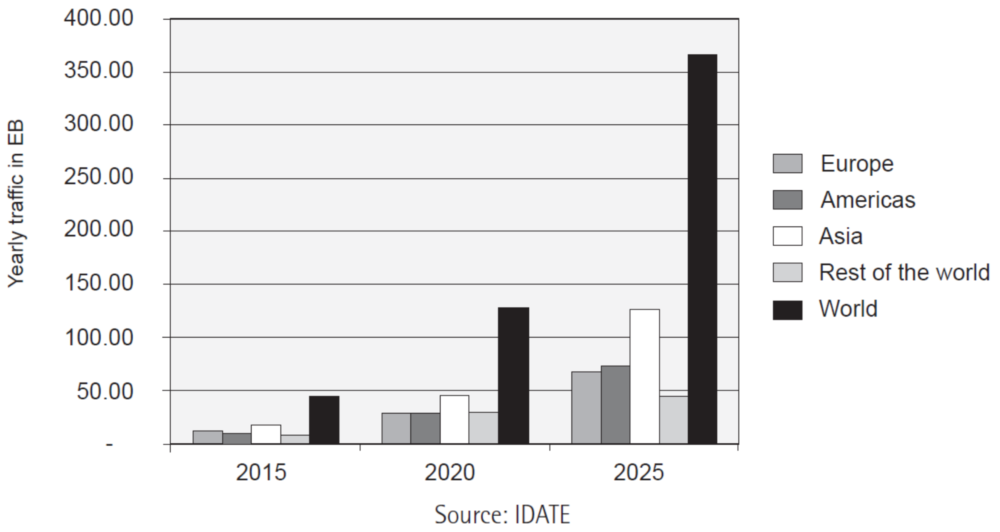


Figure A-4: 2025 mobile traffic forecasts [Source: UMTS[22] (IDATE)]



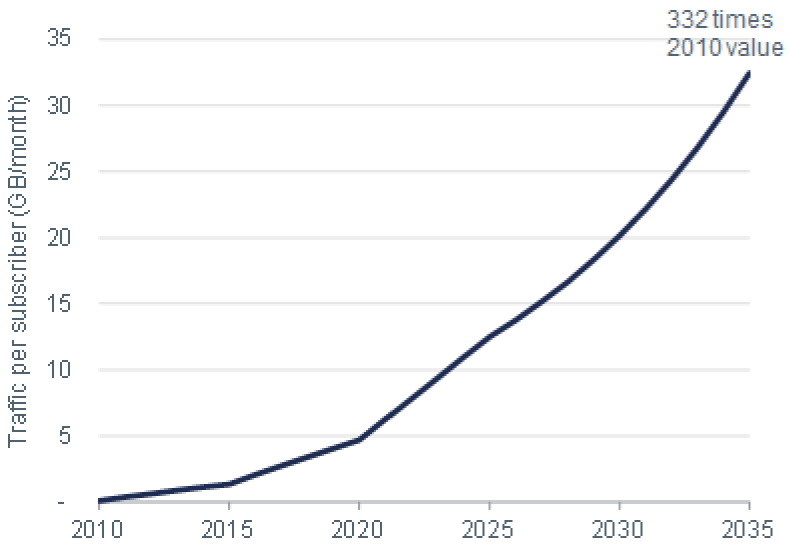
To derive the forecast used in our model we start with the 2010 traffic as stated for a typical Western European country in the UMTS Forum report. We then apply a trend of the average of the upper and lower bounds from the ITU publication, until 2020. We then apply the global trend forecast from 2020 to 2025 in the UMTS Forum report to derive a forecast for 2025. After 2025, we have assumed a year-on-year

21 '*Future Spectrum Requirements Estimate for Terrestrial IMT, Report ITU-R M.2290-0*', ITU, December 2013.

22 '*Mobile traffic forecasts 2010-2020 report*', UMTS Forum, January 2011.

increase of 10%, in line with the trend up to 2025. The resulting forecast per SIM (including voice-only SIMs) is displayed below in Figure A-5.

Figure A-5: Traffic forecast per SIM for generic Western European operator [Source: Aetha, based on forecasts from the ITU and UMTS Forum]



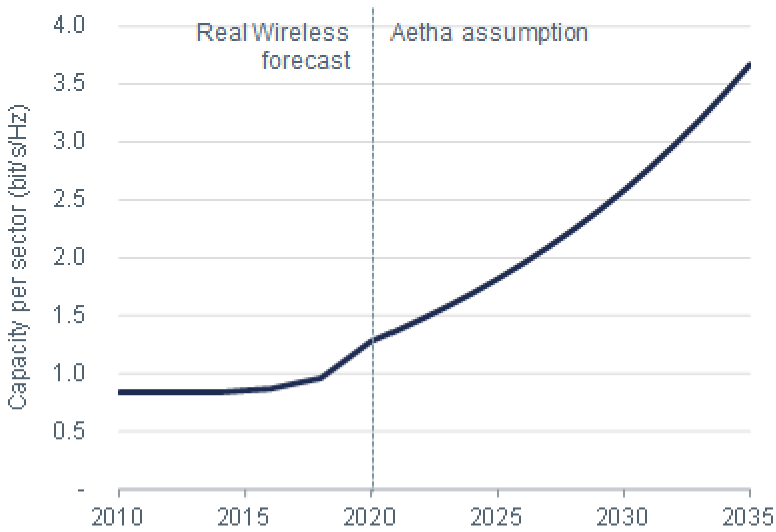
We have assumed the Kenyan traffic forecast to follow the growth rate in Figure A-5, albeit trailing by a constant number of years as determined by the difference in present-day data consumption.

A.1.2 Sector capacity assumptions

The spectral efficiency of an LTE carrier determines how much traffic within a sector can be carried over the bandwidth of the carrier. Improvements in technology and utilisation lead to improved spectral efficiency. A Real Wireless study for Ofcom into LTE capacity gains[23] includes a forecast of spectral efficiency for LTE until 2020. We have utilised this forecast and extended it using the CAGR from 2014 to 2020 to give a year-on-year trend of approximately 7% thereafter. The forecast used is shown below in Figure A-6.

23 '*Report for Ofcom: 4G Capacity Gains*', Real Wireless, 27 January 2011.

Figure A-6: Spectral efficiency of LTE [Source: Real Wireless, Aetha]



We have assumed that unpaired spectrum has the same capacity per MHz as paired spectrum.

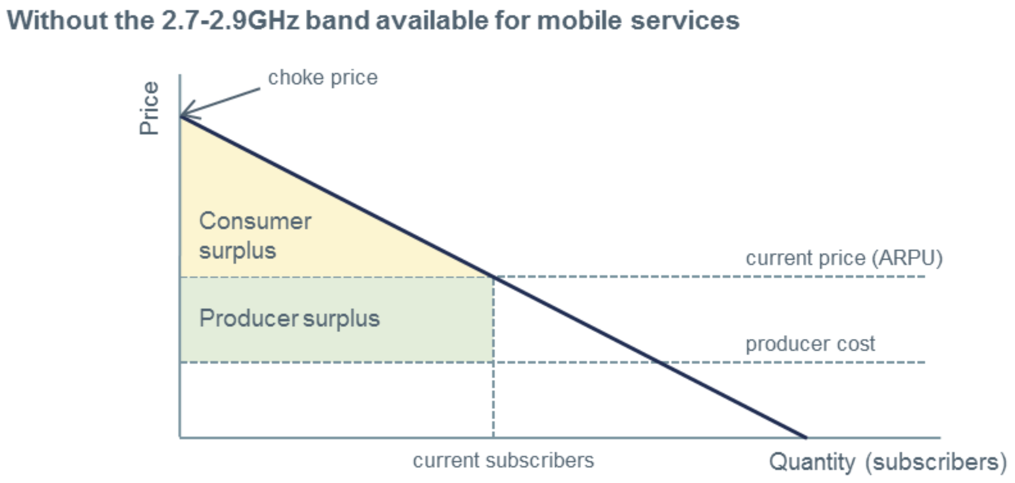
A.2 Passing the cost savings to consumers

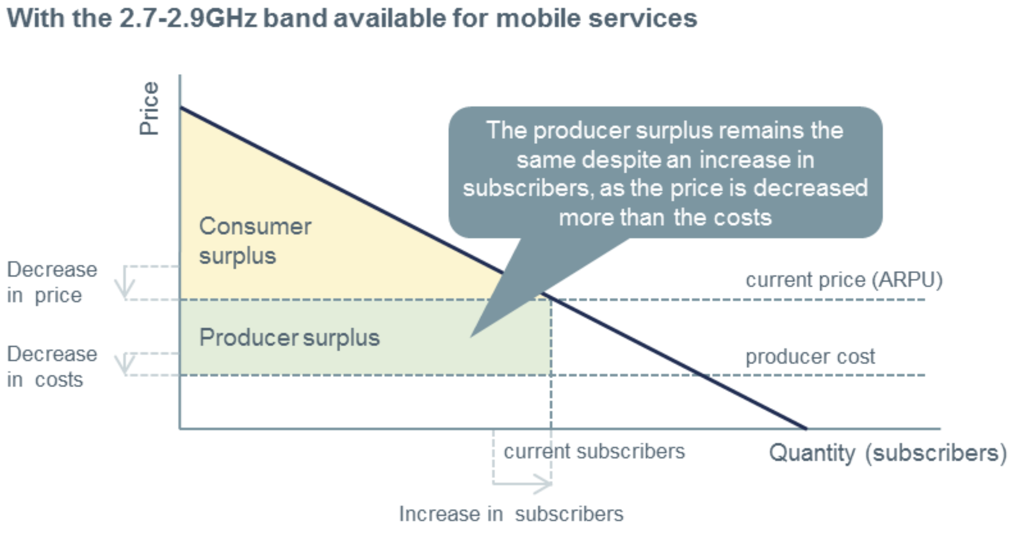
In Section A.1 we provided details for the calculation of the network cost savings for a generic operator. In a competitive market these cost savings would be passed on to the consumer in the form of lower prices (or equivalently, better bundles), in order for the operator to retain its position in the market. The model calculates the consumer surplus once the savings have been passed on, in the scenarios with and without the 2.7–2.9GHz band available for mobile services. The difference between the two is then the total economic benefits of the band to mobile broadband services in Kenya.

The network cost savings, corresponding to an increase in producer surplus before any price reduction, are calculated for each year. The model converts these savings into consumer surplus, such that the producer surplus is the same in the scenario with and the scenario without the 2.7–2.9GHz band available for mobile services. That is, the producers, i.e. the MNOs, make the same profit each year regardless of the availability of the 2.7–2.9GHz band.

As the MNOs lower their prices, they attract more subscribers. Hence operators are able to drop their prices by more than their cost savings in the scenario with the 2.7–2.9GHz band available for mobile services. This is illustrated in Figure A-7 below. Note that the model calculates a separate linear demand curve for each year, which is used in both scenarios.

Figure A-7: Producer and consumer surplus in the scenarios with and without the 2.7–2.9GHz band available for mobile services
[Source: Aetha]





In order to define the demand curves, we have assumed ARPU levels for Kenya to remain constant, in nominal terms, at their present-day values[24] of USD12.4 per month per SIM. In real terms this represents a decline in ARPU levels over time.

The demand curve for 2013 is derived from the ARPU value and subscriber numbers for the generic market, along with a price elasticity of demand. The price elasticity is a measure of how the subscriber numbers would react to a change in the price of the service. It is the percentage change in the number of subscribers resulting from a one per cent change in price. Estimates of the price elasticity for mobile services vary considerably within academic literature. Therefore, we have used a 'symbolic average' of estimates from a variety of studies of -0.55, as is suggested by a recent survey of Benzoni & Deffains.[25]

[24] Estimate based on site data provided to us by the GSMA.

[25] '*Market Homogenisation or Regulation Harmonisation? The Welfare Cost of a European Mobile Market without the Later Entrant Operators*', L. Benzoni & B. Deffains, 2012.

From the demand curve for 2013 we have inferred a choke price, i.e. the minimum price at which there would be no subscribers (as shown in Figure A-7 for the scenario with the 2.7–2.9GHz band made available for mobile services). Demand curves for the years following 2013 are then based on a forecast trend of the choke price. We have assumed that the choke price follows the same trend as the ARPU, but with an additional decrease of 1% each year, to reflect the decreasing value of the service as it increases in age.

To calculate producer surplus in the scenario without the 2.7–2.9GHz band made available for mobile services (and hence also in the scenario with the band available for mobile services, as the producer surplus is set to be equal in both scenarios), we assumed that the producer costs are 50% of the producer revenues, based on the current financial situation of various operators. In the scenario with the 2.7–2.9GHz band made available for mobile services these costs are lowered by the network cost savings per subscriber from the availability of the band. We have assumed that an increase in subscribers does not affect the producer cost per subscriber (i.e. overall producer costs are proportional to the number of subscribers).

In the scenario without the 2.7–2.9GHz band made available for mobile services the consumer surplus is then calculated for each year, from the demand curves, subscriber numbers and ARPU forecasts. In the scenario with the 2.7–2.9GHz band made available for mobile services, with the producer surplus fixed and producer costs calculated, the demand curves then define both the current subscriber numbers and ARPU for each year. From this the consumer surplus is calculated.

The consumer surplus for each scenario is then discounted to give a net present value for 2015, using the social discount rate of 3.5%.[26] The difference between the net present values, for the scenarios with and without the 2.7–2.9GHz band, is then taken in order to arrive at the total benefits of the 2.7–2.9GHz band being made available mobile broadband services in Kenya.

[26] '*Social discount rates for the European Union'*, D. Evans, 31 October 2006.