Application of spectrum liberalisation and trading to the mobile sector - A further consultation

User manual for the accompanying models
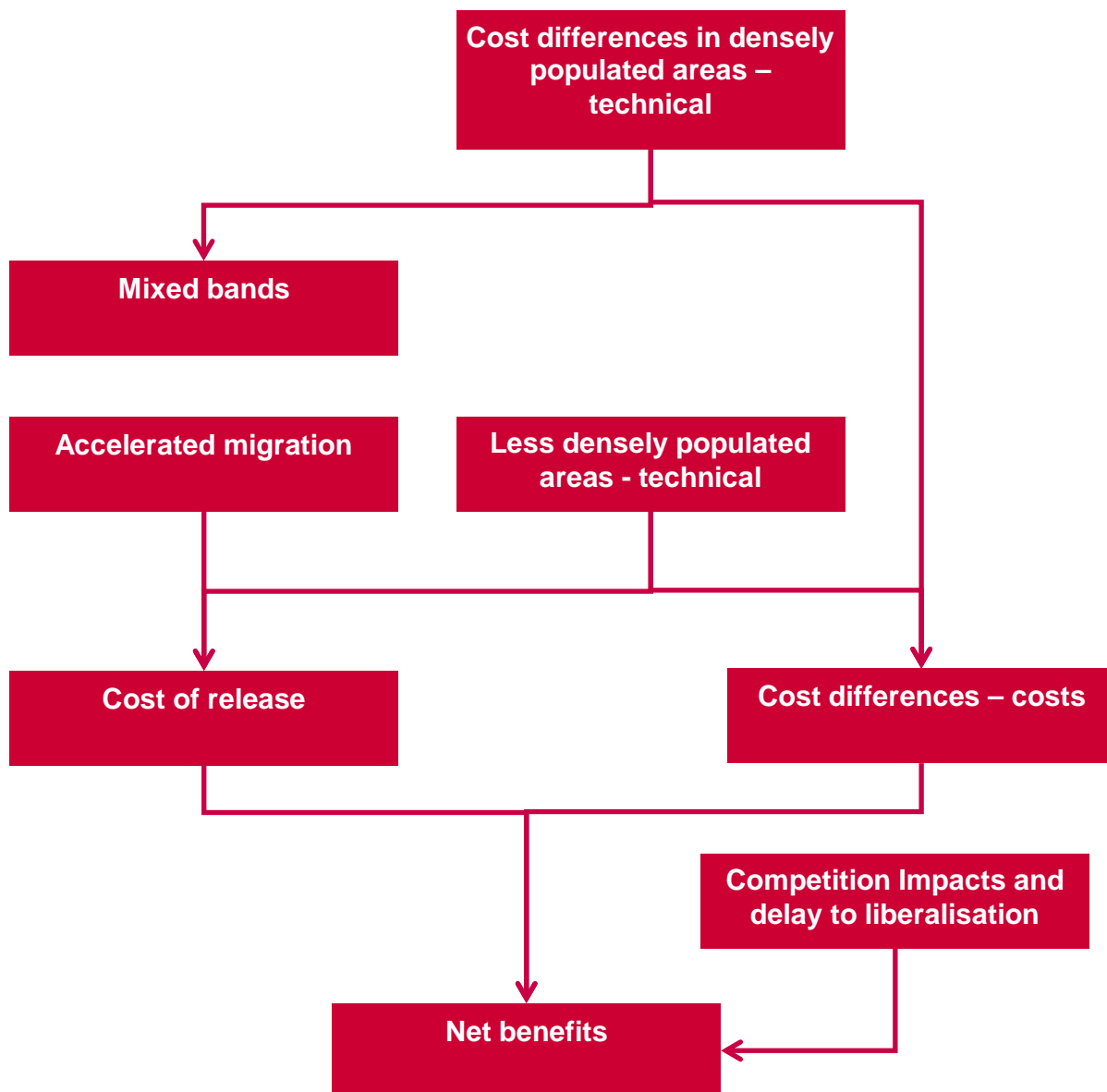
Contents

Section 1

Introduction

1   This document is a user manual for the techno-economic models released with the Consultation document "Application of spectrum liberalisation and trading to the mobile sector: Further consultation," dated February 2009. It should be read in conjunction with these models.

2   There are eight models included within the consultation material. These correspond to particular annexes within the consultation document, as listed below:

   2.1   Net benefits model, whose results are described in Annex 7

   2.2   Competition impacts and delays to liberalisation model, whose results are described in Annex 9

   2.3   Cost differences in densely populated areas – technical model, whose results are described in Annex 13

   2.4   Mixed bands model, whose results are described in Annex 13

   2.5   Less densely populated areas – technical model, whose results are described in Annex 14

   2.6   Cost differences – costs model, whose results are described in Annexes 12 and 15

   2.7   Cost of release model, whose results are described in Annex 16

   2.8   Accelerated migration model, whose results are described in Annex 16

3   Sections 2 - 9 of this document describe the models, in the order given above, and how to use them to generate outputs provided in the consultation document. For the more complex models, examples of using the model are also provided.

Remarks relevant to all models

4   Each model is a single, standalone Microsoft Excel workbook. Three of the workbooks contain macros, although they are only used to re-calculate the workbook numerous times under multiple scenarios and then paste the results into the same workbook. When opening these workbooks, macros should be enabled. Wherever a macro can be used, pressing a labelled button within the workbook can activate it.

5   Confidential information has been removed prior to publication. Consequently, results generated will not always correspond exactly to those in the consultation document.

6   All the workbooks should be compatible with Microsoft Excel 2000, 2003 or 2007.

7   Due to their relatively small size, workbooks are provided with automatic calculation enabled. Changing values of inputs should cause them to re-calculate automatically. Pressing Ctrl-Alt-F9 will however ensure a full re-calculation of the workbook.

8   Although the models do not have active workbook links between them, outputs are taken from particular models and pasted into others. The information flow is summarised in the figure below: refer to the respective section of this document for instructions on how to update the information to be pasted into a particular model.

Figure 1 – Information flow between models

9   A "Contents" worksheet is included at the front of each workbook, displaying the workbook title, objective and a summary of the purpose of each worksheet.

10   The cell formatting styles used within the workbooks are demonstrated on the "Style Guidelines" worksheet in each workbook. Cell formatting is used to allow the user to distinguish between

         10.1   Parameters, or hard-coded cells whose values could be changed

         10.2   Data, or hard-coded cells whose values should only be changed should better data become available

10.3   Calculations, which are cells containing formulae that should not be changed

10.4   Outputs, which are results of interest to a user

10.5   Annotations, which are intended to provide explanation for a user.

11   A "Model Structure" worksheet includes a roadmap summarising the calculation within the workbook. Each box in the roadmap contains a hyperlink to the relevant part of the workbook. Clicking once on the relevant box will run the hyperlink.

12   Inputs are provided on one or more worksheets at the start of the workbook. Named ranges are used to link the inputs into the calculations, making auditing of formulae easier.

13   Where inputs should only take one of a particular range of values, drop-down boxes are used to restrict the values that can be used.

14   Where possible, charts and tables that appear in the consultation document are included within the model in order to allow the user to duplicate these outputs for themselves.

15   We recommend avoiding using the computer for other tasks while running the models, and in particular embedded macros. In particular, we would recommend against using the "copy to clipboard" function in other programs, while running macros.

Net Benefits Model

Introduction

1   This section describes how to use the net benefits model to compare a range of policy options, under a variety of scenarios, as described in Annex 7.

2   The policy options considered are:

- Regulated access

- Mandatory release – 1 block

- Mandatory release – 2 blocks

- Mandatory release – 3 blocks

3   For each of these options, we consider a version where the regulatory action disrupts a commercial outcome that would have occurred in the absence of intervention, and another where this disruption does not occur.

4   For each option, we also consider a significance scenario, and commercial outcome, as described in Annex 7. These are illustrated below:

Figure 2-Scenarios and outcomes
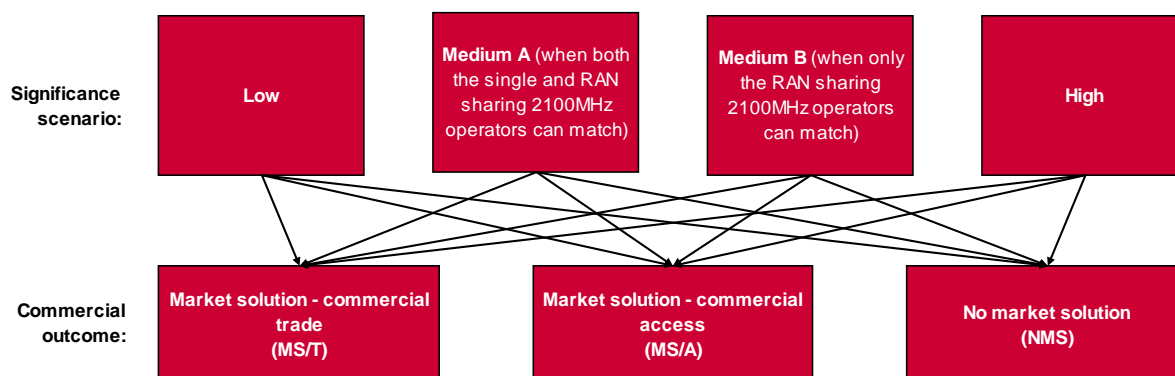
How to Use

5   The control panel holds all of the inputs. It also allows you to set the following options:

- The welfare standard to run the model - total welfare or consumer surplus only.

- The percentage of costs that are passed on to consumers - used to generate consumer welfare impacts where we have not estimated these directly.

- The length of the interim period (2 years, 3 years or 4 years)

- Low, base or high net benefits that the individual option output sheets are currently using.

4

6	When these options are changed, the results need updating. This is done by performing a "full calculate" (Ctrl + Alt + F9).

7	For each policy option, there are four sheets (two for the disruption outcome, and two for the non-disruption outcome):

Table 1 - Worksheet descriptions

Name	Description
C&B	This sheet sets out the names of the costs and benefits that apply in each outcome, for a particular intervention.
Output	This sheet evaluates the names on the C&B sheet to show the actual costs and benefits, and the net benefit, under each of the twelve possible outcomes.
C&B (D)	As above, but for when the intervention disrupts the commercial outcome.
Output (D)	As above, but for when the intervention disrupts the commercial outcome.

8	The names of the costs and benefits on the Output sheets are evaluated using a user-defined function (yEval).

9	This function evaluates the text in a cell as though it were a formula i.e. if it had an "=" in front of it.

Section 3

Competition Impacts and Delay to Liberalisation

Introduction

1   This document is a user manual for the quantitative model used to quantify two separate effects:

   o   Welfare effects due to changes in the competitive intensity in the market for high quality mobile broadband services.

   o   Foregone benefits due to a delay to the launch of innovative new services.

Competition Impacts

2   In order to quantify welfare effects due to changes in competitive intensity we have used the Cournot oligopoly model[1] of competition as a theoretical foundation to analyse the welfare effects of changes in the degree of competitive intensity.

3   The model also allows for two different assumptions to be made about the shape of the market demand curve: it can take either a linear or negative exponential function form. The former assumes that demand takes the form *$P=a-bQ$*, whereas the former assumes that demand takes the form *$Q=Ae^{bp}$* or, equivalently, *$P=(lnQ-lnA)/b$*.

4   The calculations for the linear demand curve are located on the "Linear Demand calcs" worksheet and the calculations for the negative exponential demand curve are located on the "NegExp Demand calcs".

5   The fixed inputs for both market definitions of the model are stored on the "Forecasts" tab. The inputs are forecasts of total revenue and subscriber volumes covering the period 2008-2027. The total revenue is divided by the number of subscribers to give the implied ARPU forecast. The subscriber and ARPU numbers are used as estimates of quantity and price respectively, and are used to calibrate the Cournot model.

6   The model uses Analysys Mason forecasts of total UK mobile revenues as inputs for the period up to and including 2013. For the rest of the period the volume of subscribers is assumed to grow at a constant rate equal to the rate of subscriber growth between 2012 and 2013 and revenues are assumed to grow at a rate specified in the Control tab.

•   The model allows the user to dimension the assumed relevant market by specifying the proportion of consumers sensitive to changes in quality and the proportion of UK mobile revenues affected.

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[1] See Tirole, The Theory of Industrial Organisation (1989) p. 218 or Church and Ware, Industrial Organization: A Strategic Approach (2000) p.243 for a detailed exposition of the model.

Delay to liberalisation

7 A delay to liberalisation may result in foregone benefits to consumers and producers from the delay to the launch of innovative new services. This section of the model aims to quantify these foregone benefits due to a delay to liberalisation.

8 This section of the model quantifies the flow of economic benefits from mobile services over a 20 year period. It assumes one of three migration profiles from GSM to moderate 2100MHz services and from moderate 2100MHz to fast 900MHz services.

9 The values of consumer and producer surplus from the competition impacts model, using the total mobile market i.e. 100% of subscribers, and 100% of revenues, to parameterise the model.

10 Each successive mobile technology is assumed to generate a proportionate increase in economic welfare from those services, so as subscribers migrate from GSM to moderate 2100MHz to fast 900MHz over time, economic welfare from the total mobile market increases. The size of this uplift is specified on the control tab.

11 The delay to liberalisation is assumed to delay the migration from moderate 2100MHz to fast 900MHz, however the delay attenuates over time such that the delayed migration profile catches up with the base migration profile. The catch up period is also specified on the control tab.

12 The results for each delay period is in the Delay_X tab where X is the delay period. The results are reported in NPV terms, using 2008 as the base year

How to Use

Competition Impacts

1 The variable inputs for the model are specified in the "Control" tab. These are selected via a drop down box, and what assumption each option corresponds to can be found by expanding the plus button next to below the drop down box.

    1.1 The dimensions of the relevant market are specified by selecting the proportion of UK mobile consumers in the affected market segment in cell F4 and the proportion of UK mobile revenues affected in cell F6.

    1.2 The number of players in the factual and counterfactual are selected in the drop-down boxes in cells F11 and F20.

    1.3 Cells F22, and F31 are used to select the period of competition effects. The first and final years of full competition effects are displayed in cells F27 and F29. The diminution period F31 is the number of years it assumed it takes for the competition effects to attenuate to zero.

    1.4 The assumed elasticity for the calibration stage is selected in cell F41.

    1.5 To select an exogenous cost trend cell F48 should be set to Enabled, otherwise the marginal cost will be determined given the equilibrium quantity and price. If the exogenous cost trend is disabled then the average marginal cost is calculated in each period given the baseline market

development parameters i.e. the price, quantity and number of players in each period.

1.6   The price of substitutes is assumed to influence the choke price of the demand curve and assuming an exogenous trend in the price of substitutes can be selected by setting F55 to Enable.

1.7   Cell F62 is used to specify the assumption about how the relevant market revenues will grow from 2013 onwards.

1.8   Cell F71 specifies the desired level of coverage of all operators in the market. This is used to produce the quantity inputs used in the calibration stage.

2   The inflation rate, nominal and real social discount rates are specified in cells F132:F134.

3   The outputs from the model are differences in consumer and producer surplus between the factual and counterfactual and are reported in two tables in the Control tab, given the assumptions about the shape of the demand curve.

Delay to liberalisation

4   The variable inputs for the model are specified on the "Control Delay" tab. These are selected via a drop down box, and what assumption each option corresponds to can be found by expanding the plus button next to below the drop down box.

5   The base case migration profile from GSM to moderate 2100MHz is selected in cell C5. There are three profiles for the migration of GSM to moderate 2100MHz from low to rapid migration which are displayed in cells A59:AA61.

6   The economic value of 2G is specified in the "Surplus calculations" tab which details the input parameters used in the Competition Impacts model to generate the consumer and producer surplus for 2012. The economic welfare per subscriber per month is reported on the "Control Delay" tab in cell C20 and the proportion of this welfare which is consumer surplus is reported in cell C22.

7   The percentage uplift in economic welfare of fast 900MHz over moderate 2100MHz and moderate 2100MHz over GSM is specified in cell C27.

8   The number of years *after the delay period* in which the delayed migration profile[2] from moderate 2100MHz to fast 900MHz services catches up with the base migration profile is specified in cell C37.

9   The real discount rate is specified in cell C45. This may differ from the discount rate used in the Competition Impacts model.

Section 4

Cost differences in densely populated areas – technical model

Introduction

1   This section describes how to use the 'Cost differences in densely populated areas – technical' model to estimate the number of sites that an operator would be required to deploy in order to meet a range of UMTS and HSDPA service requirements.

2   This model is a standalone Excel workbook called "Cost differences in densely populated areas – technical model.xls" and contains several macros that are used to run the model multiple times for various scenarios.

3   For more detailed information on the methodology of our calculation or the choice of particular parameters, review Annex 13 of the Consultation document "Application of spectrum liberalisation and trading to the mobile sector: Further consultation," dated February 2009.

4   A flow diagram for the model structure, also included on the "Model structure" worksheet in the model, is given below:
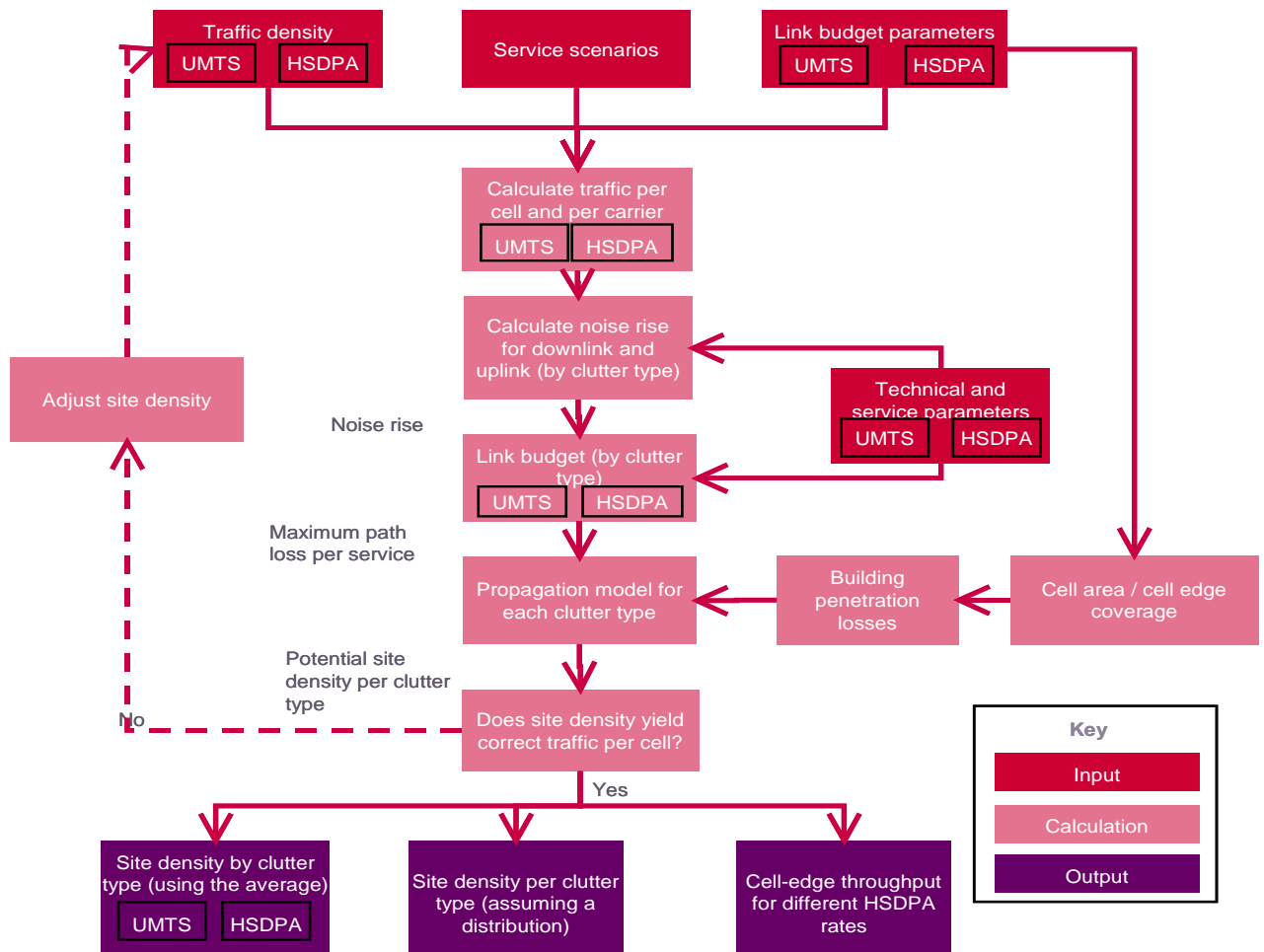
5   The model allows the number of sites to be calculated for different frequency bands, for different numbers of carriers and for a range of data rates and user demand volumes.

6   The model takes technical and service parameters for a given scenario as input and produces the density of sites to support this service at a given frequency as output.

7   The site density is calculated for each of a number of generic clutter types, which are used to specify both the propagation and traffic characteristics. In this way the national site numbers can be derived from knowledge of the characteristics of the clutter over the whole target coverage area. For this study, the target areas are the most densely populated parts of the UK where 80% of the population live. Additionally, the model permits the generic analysis of the variation of site density with population and hence traffic distribution.

Structure of the calculation

8   The variable inputs for the model are specified in the "Scenario", "Ctrl," "Params UMTS", and "Params HSDPA" worksheets:

  8.1   The "Scenario" worksheet summarises how the inputs are varied for the scenarios used within the consultation document. There are three different sets of scenarios: a set where UMTS parameters are varied, another where HSDPA-specific parameters are varied and a third set where the relationship between cell-edge throughput and assumed cell-area coverage probability is examined. The model can generate the outputs for each set of scenarios using a macro activated by pressing the appropriate red button at the top of this worksheet. When each macro is finished, the over-written inputs are restored to their value in the base case scenario.

  8.2   The "Ctrl" worksheet acts as the main control worksheet of the model and contains the variables that can be changed to reflect different deployment scenarios for a given set of system parameters.

  8.3   The other two worksheets define the equipment configuration, system performance and service offering.

9   Given the number of inputs in this particular model, a default value in green text has been stated beside every input cell in the model. This allows the user to check whether or not the model is using the default values.

10   Two different strands of calculation occur when the input parameters are updated: traffic-demand related and link budget related.

  10.1   Traffic demand-related calculations are performed in the "Traffic Demand UMTS" and "Traffic Demand HSDPA" worksheets

  10.2   Link budget-related calculations are performed within worksheets prefixed "LB." For the UMTS network, each clutter type and indoor or outdoor calculation is conducted on a separate worksheet. For the HSDPA network, all calculations are conducted in the same worksheet, including variations to reflect differences in the shadowing margin, for each clutter type and for the indoor or outdoor distinction.

10.3   The derivation of the active user density versus capacity is also performed within these link budget-related worksheets.

11   The output number of sites required to provide coverage is calculated in the worksheets prefixed "Dimen":

11.1   The "Dimen UMTS Average" worksheet presents the dimensioning results for the current scenario as defined by the input parameters. It assumes an average number of active users derived from the UMTS traffic demand.

11.2   The "Dimen UMTS Distribut" worksheet presents the dimensioning results assuming a distribution of the number of active users about the average value, which is also derived from the UMTS traffic demand level.

11.3   The "Dimen HSDPA" worksheet presents results for the current scenario assuming an average number of active users provided by the HSDPA traffic demand.

12   The results for all three sets of scenarios are provided in worksheets at the end of the workbook: the prefix used in the worksheet name specifies the set of scenarios that the outputs belong to. Hence:

12.1   Worksheets U1-U19 contain the outputs for the UMTS-specific scenarios.

12.2   Worksheets H1-H13 contain the outputs for the HSDPA-specific scenarios.

12.3   Worksheets R1-R4 contain the outputs for the analyses of the relationship between HSDPA cell-edge throughput and the assumed cell-area coverage probability.

13   Within each of these three groups of scenarios, the output worksheets are more or less identical. The only difference is that the name of the worksheet is hard-coded into cell A2. This value is then used to give the scenario description in cell A1. A template worksheet simply called "H" is included for the HSDPA-specific scenarios. It contains the tables on the other output worksheets in an identical format. When the macro for the HSDPA-specific scenarios is run, the outputs are first pasted onto this worksheet, before the full set of these pasted values are then copied and pasted onto the relevant output worksheet.

14   Several worksheets contain supporting material and these are located later within the model. These include:

14.1   "PL" (Path Loss) worksheet,

14.2   "BPL" (Building Penetration Loss) worksheet,

14.3   "EdgeVsArea" worksheet,

14.4   "RateVsLocation HSDPA" worksheet.

How to use

15   As stated in paragraph 8, the inputs to the model can be altered in the "Scenario", "Ctrl", "Params UMTS" and "Params HSDPA" worksheets. If the inputs for any of the three sets of scenarios are to be edited, then this can be done on the "Scenario"

worksheet. For each set of scenarios, is assumed that all the inputs in the model not specified in the table are set to their default values. In order to set the model to the values of a particular scenario, select the scenario using the corresponding drop-down box at the top of the worksheet and click on the corresponding "Transcribe" button. A macro will then update all of the inputs in the model specified in that table with the values for that scenario.

15.1   For example, suppose that you want to se the model up with the settings for the 2nd UMTS scenario (U2). Then, select the value "Shallow BPL" from the drop-down box in cell D3 on the "Scenario" worksheet and click the "Transcribe" button on row 3.

16   Note that parameters common to both the HSDPA and UMTS link budget calculations reside in the "Params UMTS" worksheet so as to avoid repetition.

17   Due to the non-linear nature of some HSDPA-related quantities, the alteration of the Desired Cell Edge Throughput value on the "Params HSDPA" worksheet in cell D47 should be followed by a left-click on the "Match Demand" button, which sits at the top of this worksheet. This runs a macro that performs HSDPA-related adjustments to the value of cell E134 as part of the link-budget on the "LB HSDPA" worksheet using the Goal Seek functionality within Excel. Since the outputs from Goal Seek calculations can vary very slightly with the starting point, this input value in cell E134 is always set to 1 prior to using Goal Seek.

18   Three additional macros are used to produce the results of the studied scenarios. These can be activated by corresponding buttons at the top of the "Ctrl" worksheet, labelled "Run UMTS", "Run HSDPA" and "Run cell-edge versus cell-area." When each of them is running, the status bar auto-updates with a message stating how many scenarios have been completed. The first two of these buttons should complete their calculations in less than two minutes, but the third of these requires a significant amount of time (over 15 minutes) due to the number of Goal Seek calculations required.

19   In order to preserve the integrity of these macros, existing worksheets should not have their names changed or be deleted and existing named ranges should not have their names changed.

20   Each macro stores different outputs for the three different groups of scenarios, which is why the layout of the three types of output worksheet differ:

20.1   The UMTS-specific worksheets U1-U19 store the planning thresholds separately for speech, basic data and advanced data for each clutter type. In addition, the number of sites required for 5 different carrier deployments are also separately stored for both basic data and advanced data.

20.2   The HSDPA-specific worksheets H1-H13 contain the number of sites required for a range of user demands, for 3 different carrier deployments, each at two assumed BPL depths and three different data rates.

20.3   Worksheets R1-R4 store the cell-edge throughput for a range of assumed cell-area coverage probabilities and for six different HSDPA site deployments.

21   Refreshing the screen throughout is suppressed during the execution of the macros to speed-up the calculations.

12

22   The Excel macros can only change those inputs summarised in the three tables on the "Scenario" worksheet. When the macro has finished, the values for those inputs are restored to the values in the base case (which is always the first line of the table). As a result, the Excel macros implicitly assume that the model has the values for all other inputs set to the default settings. These are specified in green text beside each input cell. This means that the output results generated by the macros will be inconsistent if these other input parameters are altered beforehand.

23   Key outputs within the calculation can be found as follows:

23.1   The minimum number of sites required meeting the coverage and capacity targets are calculated on the worksheets prefixed by "Dimen".

23.2   The numbers of successful connections for the three UMTS services (voice, basic data and advanced data) are also considered on these worksheets.

23.3   The respective site densities are calculated from the Link Budget (LB) and Traffic Demand worksheets after the method described in Annex 13 in the consultation document. The total number of sites is found by using the clutter breakdown as provided by the user, in the "Scenario" worksheet.

Supporting material

24   For those scenarios that assume a Pareto distribution of the traffic demand level, similar calculations as with the average case are performed. Reference material for the required calculations is provided in the "Dimen UMTS Distribut" worksheet.

25   The number of sites for HSDPA is calculated for specific demand levels within the "Dimen HSDPA" worksheet. A chart is included in order to aid visualisation of the dimensioning results, called "C_Sites".

26   The supporting worksheets stated in paragraph 14 are used to generate input for the UMTS and HSDPA dimensioning exercises as follows:

27   The "RateVsLocation HSDPA" worksheet is a separate analysis to illustrate the difference in in-building coverage for different sized networks deployed using the different frequency bands considered. A chart is included In order to aid visualisation of the dimensioning results, called "C_CellEdge". Given a number of sites associated with a specific deployment, this worksheet calculates the cell-area coverage probability for a range of cell-edge throughput requirements. This worksheet is not updated automatically by altering the model inputs. Instead, it serves as an intermediate step in order to produce the output results when running the third group of scenarios. The contents of the table are then deleted after the macro is completed. However, pressing the "Calculate cell-edge throughput" button at the top of the "RateVsLocation HSDPA" worksheet can generate the outputs for the current model setup.

28   The "PL" worksheet provides a description and the implementation of the Path Loss model, which is an extension of the Okumura-Hata model as described by CEPT (European Conference of Postal and Telecommunications Administrations) in WGPT SE-21.

29   The "BPL" worksheet describes the different choices for the Building Penetration Losses and the calculation of the respective shadowing margins

30   The "EdgeVsArea" worksheet provides a detailed cell-area to cell-edge probability conversion table.

Example 1: A simple walk-through example

31   Assume the desired output is the number of sites required to provide coverage of the 80% of the population with a network deployment as in the following:

31.1   2100MHz

31.2   3 sectors per site and 2 carriers per sector

31.3   95% cell-area coverage probability

31.4   1.2Mbps data rate at cell-edge

32   The model user should input these values in their respective cell:

32.1   2100MHz, 3 sectors per site, and 2 carriers per sector in the "Ctrl" worksheet.

32.2   95% cell-area probability corresponds to 87% cell-edge probability (see translation table on the "EdgeVsArea" worksheet), which is then used as an input on the "Params UMTS" worksheet.

32.3   1.2Mbps cell-edge data rate is entered in the "Params HSDPA" worksheet. Note that after typing 1.2 in the respective cell, the user should press "Enter" and then press either of the cursor keyboard buttons, or click elsewhere on the spreadsheet so as to store the new cell-edge throughput value. After doing this, the user should then left-click on the "Match Demand" button so as to perform HSDPA-related link-budget adjustments.

33   The dimensioning results for different traffic demand levels are available on the "Dimen HSDPA" worksheet. For example, for a typical 3MB/user/day traffic demand level, the required number of sites for the different clutter types and the total number of sites over all considered clutter types are presented.

Example 2: Varying the coverage confidence when coverage limited

34   Assume the desired output is the number of sites required to provide coverage of the 80% of the population with network deployment as in the following:

34.1   900MHz or 2100MHz

34.2   3 sectors per site and 2 carriers per sector

34.3   Variable cell-area coverage probability

35   The user should input these values in their respective fields:

35.1   The inputs 2100MHz, 3 sectors per site, and 2 carriers per sector in the "Ctrl" worksheet.

35.2 The cell-area probability corresponds to a certain cell-edge probability (see the translation table on the "EdgeVsArea" worksheet), which can then be input on the "Params UMTS" worksheet.

36 The respective number of sites is calculated in the "Dimen UMTS Average" and "Dimen UMTS Distribut" worksheets. By varying the frequency and the cell-area probability values, the impact of the coverage confidence (over the entire coverage area) can be examined, as explained in Annex 13.

Example 3: Breakdown of site requirements by geotype

37 Assume the desired output is to examine how the estimated number of sites is disaggregated over the different geotypes.

38 Assume that the HSDPA network deployment parameters are as follows:

38.1 900MHz

38.2 3 sectors per site and 2 carriers per sector

38.3 95% cell-area coverage probability

38.4 2.4Mbps per user at cell-edge

39 The user should input the parameters in paragraphs 38.1 to 38.3 as in the above examples.

40 The 2.4Mbps input lies within the "Params HSDPA" worksheet. Note that after typing 2.4 in the respective cell, the user should press "Enter" to store the new cell-edge throughput value. Then, the user should left-click on the "Match Demand" button so as to perform HSDPA-related link-budget adjustments.

41 The dimensioning results for different traffic demand levels are available on the "Dimen HSDPA" worksheet. The results are disaggregated over the different geotypes.

Example 4: Exploration of different demand levels

42 Assume the desired output is to examine what the estimated number of sites is for 60MB/user/day.

43 Note that this traffic demand level lies between the 50 and 100MB/user/day, which are the default traffic demand values.

44 The user should input the value 60 in the "Traffic demand levels (MB/user/day)" table. The table lies in "Lists" worksheet and corresponds to the named array "demand.options". Note that the values in the table should be in ascending order. Thus, the value 60 should replace either the value 50 or the value 100MB/user/day.

45 Multiple alterations of the table inputs are also permitted, as long as the ascending order in demand levels is preserved. Instances of descending traffic demand levels may produce false site count estimations.

46 Exploration of traffic demand levels outside of the default range (0.1 to 100MB/user/day) may result in an error or may produce false site count estimations.

Model limitations

47   To reduce the complexity of the model, for ease of implementation, some simplifications have been made. Hence, there are some known limitations associated with the model which include:

47.1   No account is taken of real-world propagation, cost or site planning constraints.

47.2   The approach analyses a single service and user class at a time.

47.3   No direct account is taken of power control and call admission control processes that are a feature of realistic networks.

47.4   Interference control using features such as antenna downtilts is not modelled directly.

Section 5

Mixed bands model

Introduction

1   This section describes how to use the 'Mixed bands' model to estimate the number of sites required for an operator to build or extend their network for different UMTS demand scenarios using spectrum from different combinations of frequency bands.

2   This model is a standalone Excel workbook called "Mixed bands.xls" and contains no macros.

3   For more detailed information on the methodology of our calculation or the choice of particular parameters, review Annex 13 of the Consultation document "Application of spectrum liberalisation and trading to the mobile sector: Further consultation," dated February 2009.

4   A flow diagram for the model structure, also included on the "Model structure" worksheet in the model, is given below:
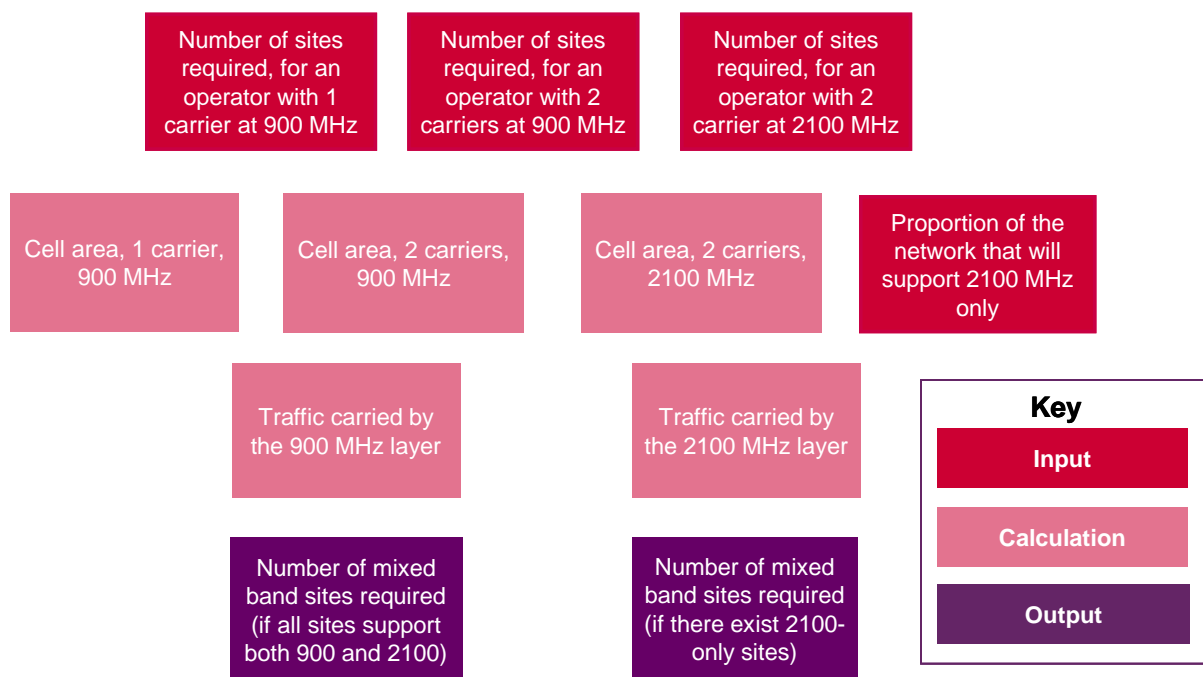
How to use

5   The inputs for the model are specified in the "Inputs" worksheet. The only input is the ratio of total 2100MHz cells to total 900MHz cells, since a network operator is likely to have some 2100MHz-only sites. This ratio can be specified in cell F31.

6   The two remaining quantities on this worksheet are datapoints:

6.1   The number of sites required for a given demand scenario and single band spectrum portfolio stored in cells D6:Q8. These are pasted directly from the

> "Cost differences in densely populated areas – technical" model. For instance, cells F8:S10 on the "H1" worksheet in that model provide inputs for a Depth 2 Building Penetration Loss (BPL) and a data rate of 384kbps.
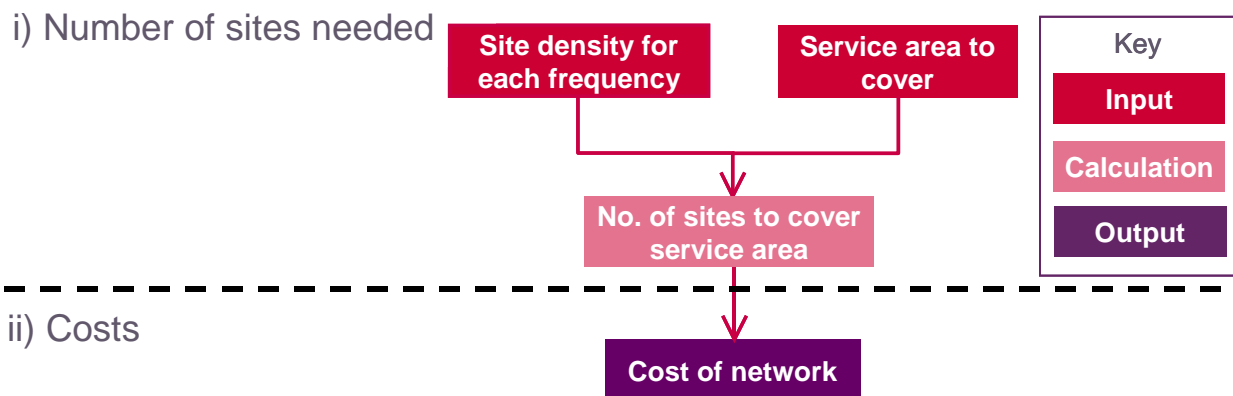
6.2 An estimate of the area in which 80% of the population lives, in cell F35. This value is only used during the calculations to give meaningful intermediate values and is divided out again in the last stage at the calculation. The use of any positive number will give the same final base station volumes.

7 These inputs feed into the main calculation in the "Model" worksheet and the outputs are derived into two tables at the bottom of the worksheet, namely cell sizes and actual base station volumes. These are derived for thirteen different data rates (from 0.3-100Mbit/s).

Section 6

Less densely populated areas – technical model

Introduction

1   This section describes how to use the 'Less densely populated areas – technical' model to estimate the total number of base stations needed to deploy a basic 3G service in less densely populated areas using 900MHz, 1800MHz or 2100MHz spectrum. This is a crucial input in estimating the network costs.

2   This model is a standalone Excel workbook called "Less densely populated areas – technical.xls" and contains no macros.

3   For more detailed information on the methodology of our calculation or the choice of particular parameters, review Annex 14 of the Consultation document "Application of spectrum liberalisation and trading to the mobile sector: Further consultation," dated February 2009.

4   The model has a single core calculation on one worksheet, but this worksheet is duplicated in order to calculate the result for several scenarios. This section will describe how to navigate between the inputs, calculations and outputs within the model.

5   A flow diagram for the model structure, also included on the "Model structure" worksheet in the model, is given below:

i) Number of sites needed

Site density for each frequency	Service area to cover	Key
		Input
		Calculation
No. of sites to cover service area		**Output**

ii) Costs

Cost of network

How to use

6   There are two types of inputs used in the model: those whose values are constant across all scenarios and those whose values are varied by scenario. The former are stored in the "Inputs" worksheet and the latter are tabulated in the "Scenarios" worksheet. Inputs are given named ranges so that they can be easily tracked on the calculation worksheets.

7   The inputs that are currently varied by scenario are:

- Coverage area

- Information rate

- Penetration loss variability

- Body loss (transmit)

- Body loss (receive)

- Signal to noise ratio

- Receiver noise figure

- Combiner, cable and connector losses

- Receiver antenna gain

- Fast fading margin (with TPC headroom)

- Vehicle penetration loss (dB)

- Coverage target

- Transmit antenna gain

- Soft handover gain.

8   The variation of these inputs is what is required in order to generate the ten scenarios that are set up in the model (the base case and Case 1- Case 8). Each scenario has its own calculation worksheet named after the scenario (e.g. the base case is calculated on the "Base Case" worksheet). The reason for this naming is given in paragraph 10 below.

9   Cases 1 through to 7b are included in the Sensitivity Analysis and Case 8 is the Base Case from the consultation 2007.

10   The numbers of base stations for each frequency band are derived for each scenario and the results are then placed into a Summary table on the OUT worksheet. The formulae used in this table require that the calculation worksheet for a scenario has the name as given in the cells D5:D16 on the "Inputs" worksheet. This list of scenario names and the worksheet names must therefore always be synchronised.

11   Changing the value of one input on the "Inputs" worksheet is likely to change the outcome of every scenario. Changing the value of an input in a table in the "Scenarios" worksheet will only change the outcome of the scenario corresponding to the row in the table containing that input. All of the values in these tables are currently pasted values.

12   The core of the calculation is to calculate base station volumes; this is achieved by multiplying a derived site density by the required coverage area.

13   The derived site density (Site Density$_{new}$) is calculated by applying a correction factor to the site densities value calculated in the 2007 consultation multiplied by a correction factor.

- Site Density$_{new}$ = Correction Factor x 2007 consultation Site Density

14   Correction Factor = The correction factor is derived by $\left(10^{\frac{2.\Delta PL}{(10.\alpha)}} \right)$

Where:

α = path loss coefficient

ΔPL = change in allowable path loss, representing the net changes in the link budget calculations.

15   As the most important result of the calculation worksheets, this final step of deriving the base station requirements using an adjusted site density is completed at the top of each worksheet.

16   The calculations in the lower part of each calculation worksheet form a link budget calculation in order to calculate the maximum allowable propagation loss from each base station for each frequency band in that scenario.

Cost differences – cost model

Introduction

1   This section describes how to use the 'Cost differences – cost' model to estimate the costs for an operator to build or extend their network from current capacity for different UMTS demand scenarios using different frequencies.

2   This model is a standalone Excel workbook called "Cost differences – costs.xls" and contains macros that automate particular calculations. These macros can be run various sets of scenarios using four buttons:

   2.1   Two buttons on the "Unit cost calculator" worksheet, which recalculate unit costs for sites and equipment over time

   2.2   One button on the "Results" worksheet, which will run the set of scenarios on this worksheet

   2.3   One button on the "Scenarios" worksheet, which will run the set of scenarios on the "Results" worksheet for several different unit cost parameters

3   For more detailed information on the methodology of our calculation or the choice of particular parameters, review Annexes 12 and 15 of the Consultation document "Application of spectrum liberalisation and trading to the mobile sector: Further consultation," dated February 2009.

4   A flow diagram for the model structure, also included on the "Model structure" worksheet in the model, is given below:

22
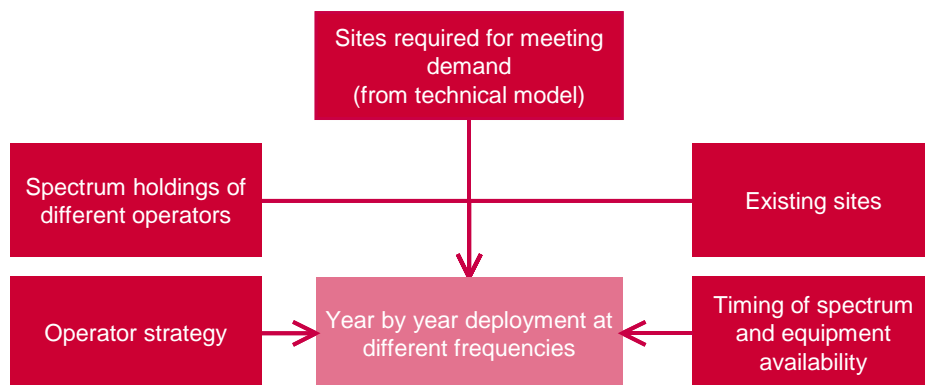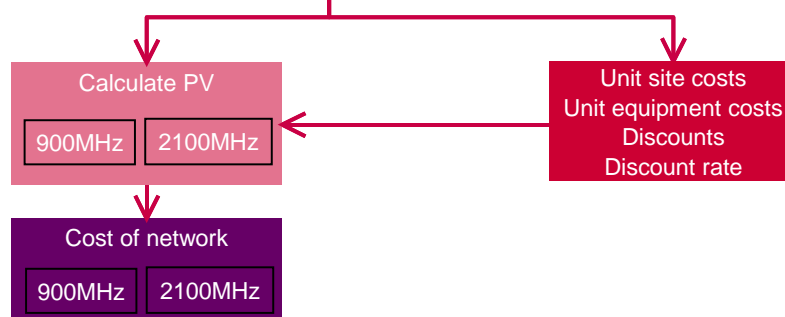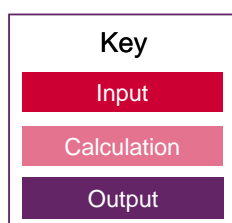
How to use

5   The variable input parameters for the model are specified in the "Inputs" worksheet. Where only particular values can be used for the input, a drop-down box with a list of the available options is provided.

6   The major input parameters in the model are as follows and are described in more detail in paragraphs 7 to 12:

6.1   Target site numbers

6.2   Unit cost parameters (including the unit capex, unit opex, price trend, asset depreciation and discount rate)

6.3   Roll out parameters (including site cost discounts, existing site numbers, pre-committed roll out, upgrade preferences, access to 800MHz spectrum, assumed roll out profile of existing UMTS2100 sites)

6.4   Sensitivities

6.5   Scenarios

6.6   Scenario runs

7   There are three sets of target site numbers. These are a target number of UMTS900 (combined with UMTS2100) sites, the equivalent number of UMTS2100 only sites that would be required to give the same quality and the equivalent number of sites at 800MHz that would also give the same quality. These inputs should only be changed in cells F86:H185 within the scenario table on the "Sensitivities" worksheet.

8   The unit cost parameters can be found at the top of the "Inputs" worksheet and feed into the unit cost calculations on the "Unit cost calculator" worksheet. These parameters should only ever be changed on the "Inputs" worksheet and not on the "Unit cost calculator" worksheet. The "Unit cost calculator" worksheet calculates the unit cost of a site built in a given year and decommissioned in a given year, if it is decommissioned at all. Two macros, which can be activated by the buttons "Update site costs" and "Update equipment costs" on the "Unit cost calculator" worksheet, determine these costs for all combinations of build years and decommission years. The outputs of these two macros are pasted onto the "Site unit costs" and "Equipment unit costs" worksheets, which then feed into the cost calculation on the "Total cost" worksheet. Whenever a unit cost parameter is changed, these two macros must be re-run to update the site and equipment unit costs. Otherwise, the results generated will be those based on the unit cost parameters in use when the macros were last run. Both macros take approximately three minutes each to run.

9   Those parameters classified as "roll out parameters" are all the other parameters on the "Inputs" worksheet. These feed into the "Roll out (site numbers)" worksheet and determine the site roll out profiles for the 900MHz operator, the single 2100MHz operator and the RAN sharing 2100MHz operator given a set of target site numbers. The unit costs are then used to calculate the total cost for each of the operators. All of these parameters should not be changed on the "Inputs" worksheet. Instead, so that batches of results can be generated within the model, we have included functionality to run sensitivities, as described in paragraph below.

10   A sensitivity is a set of values for every roll out parameter. All of the sensitivities set up within the model can be found on the "Sensitivities" worksheet. These enable the user to store different sets of roll out parameters. As stated above, it is only on this worksheet that roll out parameters should be changed. If the user wishes to run different sensitivities to those already stored on the "Sensitivities" worksheet, then it is recommended that they save another version of the model and over-write the existing sensitivities.

11   A scenario is used to select a sensitivity within the model. It consists of a set of target site numbers and a selected sensitivity. Together these will determine the number of sites deployed by each operator (900, single 2100 and RAN-shared 2100) and when these sites are deployed. This resulting roll out profile is turned into costs by applying the unit costs. "Scenarios" are entered into the "Results" worksheet in the table starting in row 86. A scenario is one row on this table and should also have a description and a scenario number in addition to a set of target site numbers and a sensitivity number. This sensitivity number corresponds to that in the table of sensitivities on the "Sensitivities" worksheet. The row above the start of the table (row 85) should not be edited. Up to 100 scenarios can be entered into this table. The scenario number must be sequential and begin at 1. It is the scenario number that allows the model to recognise a scenario in the table. Hence, scenario numbers should occur in the table if and only if there is a corresponding scenario. There should never be blank rows between scenarios.

12   Scenario runs allow all of the scenarios listed in the "Results" worksheet to be calculated for different sets of unit cost parameters. Scenario runs are summarised on the "Scenarios" worksheet. Scenario runs can be calculated using the macro button "Update all scenario runs" at the top of the "Scenarios" worksheet. This is described in more detail in paragraph 15 below. The input parameters that can be varied between scenario runs are:

    12.1   Cost scenario (low, medium or high)

    12.2   Opex as a proportion of capex

    12.3   Site cost trend

    12.4   Equipment cost trend

    12.5   Commercial discount rate.

Generating results

13   Results can be generated across all scenarios for either the current unit cost parameters or for those across all scenario runs.

14   In order to generate the results for all scenarios entered onto the "Results" worksheet based on the current unit cost parameters, click the button "Update results" on this worksheet. This runs a macro that goes down the table of scenarios, and for each scenario enters the set of target site numbers and set of roll-out parameters into the model, pulling out the total cost for each type of operator. The cost differences are also calculated. The model calculates results for both the single and RAN shared 2100 operator simultaneously, so the final parameter in cell E156 on the "Inputs" worksheet should not be changed. The results are then pasted into a table to the right of the scenarios table. The buttons "Update site costs" and "Update equipment costs" on the "Unit cost calculator" worksheet should be pressed before pressing the

"Update results" button, to ensure that the site unit costs are calculated using the current site cost parameter on the "Inputs" worksheet.

15   In order to update all scenario runs, the button "Update all scenario runs" should be pressed on the "Scenarios" worksheet. For each scenario run summarised in the table, this macro:

   15.1   Over-writes the unit cost parameters with those for the scenario run

   15.2   Updates the site and equipment unit costs based on the new parameters

   15.3   Re-calculates the outputs for all the scenarios

   15.4   Pastes the outputs from the "Results" worksheet (the named range "SR_copy_area") into an output worksheet after the "Scenarios" worksheet. Their worksheets names take the form "SR*n*," with worksheet SR*n* containing the scenario outputs from the nth scenario run. The outputs are pasted into the named range "SR*n*_paste_area" on the worksheet "SR*n*."

16   A single worksheet called "All results" pulls the results of the scenario runs together from the worksheets for each scenario run. The charts C1-C9 are then derived from this worksheet.

17   The model also produces charts for the 900MHz and 2100MHz operators that show how many sites they roll out and when. Note that the single 2100MHz operator and RAN-shared 2100MHz operator roll out profiles should the same, provided that they pre-commit to the same roll out by 2010. The only difference between them is the costs that they face.

18   The charts are named "C_900_op" and "C_2100_op" and show the charts associated with the scenario that the model is currently running on. This is determined by the value of the named range "Current_scenario" on the "Results" worksheet (cell E85). If the user wishes to generate the charts for a particular scenario, then they can do so by changing "Current_scenario" manually. Since this is simply calling values from the output table, the user does not need to click on "Update results."

Section 8

Cost of release model

Introduction

1   This section describes how to use the 'Cost of release' model to estimate the costs to the operators of clearing various quantities of 900/1800MHz spectrum to allow release of a proportion of this spectrum to third parties.

2   This model is a standalone Excel workbook called "Cost of Release model.xls" and contains several macros to both run scenarios within the model and to update the model with outputs from the Accelerated migration model.

3   For more detailed information on the methodology of our calculation or the choice of particular parameters, review Annex 16 of the Consultation document "Application of spectrum liberalisation and trading to the mobile sector: Further consultation," dated February 2009.

4   A flow diagram for the model structure, also included on the "Model structure" worksheet in the model, is given below:
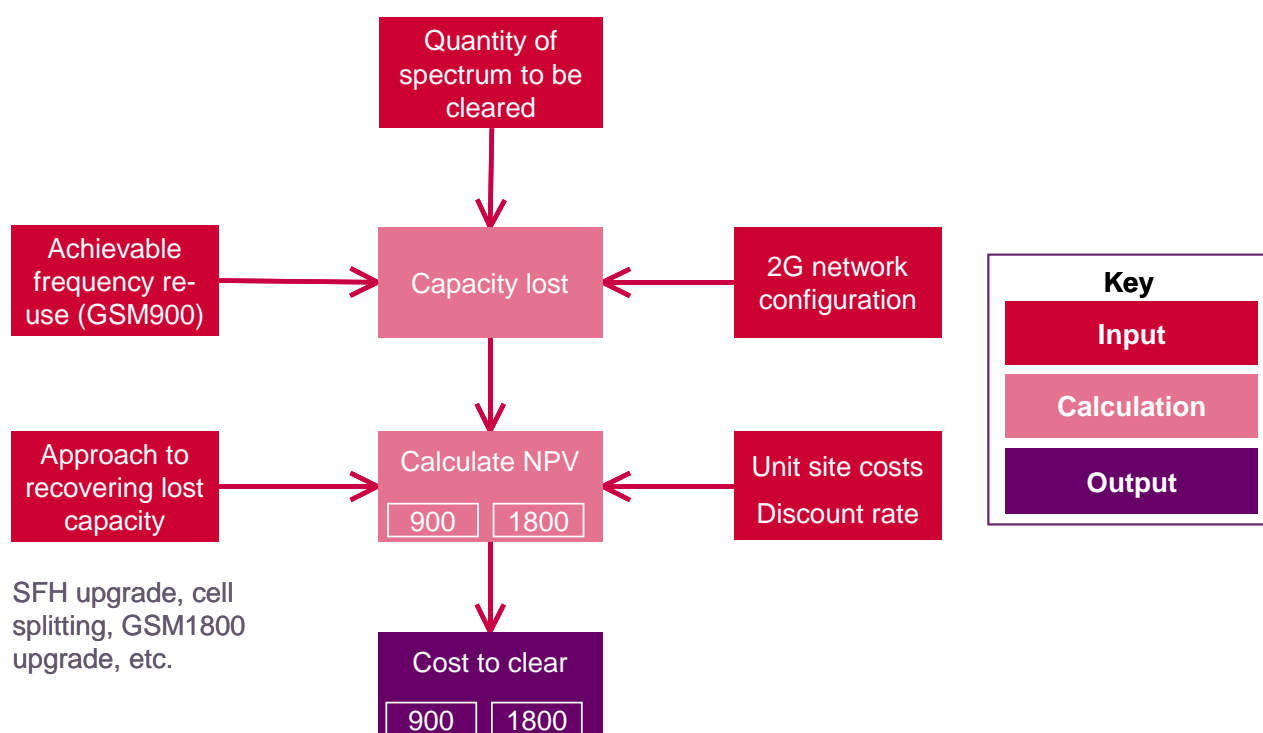
5   The purpose of the model is to estimate the costs of clearing various quantities of 900MHz and/or 1800MHz spectrum of GSM carriers to allow release of some proportion of this spectrum to third parties.

How to use

6   The variable inputs for the model are specified in the "Ctrl" worksheet and the "UnitCosts" worksheet. Site and transceiver data is entered separately on the "Counts" worksheet, although the released model contains illustrative values only.

7 The inputs on the "Ctrl" worksheet that are varied in the scenarios presented in the consultation document are highlighted in bold and can be found in the following cells:

7.1 The year in which spectrum is released in cell E4

7.2 The SFH clustering factor in cell E13

7.3 The inflation of site acquisition costs over time in cell E20

7.4 The GSM1800 spectrum available (MHz) for the 900/1800MHz operators (Networks A and B) in cells E36 and E37

7.5 The switch to "Remove interleaving" in cell E68, which includes the costs of removing interleaving to SFH upgrade costs

7.6 The proportion of overall traffic as a percentage of current levels in cell E70

7.7 The site upgrade unit cost level in cell E75, which is used to multiply site unit costs. Although a medium level is included, the settings most commonly employed are "Low" and "High."

7.8 The discount rate in cell E83.

8 Cell E97 on the "Ctrl" worksheet contains a value for the number of UMTS2100 base station sites required to cover the area remaining after covering the first 80% of the population. This value is taken from cell F42 on the "Base Case" worksheet in the "Less densely populated areas - technical" model and must be pasted in manually to update it.

9 There are four operators captured in the model, labelled A, B, C and D. Networks A and B are intended to model the combined 900/1800MHz operators, whereas Networks C and D are intended to be the 1800MHz-only operators. Input parameters that vary by network have been made to be indistinguishable between the two pairs of A and B and C and D, with one exception. This is the input for the number of UMTS2100 carriers available, where one network (A) has been given 3 carriers to reflect reality.

10 Separate unit costs (and cost trends) are provided on the "UnitCosts" worksheet for different site upgrades in different parts of the UK. The upgrades are those for cell splitting and 2.1GHz widening, or for Synthesised Frequency Handover (SFH) and upgrades to the GSM1800 equipment.

11 The site and sector numbers on the "Counts" worksheet, which have been populated with dummy data in the released model, are broken down into some detail. Specifically:

11.1 Sites are broken down to those macro sites with and without GSM1800, and then split into those within the area of the first 80% of the population (split further into those within and outside the M25) and the rest of the UK.

11.2 Sectors are split by the number of carriers they use and further by site type:

a) By region: those within the area of the first 80% of the population (split further into those within the M25 and outside the M25) and the rest of the UK.

b) By base station configuration: sites with GSM900 only, sites with GSM1800 only, sites with separate GSM900 and GSM1800 sectors and sites with combined GSM900 and GSM1800 sectors.

12   The outputs of the model are the costs of a selection of options to upgrade the GSM networks in order to accommodate a particular level of traffic using fewer GSM carriers, as discussed in Annex 16. Different options are considered depending on whether the operator has access to either 900MHz and 1800MHz spectrum (i.e. A and B) or only 1800MHz spectrum (i.e. C and D). Each option is calculated on a different worksheet at the end of the model, with A and B calculated on worksheets prefixed by "AB" and C and D calculated on worksheets prefixed by "CD." The full cost of release of spectrum is calculated for all networks on the "ABCD1" worksheet. Hence, the different options are calculated in parallel.

13   The options calculated are summarised in two tables on the "Results" worksheet, in cells E8:G14 and E297:G301. The worksheets names in the middle column should not be edited unless the corresponding worksheets also have their names changed.

14   Certain costs of handset migration are taken from the Accelerated migration model, which are pasted onto the "Results" worksheet. These can be updated by taking the following steps:

14.1   Ensure both the Cost of Release and Accelerated migration model are open and that the Accelerated migration model is set to its default values (which are the values in green text in column F on the "Control" worksheet beside the input parameters).

14.2   Set cell H104 on the "Results" worksheet equal to the name of the Accelerated migration model (the default name of "Accelerated Migration.xls" is currently entered).

14.3   On the "Results" worksheet in the Cost of Release model, click on the button "Update first block values." This updates the cells in the range J119:J125, which are used to work out which line of the output table in the Accelerated migration model is required. This is explained in more detail below in paragraph 16.

14.4   Click on the button "Update handset migration costs." If the Accelerated migration model is not open, or if cell H104 is incorrect, then an error dialog box will appear and the process will be stopped. The input values required for the Accelerated migration model (date of release and growth in 2G SIMs) are provided in the table in the range E119:I125 on the "Results" worksheet in the Cost of Release model.

15   The outputs from the Accelerated migration model are the costs associated with migrating handsets according to both the number of spectrum blocks to be cleared by accelerated migration and the number of blocks already cleared by other methods. The values are taken from the cells H64:K70 on the "Cost of Migration" worksheet, although the total cost of release is taken from cell G74. These cells take the outputs of the actual model, double them to capture both operators (A and B, or C and D) and then round them to the nearest £5 million.

16   For each scenario run in the Accelerated Migration model by the second macro in paragraph 14.4, the correct line in the output table in the Accelerated Migration model is identified by the cells calculated by the first macro stated in paragraph 14.3.

This value is the number of blocks cleared by other means. For example, the first handset migration scenario assumes that 4 blocks are cleared by means other than handset migration. The outputs taken are those on the fifth row of the output table in the Accelerated Migration model, corresponding to the row for 4 blocks cleared by other means. Since costs are required for the number of blocks cleared between 1 and 6 blocks, in this example, the following values are pasted into the Cost of Release model:

16.1   The handset migration cost for 1, 2, 3 and 4 blocks is zero.

16.2   The costs for 5 and 6 blocks are the first and second values respectively in the fifth row of the output table in the Accelerated Migration model.

17   The values in the range J119:J125 on the "Results" worksheet are calculated using the second macro for each handset migration scenario. This macro pastes, for each handset migration scenario, the value of the formula in cell J117 on the "Results" worksheet into the corresponding row in the range J119:J125.

18   The consultation document contains several tables of model outputs with separate columns when low and high unit costs are used. These tables are duplicated on the "Tables" worksheet at the end of the model. A macro can be run using a button labelled "Re-run for high and low unit costs" on the "Results" worksheet, which calculates the model on both the low and high unit cost settings and then pastes the output costs into these tables.

Section 9

Accelerated migration model

Introduction

1   This section describes how to use the 'Accelerated migration' model to calculate the likely cost to operators of accelerating their migration of their customers from 900MHz to 2.1GHz spectrum, if a proportion of 900MHz capacity is taken away.

2   This model is a standalone Excel workbook called "Accelerated migration.xls" and contains no macros.

3   For more detailed information on the methodology of our calculation or the choice of particular parameters, review Annex 16 of the Consultation document "Application of spectrum liberalisation and trading to the mobile sector: Further consultation," dated February 2009.

4   Outputs from this model are used to feed into the Cost of release model: the process for updating this data is described in paragraphs 14 to 17.

5   A flow diagram for the model structure, also included on the "Model structure" worksheet in the model, is given below:
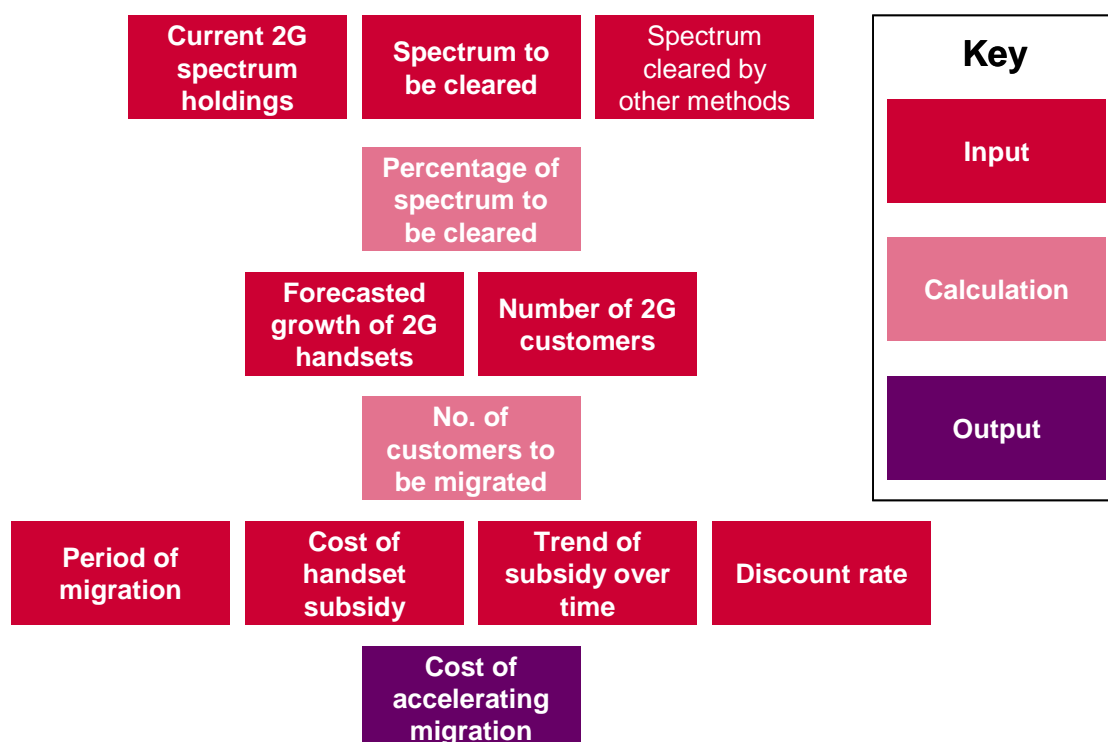
How to use

6   The variable inputs for the model are specified in the "Control" worksheet. In almost all cases, these are selected using a drop down box, from a list of options specified

below the input cell within grouped rows. These inputs are summarised below in paragraphs 9 to 19.

7   There are two stages of calculation in the model:

   7.1   On the "Spectrum to be Cleared" worksheet", the amount of spectrum to be cleared according to the inputs is derived. If the amount of spectrum to clear exceeds the total holdings, then the value #N/A is returned in the table

   7.2   The cost of accelerating the migration of handsets to 3G in order to clear this quantity of spectrum is then calculated on the "Cost of Migration" worksheet, resulting in an NPV (in 2007/08 prices) of the total cost in the cell range G51:K57.

8   By altering any of the inputs, the NPV of the total cost of the accelerated migration re-calculates in this table.

9   The number of blocks of 900MHz spectrum to be cleared and already cleared per operator by accelerating the migration can be entered into cells E3 and E13 on the "Control" worksheet respectively. Up to 3 blocks can be entered into each cell, although this is only realistic if 1800MHz holdings are included.

10   The 1800MHz spectrum holdings can either be included or excluded using the binary choice in cell E15, with the efficiency of the holdings specified in E20. If 1800MHz spectrum is included, then the specified proportion of the 1800MHz holdings are included within the spectrum in scope in the "Spectrum to be Considered" worksheet.

11   An option of clearing all spectrum can be selected in cell E22. If this is selected, then, regardless of the assumptions above, the entire spectrum is cleared.

12   The year in which release occurs is entered into cell E27.

13   The number of years in which the release of spectrum occurs can be entered in cell E39, with options from 1-3 years.

14   The cost of a 3G handset subsidy in 2007/08 sterling is entered in cell E45.

15   An absolute difference in the cost trend between 2G and 3G real handset prices can be entered in cell E52, in 10% increments. A value of –10% means that 3G prices are falling 10% faster than 2G prices.

16   The growth in 2G SIMs (net of migration) before the release of spectrum can be entered into cell E66.

17   The number of 2G SIMs per operator in 2007/08 can be entered in cell E81

18   The starting price and price trend for a 2G handset can be entered into cells E82 and E83 respectively.

19   A discount rate for the model is entered in cell E85.