WIK-Consult • Final Report

Study for the Commerce Commission of New Zealand

Cost Driver Sensitivity Analyses with Mobile Cost Models

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Content

1 Introduction

This study was carried out by WIK-Consult on behalf of the Commerce Commission of New Zealand during the period from 24 November to 22 December 2008. It consists of comparisons and sensitivity analyses regarding the costs of terminating voice calls and SMS messages on mobile telecommunications networks. The analyses were carried out with bottom-up cost models that were developed by the consulting companies WIK-Consult and Analysys.

In particular the report covers

- Cost driver sensitivity analyses carried out with WIK models for three types of countries representing countries of different sizes and population densities (section 2);
- Cost driver analyses with the model from Analysys used by the British regulatory authority Ofcom for its determination in 2007 regarding mobile call termination rates (section 3.2), and
- A brief statement regarding other countries' use of the Analysys model in their mobile call termination rate decisions, pointing out in particular to what extent the actual termination rates determined correspond to the calculated costs (section 3.3).

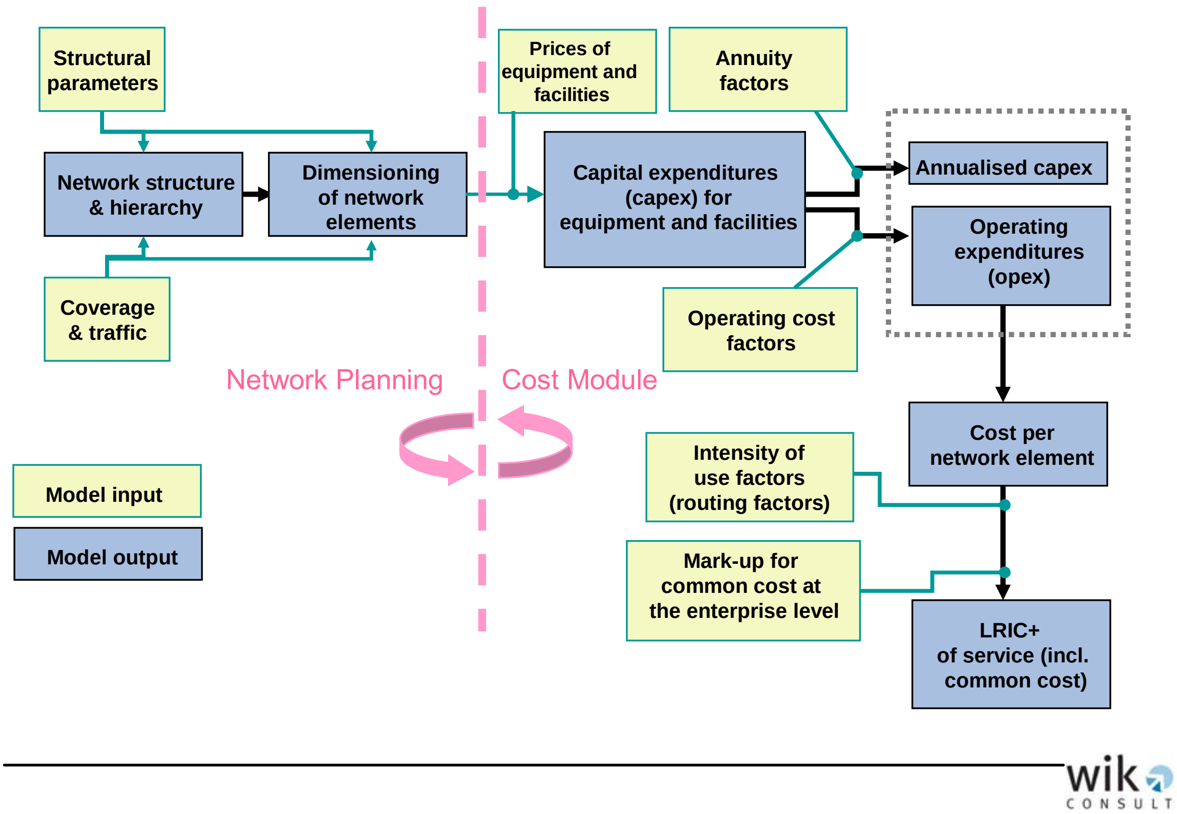
Section 4 summarises, drawing in particular attention to the most important drivers of the cost of mobile services.

2 Cost driver sensitivity analyses with the WIK model

2.1 The WIK approach to mobile network cost modelling

A detailed description of WIK's bottom-up mobile network cost model is contained in the Annex. A brief summary is best provided on the basis of Figure 1 below. As shown in the figure, the modelling process consists of two separate steps, the first being the planning of the relevant network and representing it on the computer, the second being the determination of the costs of the services of interest that are due to this network.

Figure 1: Schematic view of the modelling process for WIK's mobile network cost model



The structural parameters that the modelling process starts with are the population of the territory in question, information about the portion of the territory covered, penetration in the areas covered, average demand by subscribers during the busy hour in terms of Erlang and the distribution of that demand among the various services. Given this information, engineering know-how is applied to plan a network that efficiently delivers services demanded to subscribers as well as provides interconnection services to other networks. From the network structure thus established the list of required network elements and corresponding facilities and equipment (e.g. number of base station locations, number of switches, lengths of leased lines of various capacities) are derived. This then provides the information to carry out the cost calculation. For this the following information is required:

- prices of the facilities and equipment,
- the value of the WACC,
- the lengths of the economic lives of facilities and equipment,
- expected growth rates of the various services,
- mark-ups to determine operating expenses as a function of the replacement values of facilities and equipment,

- the matrix of the intensity of use factors (also known as routing matrix) by which the costs of the various network elements are assigned to the various services (actually a result of the network design),
- mark-ups for common cost at the enterprise level.

The cost of each service consists of three components, the user cost of capital (depreciation, cost of money), referred to as annualised capex, cost of operating and maintaining the network, referred to as opex, and common cost at the enterprise level. Annualised capex of each facility or piece of equipment is determined using the annuity approach that integrates depreciation and cost of money as well as expected changes in the prices of these inputs and the expected growth in output (an extension of the so-called "tilted" annuity approach). Opex is determined on the basis of a mark-up on the values of the network elements where these values are at replacement prices. The reason for this approach is that this cost component is very difficult to model explicitly and there exist so far no such models that are able to do so, further because the approach we use has been empirically validated by actual data from operators. Common cost at the enterprise level is added to network costs as a mark-up; it is also based on evidence from operators' cost records. Note that no common costs are calculated at the level of the network as any cost component of a network element that does not vary with volume – usually only over a certain volume range – is rolled into the network cost for the various services.

The model determines costs according to the LRIC cost standard which implies that whenever there is joint use of resources, the costs of these resources are assigned to services according to the principle of cost causation. This is implemented by determining the costs of network elements and assigning shares of these costs to the various services according to the intensity with which they use the network elements. Whenever such network elements are also used by services not modelled (for example whenever their is shared use of facilities by different networks), this is taken account of by including the applicable share of the costs only.

Being truly bottom-up, the WIK model takes a scorched-earth perspective with respect to the locations of base stations. Further, it is based on 2G technology. In many jurisdictions there is currently a transition from 2G to 3G technology. Successful 3G deployment should lead to costs per unit of service that are lower than those due to a 2G network. The WIK model is constructed on the assumption that initial higher costs of 3G technology, which would be of a transitory nature, are not to be blended into the cost of services that are modelled to be provided by an efficient 2G operator.

Below we present results of cost driver sensitivity analyses for three types of countries. The corresponding model calculations were carried out in 2006 and 2007 based on data which was then available. The complete model as described above was available for two of these country types, i.e. what we will call the "small densely populated (SD)" and the "large sparsely populated (LS)" country types. For the "medium sized densely populated (MD)", a version of the model was used that focuses on the access network composed of base stations (BTSs) and base station controllers (BSCs) and uses for the higher network segments benchmark values. With this version only a smaller set of sensitivity analyses could be carried out.

2.2 Sensitivity analyses

2.2.1 The setting

The starting point are implemented WIK cost models for three different types of countries, categorised as follows:

- SD: a small densely populated country (not unlike Austria, Switzerland, Slovakia, etc.)
- MD: a medium sized densely populated country (not unlike Germany, France, UK, etc.)
- LS: a large sparsely populated country (not unlike Canada, Australia, Brazil, etc.)

The basic cost drivers of mobile services, and therefore also of termination services, are demand, technology (which determines the structure of the network), and the prices of the inputs. Decisions by the management of an operator, e.g. regarding the quality of services delivered, can critically affect costs and therefore also qualify as cost drivers. Sometimes, intermediate output variables are considered to be cost drivers if they are of particular significance, e.g. the number of base stations given that these constitute by far the largest share of the cost of a mobile network.

For each of the country types listed above, we start from a base case calculation which is described in detail at the end of this subsection. Cost driver sensitivity analyses are then carried out by determining the costs of termination with the values of particular cost drivers having been changed, and evaluating the resulting differences. Each such analysis is called a scenario. The parameter changes defining the scenarios are as follows:

- volume changes due to decreases in market share and to a general decrease in demand,
- change in the composition of demand, in particular a shift consisting in a decrease in the volume of voice calls and an increase in the volume of SMSs and MMSs,
- changes at the level of the network, notably a change in the QoS and a shift from the use of one frequency spectrum band to another one,
- changes in cost parameters, e.g. the WACC and the prices of facilities and equipment.

The scenario shown under the second bullet, covering a shift from voice to SMSs, will report the cost and cost changes of terminating SMSs, in addition to the costs of terminating voice calls. In the remaining scenarios, only the effects of parameter changes on the costs of voice call termination will be shown. The effects on the cost of SMS termination will all be in the same direction and of the same relative magnitude as those for voice.

The features of the base case for each country type are as follows:

- a 35 % market share,
- an amount of investment per base stations, including its share for the base station controller (BSC), that ranges between 190,000 and 200,000 Euro,
- a WACC equal to 10 %,
- penetration equal to 96 %.

The costs resulting from the base cases are always shown together with those for the various scenarios to be able to assess the magnitude of the relative cost changes due to the parameter changes.

2.2.2 Changes in volume

Table 1 shows the cost of termination for the base case and two scenarios with volume changes:

- Scenario 1: Decrease of market share from 35 % to 25 %.
- Scenario 2: Market share as in the base case but a general reduction of 28.5 % in volume (the 28.5% correspond to the shift from a 35 % to a 25 % market share).

For these scenarios, figures for the total volumes in minutes are also provided. These are so-called network minutes, i.e. the minutes carried by the base stations. This is important as calls that remain on the same network from start to end uses a base station twice; their proportion therefore influences network size. Note, too, that data services, which are normally measured in different dimensions, are included in terms of voice minute equivalents.

For scenario 2, which involves the reaction of cost to a percentage change in a cost driver, the value of the *elasticity* of the reaction to this parameter change is also shown in table 1. (An elasticity is here defined as the percentage change in the cost per minute divided by the percentage change in the cost driver.) As regards subsequent scenarios, whenever cost driver changes can be expressed as a percentage change, elasticity values will also be shown.

Scenario 2 cannot be carried out with the MD country type model.

Table 1: Cost changes due to changes in volume

Cases calculated		Results for		
		SD	MD	LS
Base case:	Cost/minute	3.51 €ct	3.69 €ct	4.18 €ct
	Total volume in minutes	4.2 bn	ca. 53.00 bn	11.5 bn
Scenario 1:	25 % market share			
	Cost/minute	3.78 €ct	3.82 €ct	4.83 €ct
	Relative change	+7.7 %	+3.5 %	15.6 %
	Total volume in minutes	2.973 bn	ca. 42.00 bn	8.188 bn
Scenario 2:	Decrease in demand by 28.5 %			
	Cost/minute	3.88 €ct		5.02 €ct
	Relative change	+10.5 %		+20.1 %
	Elasticity	-0.37		-0.71
	Total volume in minutes	2.974 bn		8.189 bn

Comments:

(1) The fact that the cost of termination for LS is highest reflects the relatively high costs of transport between nodes which is due to the great distances in that country. The costs for the other two country types are correspondingly lower where, as we will see below, costs of transport are particularly low in an SD type country.

(2) Lower volumes, both when due to a lower market share or to generally lower levels of demand, have the effect of decreasing the economies of scale that may be realised. The most important example for which this is true are base stations that need to be set up in areas to be covered independently of whether the market share is high or low, and in particular even if traffic is not enough to fully utilise them. This shows in the higher cost per minute across the three country types and for each of the two scenarios.

(3) The two scenarios reflect reductions in volume of about the same size (see the volume figures). In both cases the cost rises but there are differences in the magnitudes. In scenario 2 the cost rises more than in scenario 1 due to a different geographical distribution of volumes in the two cases.

While Table 1 gives results from a cross section of models for countries at about the same time (2006/2007), Table 2 compares results with the same model for the MD type country over two periods.

Table 2: Cost changes due to growth in demand over time

Cases calculated	Results for market share* of		
	15 %	25%	35 %
Cost calculations for 2005			
Cost/minute (in Euro cent)	6.42 €ct	5.11 €ct	5.04 €ct
Total volume in minutes	ca. 11 bn	ca. 21 bn	ca.33 bn
Cost calculations for 2007			
Cost/minute (in Euro cent)	4.08 €ct	3.82 €ct	3.69 €ct
Total volume in minutes (in billion)	ca. 28 bn	ca. 42 bn	ca.53 bn

* The actual calculations were made for market shares close to the shown values.

Comments:

(4) There are decreases in cost due to higher market share in both the 2005 and the 2007 rounds of calculations. However, the decreases are steeper in the earlier round, especially from a 15 % to a 25 % market share, due to the fact that overall demand was not so high yet at the time so that low market share meant a larger share of base stations that were coverage and not traffic driven. (It needs to be kept in mind that base stations are responsible for the highest share of cost.)

(5) Note that the 35 % market share *volume* in the earlier round is higher than the 15 % market share *volume* in the later round, yet the *cost/minute* is higher for the higher volume in the earlier round. This is again due to the fact that at the time of the earlier round overall demand was not yet as strong and a large share of that 35 % market share demand came from areas with coverage driven base stations while at the occasion of the later round overall demand had become substantially stronger and a large share of the 15 % market share demand came now from areas with traffic driven base stations.

2.2.3 Change in the composition of demand

Results for the third scenario can only be provided with the models for the SD and LS country types. It is defined as follows:

- Scenario 3: An tenfold increase in the volume of SMSs with a compensating decrease in the volume of voice services.

Note that this increase in SMSs is large enough that through it more information (in terms of content) could be exchanged than through all minutes of voice calling that – after this shift – still remain to be carried over the network. Yet these voice call minutes require more than 90 % of network capacity while the new volume of SMSs requires less than 4 %.

Table 3 shows the changes in the costs of both types of termination relative to the base case.

Table 3: Cost changes due to shifts in demand from voice to SMS messages

Cases calculated		Results for	
		SD	LS
Base case:	Cost of terminating one minute of a voice call	3.51 €ct	4.18 €ct
	Cost of terminating an SMS	0.063 €ct	0.025 €ct
Scenario 3:	Shift from of demand voice to SMSs		
	Cost of terminating one minute of a voice call	3.78 €ct	4.22€ct
	Relative change	+7.7 %	+1.0 %
	Cost of terminating an SMS	0.021 €ct	0.010 €ct
	Relative change	-67.0 %	-60.0 %

Comments:

(6) The low cost of conveying, and for that matter of terminating, SMSs is due to the fact that SMSs, as noted above, require per message a much lower capacity than is needed for one minute of voice calling. In particular, according to the standard conversion rule, the capacity of one minute of voice calling is sufficient to carry 432 messages.

(7) The largest share of the cost of an SMS is actually its share of the cost of the SMS centres. In both models it is assumed that two such centres are sufficient for the volumes of messages in the base case as well as in scenario 3. From the increases in the volumes of messages follow substantially larger economies than were realised in the base cases, with the effect of reducing the cost per SMS accordingly. The effect in the SD case is relatively more substantial as here due to the lower starting volume there is still more room for realising economies of scale when increasing volume.

(8) Due to the shift in demand we observe an increase in the cost of voice call termination and a decrease in the cost of terminating SMSs. The explanation for this is that (a) in the case of voice call termination there is one effect making for higher cost, and (b) there are two opposing cost effects in the case of SMSs.

(a) The relative increase of SMS volumes and the relative decrease in voice traffic means de facto a decrease in the demand for network capacity. For example all SMSs use a base station only once while a large share of voice traffic, i.e. so-called on-net minutes, use base station services twice, at the up and at the down leg. Through this shift there is a decrease in the demand for capacity which, however, is relatively smaller than the decrease in network minutes, and therefore there is a decrease in economies of scale which increases cost. For this reason the cost of terminating voice calls increases.

(b) While the cost of SMSs is also affected by the increase discussed under (a), this increase is more than compensated by the substantial economies of scale at the level of the SMS centres as discussed in comment (7).

(9) The relative increases in network costs (reflected in the relative increases in the costs of termination) differ between SD and LS due to reasons of lumpiness in the network facilities. In the case of LS, the decrease in total volume induced a relatively larger reduction in investment than in the SD case so that economies of scale were not so much impaired and the increase in the cost per minute of termination therefore increased only slightly.

2.2.4 Changes at the level of the network

Table 4 shows the cost of termination for the base case and the following two changes in network features:

- Scenario 4: Reduction in QoS by increasing the maximum blocking probability from 2 % to 5 %.
- Scenario 5: Shift from 900 MHZ to 1,800 MHz spectrum together with a decline in QoS.

Note the simultaneous change in scenario 5 of a shift in use of spectrum and a decrease in QoS. This is done to maintain comparability across the models as the MD model results are only available in this combination. Also maintaining a maximum 2 % blocking probability with 1,800 MHz band spectrum in areas that are coverage driven would increase cost/minute so much to make this an implausible scenario.

Table 4: Cost changes due to changes in QoS and to a shift in the use of frequency spectrum

Cases calculated		Results for			
		SD	MD		LS
			Earlier round	Later round	
Base case:	Cost/minute (in Euro cent)	3.51 €ct	5.04 €ct	3.69 €ct	4.18 €ct
Scenario 4:	Reduction in QoS by increasing the maximum blocking probability from 2 % to 5 %				
	Cost/minute	3.09 €ct			3.86 €ct
	Relative change	-12.0 %			-8.0 %
Scenario 5:	Shift from 900 MHz to 1,800 MHz spectrum together with a change in QoS as above				
	Cost/minute (in Euro cent)	5.79 €ct	5.61 €ct	3.83 €ct	6.28 €ct
	Relative change (in %)	+65.0 %	+11.4 %	+3.7 %	+50.0 %

Comments

(10) The QoS variations by themselves can only be done with the SD and LS models. They show that reductions in QoS may reduce cost significantly. Since QoS is an important competition parameter, the models normally assume routinely that a high QoS (blocking probability of no more than 2 %) is implemented.

(11) It holds in each of the three cases considered that a part of the territory served does not generate enough traffic to fill the base stations there up to capacity. In these cases the number of base stations is determined by the maximum area that a base station can cover, i.e. by the radius of propagation which in turn depends on the frequency band used. When 1,800 MHz spectrum is used and there is a substantial share of territory for which the number of base stations is coverage (i.e. propagation radius) driven, costs go up sharply because this type of spectrum's propagation properties are much worse than those of 900 MHz spectrum. So that costs remain at all manageable, QoS is lowered, here by implementing a maximum blocking probability of 5 %. The fact that the cost increases shown by the MD model are much more moderate than for the SD and LS models may indicate two things: either these models overestimate the cost effect of the shift from 900 to 1,800 MHz spectrum, or the degradation of QoS implicitly modelled into the MD case is greater than the 5 % assumed here.

2.2.5 Changes in cost parameters

Table 5 shows the cost of termination for the base case and the following changes in cost parameters:

- Scenario 6: Increase in the value of the WACC from 10 % to 15 %.
- Scenario 7: Increase in prices for facilities and equipment of 10 %.
- Scenario 8: Increase in prices for base station systems (they are often imported from abroad and may therefore be subject to exchange rate fluctuations).
- Scenario 9: Cost due to base stations alone (to show the share of that part of the network in total cost).

Table 5: Cost changes due to changes in cost parameters

Cases calculated		Results for		
		SD	MD	LS
Base case:	Cost/minute	3.51 €ct	3.69 €ct	4.18 €ct
Scenario 6:	Change in the value of the WACC from 10 % to 15 %			
	Cost/minute	3.99 €ct	4.02 €ct	4.61 €ct
	Relative change	+13.6 %	+8.9 %	+10.3 %
	Elasticity	+0.27	+0.18	+0.21
Scenario 7:	Increase in prices for facilities and equipment of 10 %			
	Cost/minute	3.79 €ct	3.92 €ct	4.48 €ct
	Relative change	+8.1 %	+6.2 %	+7.2 %
	Elasticity	+0.81	+0.62	+0.72
Scenario 8:	Increase in prices for systems that are imported from abroad of 10 %			
	Cost/minute	3.72 €ct	3.85 €ct	4.36 €ct
	Relative change	+6.1 %	+4.3 %	+4.2 %
	Elasticity	+0.61	+0.43	+0.42
Scenario 9:	Cost due to base stations only			
	Cost/minute	3.20 €ct	2.33 €ct	3.03 €ct
	Share in total cost	91.2 %	63.1 %	72.4 %

Comments:

(12) In scenario 6, note first that the change in the value of the WACC from 10 % to 15 % means an increase in the WACC value of 50 %. The percentage increases shown for the cost must be seen relative to this change. The elasticities with their values around 0.2 provide the relevant information. To properly assess the low values of these elasticities, note that when the WACC increases the cost of money increases but depreciation and opex (which together are responsible for around 60 – 70 % of the total) does not so that the relative impact of the change in the WACC is reduced by that much. The differences in the elasticities across the models are probably due to differences in the lengths of economic lives of the facility and equipment items across the models.

(13) In scenarios 7 and 8, the relative high reactions of the cost due to the 10 % increases in input prices are an overstatement. In the WIK models, the opex is coupled to the value of the investment base and therefore increases in step with a change in the prices for equipment. The increases in opex calculated by the model would not necessarily follow from a change in equipment prices due to, say, a change in exchange rates. (The models were originally not constructed with this kind of sensitivity analyses in mind.) The values of the cost changes shown

should probably be reduced by about one third given that opex (beside depreciation and the cost of money) accounts for about one third of total costs.

(14) In scenario 9, the second line of figures shows the *percentage share* in total cost of termination due to the cost caused by base stations. While the figures for MD and LS are within the expected range, that for SD seems surprisingly high. This is to be attributed to the fact that SD is a small country with relatively short distances between nodes so that the share of the cost of transport is substantially lower than in the other countries.

3 Cost estimates with the Analysys model

The material in this section is based on cost calculations carried out with the Analysys mobile network cost model. It includes cost driver sensitivity analyses for the UK which was made possible by the fact that Ofcom made the model available to us. The material in this section also briefly covers the use of the Analysys model for Norway, Sweden, the Netherlands and France.

3.1 A short description of the Analysys approach[1]

Analysys also uses a bottom-up modelling approach based on the LRIC philosophy. In many respects Analysys and WIK's modelling approaches are similar although there are differences in detail. One of the differences in detail worth mentioning is that the design of cells in the Analysys model is on the basis of shares of types of territories to which the required types of base stations are summarily assigned, according to whether the cells are coverage or traffic driven, while in the WIK model cells are designed individually for the different districts which are also individually identified using GEO/GIS data. The Analysys approach should equally be considered as a legitimate approach to designing a mobile access network as the one used by WIK. There are, however, three substantial differences. The first is that Analysys' approach involves a whole series of consecutive network models spanning up to 50 years of time starting some time in the past and ending at up to 40 years in the future. It thus requires to make concrete projections of future demand to be met by the network in question and that for a large number of years (which necessarily involves a substantial degree of uncertainty). In contrast the WIK model determines the required network for a given year and incorporates expected future developments through appropriate parameters which are used to determine economic depreciation. The second difference consists in the use of a so-called *real* cost methodology. It implies that – except for changes due to efficiency gains brought about by improvements in facilities and equipment – the costs per unit of service remain essentially constant over the whole range of years covered by the costing exercise. Nominal values of the costs for a given year are obtained by

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[1] Based on Analysys, "Ofcom new LRIC model" (a set of MS Excel files), September 2006.

multiplying the real cost values with that year's inflation index. One effect is that economies of scale and density that intervene over the years are assigned equally, i.e. on an average basis, to each period.[2] Lastly, opex is in the Analysys model not derived using a mark-up on the value of facilities and equipment but it is based on physical measures of these items while nominal values are obtained on the basis of a cost index for operations and maintenance. This feature can be considered an improvement over the WIK model (which, however, could easily also be incorporated into the latter).

Ofcom's determination of 2007[3] blends the costs of termination from two models, one based on 2G and the other on 3G technology. We carried out sensitivity analyses with that part of the model that uses 2G technology.[4] It should also be noted that Ofcom based its determination on a cost estimate from the Analysys model that differs for an additional reason from the one shown in the base case below. This is because Ofcom accepted the argument from the operators that a charge for network externalities should be added to the actual cost. This item was treated in the Analysys model as a cost component but is excluded here.

3.2 Sensitivity analyses with the model for the UK

The base case for the UK corresponds in most respects to what was implemented in the Analysys model when we received it from Ofcom (but note the exception mentioned at the end of the preceding section). As far as could be ascertained, it reflects

- a market share that is assumed to be the same for each of four operators, so presumably equal to about 25 %,
- an amount of investment per base station that is substantially higher than used in the WIK model,
- lengths of economic lives for facilities and equipment similar to those in the WIK model, and
- mark-ups for common cost that are comparable to the ones in the WIK model.

However, for reasons of better comparability with the results of section 2, the model calculations reported on below were carried out using a value for the WACC of 10 %.

There are four cost driver sensitivity analyses that could be carried out with the model. These are:

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[2] Without wanting to belabour this point too much, we do not believe that these two features realistically reflect what management of operators are able to do, respectively, should be expected to do when they determine costs according to the LRIC model.

[3] See Ofcom, "Mobile call termination – Statement", London, 27 March 2007.

[4] In this context, we refer back to our comments regarding 2G vs. 3G technology in section 2.1. Further we refer to WIK's report for the Australian regulatory authority ACCC, "Mobile Termination Cost Model for Australia". In section 3.8 of this report we investigate the cost implications of using 3G technology. We there strongly advise against blending the costs of 3G technology into those of delivering 2G services.

- Scenario I: A general reduction of 28.5 % in volume.
- Scenario II: Increase in the value of the WACC from 10 % to 15 %.
- Scenario III: Increase in the prices of facilities and equipment by 10 %.
- Scenario IV: As in scenario III *plus* an increase in the cost of opex of 10 %.

The results for these 4 scenarios together with that for the base case are shown in table 5. To make them directly comparable to the ones reported in section 2, they are expressed in Euro cent. For this the cost figures in GBP cent are changed into Euro cent using an exchange rate of 1.462 € per GBP; this is the rate for 2007, i.e. the year to which the model results apply.

Table 5: Cost driver sensitivity analyses with the mobile cost model for the UK

Cases calculated		Results
Base case:	Cost/minute	5.83 €ct
	Total volume in minutes	33.1 bn
Scenario I:	Decrease in demand by 28.5 %	
	Cost/minute	6.96 €ct
	Relative change	+19,3 %
	Elasticity	-0.68
Scenario II:	Increase in the WACC from 10 % to 15 %	
	Cost/minute	6.71 €ct
	Relative change	+15.0 %
	Elasticity	0.30
Scenario III:	Increase in the prices of facilities and equipment by 10 %	
	Cost/minute	6.11 €ct
	Relative change	+4.8 %
	Elasticity	+0.48
Scenario IV:	As in scenario III, however including as well an increase in the cost of opex of 10 %	
	Cost/minute	6.37 €ct
	Relative change	+9.3 %
	Elasticity	+0.93

Comments:

(i) Base case: We note that the per minute cost of termination from the UK model is higher than corresponding cost figures obtained with the WIK models reported in section 2. One important reason appears to be that the prices for facilities and equipment used in the UK model are higher than those used in the WIK models.

(ii) Scenario I: The effect on the cost of termination due to a generally lower level of demand, expressed by an elasticity of -0.68, is higher than the one reported from the WIK model for the SD type country (elasticity of -0.37) but close to that for the LS type country (elasticity -0.71).

(iii) Scenario II: The elasticity of 0.30 with which the cost reacts to an increase in the WACC from 10 % to 15 % is similar to that reported from the WIK models (ranging from 0.18 to 0.27).

(iv) Scenario III: The elasticity shown here for a 10 % increase in the level of prices for facilities and equipment is 0.48. This is a more realistic value than the one reported in section 2 when a corresponding change was carried out in the WIK models (see comment (13) relative to scenarios 7and 8).

(v) Scenario IV: In this case the elasticity is with respect to a 10 % increase for prices of capital items as well as expenses for operations and maintenance. The elasticity value of 0.93 is somewhat higher than the values shown from the WIK model under scenarios 7. This scenario is in a way comparable to the current one since, as was explained for this scenario, the cost of opex varies with the values of the capital goods (see again comment (13) relative to scenarios 7 and 8).

3.3 Brief review of Analysys model results for four more countries

It is known that the Analysys model was also used for the calculation of the costs of mobile call termination for the regulatory authorities of Norway, Sweden, the Netherlands and France. Below are brief statements as to the relationship between the results of the cost calculations and the rate decisions taken by the regulatory authorities.

Sweden

In July 2004, the Swedish regulatory authority PTS determined mobile termination rates for a period of four years, starting in July 2004 and running through June 2008. The rates were based partly on LRIC calculations from the Analysys model that PTS used and partly on calculations from a model used by one of the operators, i.e. TeliaSonera. The weights for the estimates from the Analysys model were 25 % for 2004/05, 50 % for 2005/06, 75 % for 2006/07 and 100 % for 2007/08, and vice versa for the estimates from the operator's model. The resulting rates ranged from 0.80 SEK per minute for 2004/05 to 0.55 SEK per minute for 2007/2008. In June 2008, PTS updated its decision by determining for the period 2008/2009 a rate of 0.43 SEK per minute. This rate, using an exchange rate of SEK to the Euro of 9.37 valid at the time of the decision (June 2008)[5], amounts to 4.6 Euro cent per minute.

In the June 2008 statement, PTS points out that the model it has been using had been updated with the effect that it now calculated substantially lower costs than resulted

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5 See Oanda.com, "FXAverage – Historical Currency Averages", average value in June 2008 of one Euro in SEK , downloaded 19 December 2008.

from the earlier version. The earlier version had calculated costs that ranged from 0.428 SEK per minute for the 2008/09 period to 0.325 SEK per minute for the 2012/2013 period while the current version's calculations ranged from 0.307 SEK per minute to 0.149 SEK per minute. Using again the exchange rate valid at the time of the decision (June 2008), the high and the low cost levels for 2008/09 correspond to 4.57 and 3.47 Euro cent per minute.[6]

PTS also points out that the price determined was not based on these cost figures. Further it is worth mentioning that PTS refers to the model it uses, which we assume continues to be the Analysys model, as a hybrid model implying that to a substantial degree it is based on cost accounting data from the operators.

Norway

The publicly available version of the Analysys model[7] for the Norwegian regulatory authority NPT is populated with dummy data only. This means that it contains no information with which one could ascertain to what extent the model results were used to inform the determination by the NPT. However, from other sources[8] it is known that different levels of cost were determined for the two Norwegian operators, i.e. 0.42 NOK per minute for Telenor and 0.45 NOK per minute for NetCom. It appears that extensive consultations took place between NPT/Analysys and the Norwegian operators and that the model's results were reconciled with the operators' cost accounting records. NPT determined mobile terminations rates according to a glide path whereby a mobile termination rate of 0.45 NOK would be reached by 1 July 2010. The rate of 0.45 NOK corresponds to about 5.5 Euro cent using an exchange rate of 8.13 NOK for 1 Euro valid at the time of the decision (March 2007).[9]

The Netherlands

The Analysys model for Opta was developed in 2006.[10] It determined two different levels of cost for the mobile termination service, i.e. 5.495 Euro cent per minute for KPN and 7.086 Euro cent per minute for Orange and T-Mobile. Opta's determination provided for a glide path whereby the rates were to reach these levels (actually 5.5 and 7.09 Euro per minute) as per 1 July 2008.[11] It is known that the cost model was constructed with the cooperation of the operators where this cooperation took already place during the process of developing the model.

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[6] For the description of the process, see PTS, "LRIC prismetod för terminering av röstsamtal I mobilnät", Stockholm, 5 July 2004, and PTS, " Uppdatering av prisrekommendation för terminering av röstsamtal i mobilnät", Stockholm, 11 June 2006. The rates determined by PTS for the years for 2004 through 2007 were communicated to WIK by PTS as part of an email message.

[7] See Analysys, "NPT's mobile LRIC model, version 4" (a set of MS Excel files), December 2006.

[8] Comments by Efta Surveillance Authority, contained in a letter dated 4 May 2007, on Notification by NPT regarding Norwegian wholesale markets for voice call termination.

[9] See Oanda.com, "FXAverage – Historical Currency Averages", average value in March 2007 of one Euro in NKO, downloaded 19 December 2008.

[10] See Analysys, "OPTA BULRIC model", (a set of MS Excel files), May 2006.

[11] See Opta, Besluit aagaande de tarieven voor mobiele gespreksafgifte op het network (naam MNO), 21 June 2006.

France

In October 2007, the French regulatory authority ARCEP set mobile termination rates of 6.5 Euro cent per minute for Orange France and SFR and of 8.5 Euro cent per minute for Bouygues, to be valid from 1 January 2008 to 30 June 2009. In a decision dated 2 December 2008[12] it determined that rates for Orange France and SFR are to decrease to 4.5 Euro cent for the period from 1 July 2009 to 30 June 2010 and to 3.0 Euro cent for the period from 1 July 2010 to 31 December 2010. Analogously, the rates for Bouygues are to decrease to 6.0 Euro cent and 4.0 Euro cent, respectively. ARCEP has based its decisions on calculations with an Analysys model for an efficient operator, which in respect of the most recent decisions is available from ARCEP's website.[13] The results from this model run from 3.62 Euro cent per minute for 2005 to 2.64 Euro cent for 2008 and to 1.48 Euro cent for 2014. It is of interest that the model by Analysys for ARCEP is based on historical cost accounting (HCA) and not, as most bottom-up cost models, on current cost accounting (CCA).

4 Resumé

In general the following conclusions can be drawn from the comparisons and cost driver sensitivity analyses carried out in sections 2 and 3:

- Calculations carried out with cost models for the 2006 – 2008 period came up with cost levels for the termination of mobile voice calls that vary between 2.5 and 7.1 Euro cent per minute. The cost calculations emerging from the WIK model exercises are generally in the range between 3.5 and 5 Euro cent, those known from the Analysys models are between 2.5 and 7.1 Euro cent.
- The cost of an SMS message, as determined by the WIK model, is below one tenth of one Euro cent.
- The most important cost drivers, as revealed by the sensitivity analyses in sections 2 and 3.2, are listed below in the order of their impact on cost:
  - *Prices of facilities and equipment:* Changes flow through very strongly, as shown by elasticity values that range between 0.62 and 0.93..
  - *Variations in the volume of voice calls:* Costs are shown to react to changes in volume with an elasticity that ranges in value from -0.37 and -0.71. For example, in the WIK models such volume changes increased costs in the two relevant cases by 10 % and 20 % and in the model for the UK by 20 %.
  - *Variation in the volume of SMSs:* The cost per SMS message reacts significantly to volume changes. The main cost driver is here the SMS centres

12 See ARCEP, "Décision n° 08-1176 portant définition de l'encadrement tarifaire des prestations de terminaison d'appel vocal mobile des opérateurs Orange France, SFR et Bouygues Telecom pour la période du 1er juillet 2009 au 31 décembre 2010.

13 See Analysys; "ARCEP LRIC mobile model" (a set of MS Excel files), undated.

while network cost are minimal. There are usually only a few SMS centres needed. Their costs come close to a fixed cost that decreases rapidly per message when volume increases.

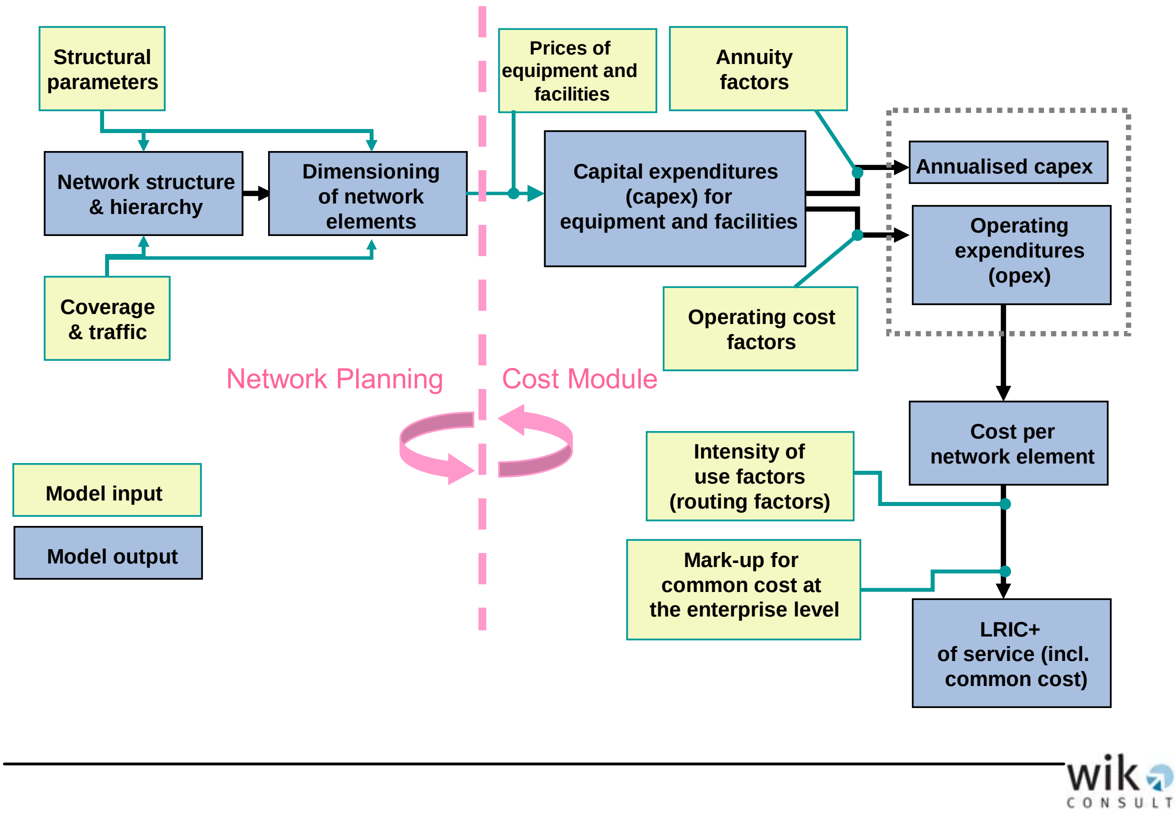
- *Changes in the QoS:* A quality of service in mobile networks of 2 %, which is the maximum blocking probability allowed, is usually implemented in the WIK cost models. If this requirement is relaxed to a value of 5 %, this may decrease cost substantially. The sensitivity analyses carried out indicate that the cost may decrease between 8 % and 12 %.
- *Shift to the 1,800 MHz spectrum band:* Depending on market share and volume of service, such a shift may have a quite substantial impact on cost. At a low level of volume it may increase cost by up to 65 %. This impact decreases when volume of traffic is large enough to utilize base stations close to capacity.
- *The WACC:* The elasticity with which the cost reacts to a change in the WACC lies between 0.2 and 0.3. For example, the increase in the WACC from 10 % to 15 % (which is a relative increase of 50 %) increased the cost by between 9 % and 15 %.

• In terms of network segments, the access network consisting of the base stations make up the most important part, shown here with shares of total cost ranging in the WIK models from 63 % to 91 %, but known by experience to usually range between 60 % and 70 %.

Annex: Description of WIK's bottom-up mobile network cost model

WIK-Consult's approach to the modelling of the costs of a mobile network consists of two modules, the network planning tool and the cost module. This is apparent from Figure 1 which provides a schematic preview of the modelling processes carried out by the WIK Mobile Network Cost Model (WIK MNCM).

Figure A-1: Schematic view of the WIK-MNCM modelling process



Studies have demonstrated that by far the largest part of the cost of constructing and operating a mobile network is due to the number of base transceiver stations (BTSs). It generally holds that the BTS share in relation to total network costs lies between 60 and 70 %. We therefore take the view that the key issue of modelling a mobile network lies in the determination of the number of BTSs for each of the various areas to be covered. The upper network elements are then deter-mined such that they connect the network of BTSs. It is one of the advantages of this approach that it is truly bottom-up in the sense that there is no predetermined BTS structure to influence relevant network costs and insofar reflects the network planning decisions of an efficient operator. The latter perspective is usually taken by regulatory authorities when they approach cost modelling and it would be appropriate for a holding company in the effort of exercising cost control over its operating companies.

The chapter is organised as follows. Section 3.1 describes in general WIK-Consult's approach to network modelling on the basis of its Strategic Network Planning Tool (SNPT) while section 3.2 deals with the determination of costs caused by the network so determined on the basis of the Cost Module. Section 3.3 discusses data input requirements and section 3.4 implementation aspects. Finally, section 3.5 highlights the advantages of our approach.

A.1. Structure of the network model

WIK-Consult has at its disposal a Strategic Network Planning Tool which provides the configuration of an optimal GSM network and which has been applied in a number of studies for regulators and carriers alike for determining the cost of call termination on mobile networks. The SNPT allows considering three different types of frequency assignments, 900 MHz, 1,800 MHz and dual band operators with both 900 and 1,800 MHz.

The SNPT divides the task of network modelling into the following two main parts:

- Mobile network design and dimensioning (MNDD)
- System assignment to network elements

Mobile network design and dimensioning (MNDD) depends on a large number of parameters. Of these some are of a technical nature and fixed given the technology while others, like market penetration, geographical and population coverage, degree of required indoor and outdoor penetration, types of services offered, demand of the users, type of available frequency and total spectrum assigned to the operator, may vary strongly. A bottom-up cost model must be in a position to provide cost estimates corresponding to each of the possible combinations of parameters and parameter values as separate scenarios. An important example of differences in parameter values is the difference between an operator with small market share serving customers with little traffic demand and an operator with a large market share and customers with high traffic demand. In the former case, the required network is determined mainly by geographical coverage with a little or no dependency on traffic, in the latter case a network is needed which is mostly driven by traffic demand. Our approach to modelling assures that such differences in network parameterisation can easily be implemented so that there will be great flexibility in determining costs corresponding to changing network configurations. This is particularly important if the model is to be used for networks in different geographical areas in which the conditions in terms of geography, penetration, market share may vary greatly.

The tool used for the MNDD is structured into the following tasks:

⇨ Determination of the geographical areas in which BTS deployment is provided

⇨ Optimal cell radius calculation

- ⇨ BTS deployment in each area
- ⇨ Determination of the network hierarchy
- ⇨ Determination of the capacity requirements of the logical link structure
- ⇨ Determination of the physical network part

A.1.1 Determination of the geographic areas in which BTS deployment is provided

The planning of a mobile telecommunications network starts with determining the areas which are to be provided with mobile access and over which BTSs are to be deployed. Such deployment will differ between areas according to the density of the mobile users present during the busy hour. The type of cell deployment in the various areas thus varies according to whether they are classified as dense urban, urban, suburban or rural, and according to such characteristics as the presence of airports, tourist attractions and the like. Areas (or districts) have thus to be identified that can be sorted and classified accordingly.

For this purpose, data about geography, distribution of population or potential users, features of special areas etc. are needed that are either to be provided by the planning departments of the networks' operators or, as the case may be, be obtained from public sources.

A.1.2 Cell radius calculation

It is necessary to calculate the suitable cell radius for a given district in order to determine the number of BTSs in this district. The basic task of the model consists in calculating the radius of a single cell in the district and to derive the area covered by the corresponding BTS using this value. The number of required BTSs is obtained by dividing the given district area by the BTS area.

For this calculation the model considers a large number of parameters which can be divided into the following categories:

- ⇨ Technical parameters of the mobile terminal
- ⇨ Technical parameters of the BTSs
- ⇨ Type of services and corresponding traffic parameters
- ⇨ Capacity parameters of the BTSs like number of TXRs and number of sectors

⇨ Parameters reflecting the topography of the area in which the BTSs are to be located as well as the density of population (urban, suburban and rural)

⇨ Design parameters such as coverage degree (mainly under indoor penetration requirements), volume of demand, frequency band used and availability of spectrum, and so on.

The model carries out the following three sub-tasks in order to arrive at the required results:

- Link budget calculation (whereby the maximum value of radio propagation power loss is calculated)
- Radius calculation by a propagation model
- Radius calculation by a traffic model

The result of the link budget calculation is used to arrive at the radius as determined by propagation. For this calculation the SNPT relies on the standard models of Okumura Hata (for frequencies up to 1500 MHz)[14] and the modified version resulting from the Eu-ropean COST 231 research project (for frequencies above 1500 MHz). The traffic model uses a modified Erlang-B model considering different blocking probabilities for capacity assignments resulting on the one hand from new calls and on the other from hand over traffic. The model includes a parameter of user movement based on an aver-age value over different types of users (pedestrians, users in cars or public transport).

The two types of radius calculation assure that both aspects, i.e. propagation driven and traffic driven cell radii are taken into account. The result with the minimum radius is then selected. The relation between the different modules of the SNPT used in determining the cell radius is as shown in the Figure 3-2.

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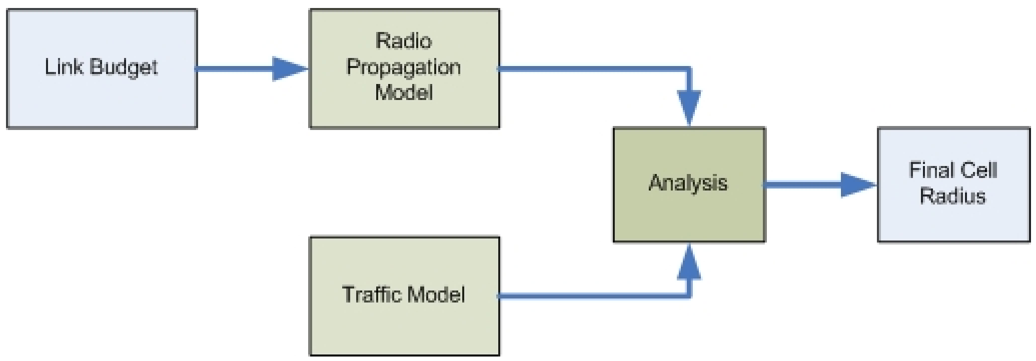
[14] See Y. Okumura, E. Ohmuri, T. Kawano, K. Fukuda, "Field Strength and its Variability in VHF and UHF Land Mobile Service", Review Electrical Communication Laboratory, Vol 16, Nº 9-10, pp. 825-873, 1968; Cost 231, "Urban Transmission Loss Models for Mobile Radio in the 900 and 1800 MHz Bands", Report of the Euro-Cost 231 Project, Revision 2, 1991.

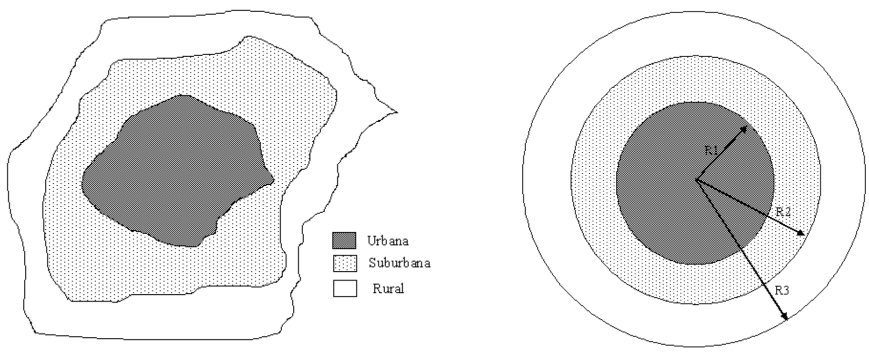
Figure A-2: Relation between different modules of the Strategic Network Planning Tool



A.1.3 Cell deployment in a specific area

The cell deployment in a geographical area - typically a city, town, village or sparsely populated rural area - is strongly related to the cell radius calculation discussed above. For this purpose, the model considers a complete area which may be a district of a large city, an average size city, a town or a village. The model allows to subdivide such an area into three sub-areas, i.e. urban, suburban and residential according to the different building types and user densities that one finds in them. Furthermore, the model takes into consideration the type of topography according to whether it is flat, hilly or mountainous. The model transforms the geographical area into a ring structure as shown in the figure below and determines according to the surface of each sub-area the required number of BTSs.

Figure A-3: Projection of the real extension of a city to an equivalent circular geographical extension



(a) real extension of the city (b) circular projection

Note that the model calculates only the number of BTSs for each of the three sub-areas and not the exact location of each BTS as this kind of decision does not form part of a strategic MNDD.

As mentioned, the model subdivides large cities into several districts and the corresponding cell deployment is developed for each of these districts separately, taking care that each district is properly subdivided into the three zone types according to building height, population density and so on.

The SNPT provides then a national cell deployment using an input list of all areas to be covered by the mobile network that is being modelled. The main data from this list are:

(1) Name or identifier of the area

(2) Geographical coordinates of its centre (in UTM)

(3) Geographical extension and number of inhabitants / working people for the

- Urban area
- Sub-urban area
- Residential area

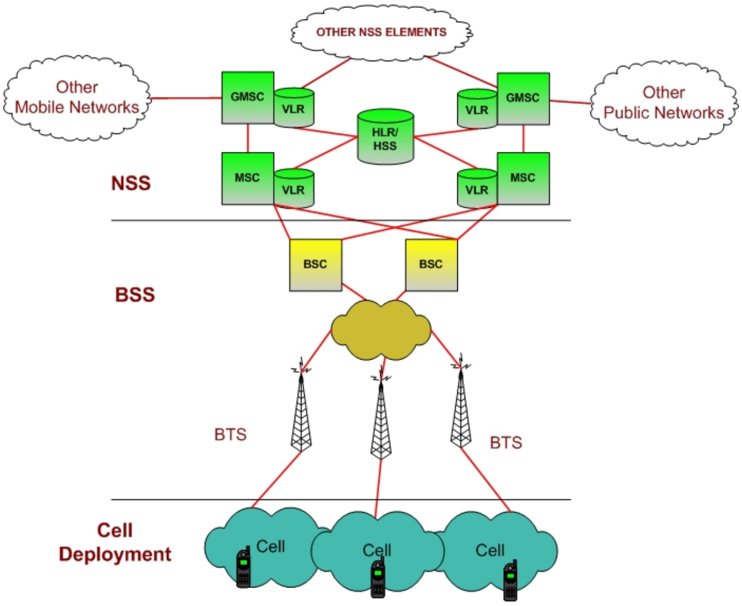
(4) Type of buildings and type of topography.

Depending on the particular features of the country in question, the design of the network may have to take into account traffic ways and tunnels which have their special requirements in terms of BTS coverage.

A.1.4 Determining the network hierarchy

Once the national cell deployment has been established, the number of BTSs and the traffic loads for the different types of services are known for each area. Based on this data, the model calculates the number of the network elements of the higher level network hierarchy [base station controllers (BSCs) and mobile switching centres (MSCs)], the areas where they are located and the assignment of the network elements of a lower level to the appropriate network element of the higher level. The figure below shows the network hierarchy of a typical mobile network.

Figure A-4: Architecture of a GSM mobile network



BSS: Base Station Subsystem, NSS: Network Subsystem

At a first step the model estimates the number of BSCs, selects the areas where these BSCs are to be located and forms BSC-BTS clusters assigning each BTS to a particular BSC. The number of BSCs is estimated on the basis of BSC capacity thresholds for both traffic and the maximum number of assigned BTSs. To determine the BSC distribution over the areas of the national network, the model uses the type of location algorithms which is being applied in bottom-up fixed network models for determining the network hierarchy.

After having determined the number and locations of the BSCs and the corresponding BSC-BTS clusters the same procedure is applied for determining the number of MSCs, their locations and corresponding BSC assignments that form the MSC-BSC clusters.

For the logical network link structure between all MSCs one may obtain either of two structures. If the number of MSC locations is relatively small, a fully meshed link structure would be appropriate. If the number of MSC locations is larger, a subdivision of the MSC level into two sub-levels may be more appropriate where the higher level contains transit switching equipment and each MSC is connected at least to two transit switches. Furthermore, the model allows to implement direct connections between two lower level MSCs based on traffic and geographic distance criteria. The model provides in this case a hierarchical traffic routing similar to the one in a two level PSTN/ISDN network. Which particular structure is chosen depends on considerations of network resilience and the costs of switching equipment relative to that of transmission equipment.

A.1.5 Determining the capacity requirements of the logical link structure

The establishment of the logical link structure of a network implies that the traffic demanded during the daily peak (busy-hour traffic[15]) and the corresponding physical capacity requirements between the network nodes are determined. For mobile networks this in turn implies that the traffic values for all services aggregated at the BTS level must be routed at least up to the corresponding MSC where one part of the traffic is handed over to other networks over corresponding interconnection interfaces while another part has to be routed downward (e.g. intranet-traffic of the same MSC-BSC cluster) or to another MSC to find there a corresponding interconnection interface or for intranet-traffic to other MSC-BSC clusters. The SNPT applies for each type of traffic routing a corresponding routing factor both to determine proper traffic routing and, later on, the costs of network elements. Thus one obtains a network hierarchy with a logical network link structure in form of a double star where the link between a BTS and its BSC supports the aggregated BTS traffic and a link between a BSC and its corresponding MSC the aggregated BSC traffic.

The model then calculates on the basis of the corresponding traffic values and the GoS for each service the required bandwidth on each of the links in the logical network structure.

A.1.6 Determining the physical network part

The mobile network hierarchy presented above leads to a physical network that is subdivided into three parts, i.e.:

(1) The physical network for the BSC cluster (connecting all BTSs to the corresponding BSC), i.e. the fixed access network

(2) The physical network for the MSC cluster (connecting all BSCs to the corresponding MSC), i.e. the backhaul network

(3) The physical network connecting the different MSCs, i.e. the core network

The model considers for the fixed access network part a radio link network in form of a tree providing point to point radio links between both a BSC and a BTS or between two BTSs. The model considers a double tree structure where the first tree connects the central point of a district to its BTSs by a star. In this central point a BTS-hub is installed. The second tree connects the BTS-hubs to the corresponding BSC location by a tree structure. An actual tree design depends heavily on the distances between the BTS-hub locations of a BSC-BTS cluster and between the BTS-hub and BSC locations. Such a detailed design is not required for a strategic MNDD and a corresponding cost

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[15] Typically, network dimensioning is determined by the total traffic during an average daily peak while the cost calculation and service pricing must be done considering daily, monthly or annual traffic volumes.

estimate. We therefore approximate the tree by the links of a multiple star structure between the BTS hubs and the corresponding BSCs. As far as locations of the individual BTSs are concerned, which the SNPT does and cannot provide, we will have to rely on an arbitrary but uniform distribution over the total of the cell areas. This must necessarily be so as any actual location will have to depend on regional conditions, on the availability of buildings and the ability of the (newly entering) operator to obtain access to relevant locations.

For the backhaul network the model considers two options, one by digital leased lines connecting in a star structure the BSCs with the corresponding MSC and the other in form of a “self healing ring structure” using dark fibre or point to point radio links. The case where the mobile operator also operates a fixed network corresponds to the leased line option for which, however, the costing exercise would have to determine an estimate of the cost in the fixed network instead of the costs of leased lines.

Concerning the core network which connects the different MSCs, the SNPT assumes also two options. According to the first, a meshed structure by leased lines is modelled where for each logical link in the MSC core network a number of digital signal groups (DSGs) is determined to provide the required capacities. For the second case, the model considers a ring structure implemented by add-and-drop multiplexers (ADMs). For a small number of MSC locations only one ring is required while for the hierachical case the SNPT determines various ring structures. The leased line option allows to consider different types of physical connections mainly determined by the SDH hierarchy (E1, E3 and STM-1). The model calculates the ring structure by an algorithm which approaches the solution of the so called travelling salesman problem.

Once the network hierarchy and the logical and physical network parts are determined, the capacities required in the network nodes and on the physical network links are known. Given the corresponding investment values for the systems that implement the network elements the model is now in a position to calculate the corresponding network and service costs.

A.2 Determining the cost of network services

Once the network structure with all its network elements is known, the costs of providing services with this network need to be determined. Total costs according to the LRIC standard essentially consist of the annual capital cost of all equipment items (capex) and of the cost of operations and maintenance (opex). In addition, common cost need to be added. In cases where some capacity is rented (primarily leased lines), the rental is used as substitute for the corresponding capex and opex on account of systems installed by the operator itself.

The following sections will present our approaches to the determination of these cost categories as well as the distribution of these costs to the various services and the determination of the cost per unit of service.

A.2.1 Capex

In a bottom-up model, once the network structure is known, the next step toward determining capex consists in the valuation of all equipment and facilities at the relevant (current) prices. Given these equipment values, we need to transform them into amounts for each of the time periods of their economic lives, or, in other words, the periods over which the equipment items are expected to provide services. These amounts should cover the depreciation of the equipment over the years as well as the return on investment (interest rate) that investors require. They should also be proportional to the volumes of use during the relevant periods. Regarding the latter point, it needs to be taken into account that volumes will normally vary between periods, i.e. most often grow from one period to the next. Also equipment prices will change over time and with them the value of the network at future times. This calls for a determination of annual amounts of amortisation (recovery of the invested capital) according to what is known as economic depreciation. In the framework of a bottom-up model this type of amortisation is most suitably accomplished through the application of a capital recovery factor determined on the basis of the annuity formula. Actually, in a bottom-up cost model there is no other consistent way of assuring adequate amortisation except by a formula that is equivalent to the annuity formula. In the following paragraphs this formula will be discussed starting from the simple version in which annual amounts are equal and then moving to considering the cases of expected future growth and expected changes in the future prices of the installed equipment. As result of this calculation we obtain what may be called “annualised capex” but we will continue to refer to as just “capex”.

Let I be the value of the equipment item, A be the amount to be recovered each year over its lifetime, further let $q = 1/(1+i)$ with i equal to the interest rate and n equal to the length of the economic lifetime, then the following relation must hold for the recovery of the invested capital:

$$I \quad = \quad A * [q + q^2 + \ldots + q^n] \ .$$

From the above formula it follows that the value for A is:

$$A \quad = \quad c * I \ ,$$

where

$$c \quad = \quad 1 / [q + q^2 + \ldots + q^n] \ ,$$

which can be shown to reduce to

$$c \quad = \quad (1/q) * [1 - q] / [1 - q^n] \ .$$

For this the appropriate interest rate (usually in its specific form as a weighted average of return on equity and interest on debt, WACC) and estimates regarding the economic lifetimes of the various equipment items need to be available.

As mentioned, above formula covers the simple version which does not account for two developments that will normally intervene during the economic lifetime of an item of equipment. The first is that for some period after the time of installing the equipment item will be underutilised and only be fully used as service volumes grow. The second factor is the observation that equipment prices change over time and that this will change the costs that new entrants at later points of time will be facing. This changes the value of the installed equipment which in turn will have to be taken into account when at that later time pricing decisions have to be made. Continuing to rely on the format of the capital recovery or annuity formula, this can be done by substituting for $q = 1/(1 + i)$ the following definition:

$$q = [(1+g)*(1+\Delta p)]/(1+ i)$$

where

g = projected average growth of services (e.g. minutes of switching) provided by the item of equipment over its economic lifetime

Δp = the average rate of change of the price of the equipment item projected during its lifetime

The approach reflected in above equation is known as the 'tilted-annuity' approach as it implies that amounts of amortisation A vary over the life of the asset according to developments in the volume of services and the price of the asset.

If values of q determined this way are inserted into the equation

$$I = A * [q + q^2 + \ldots + q^n]$$

the amortisation amounts A of the succeeding periods will each time be (1+g) times higher than in the preceding period, that is it will be in proportion to the increased volume of services expected on account of growth for that period. It is thus assured that future volumes of services carry per unit of service the same amount of depreciation as the present one. The factor Δp, following a similar argument, assures that at each point of time the amortisation is proportional to the value of the equipment item at that particular time. Now, if both $g > 0$ and $\Delta p > 0$ more of amortisation will have to be earned in each of the future periods which means that the amount to be earned in the current period becomes less. If $g > 0$ and $\Delta p < 0$, which corresponds to the situation in mobile markets (given that equipment prices have been declining steadily and continue to do so) the balance of the two effects may be positive or negative, i.e. $[(1+g)*(1+\Delta p)]/(1+ i)$ may be greater or smaller than $1/(1+i)$, depending on the absolute values of the two factors.

Regulatory authorities when carrying out cost determinations tend to take expected growth and price developments into account. From an operator's perspective it may be desirable to set the values of g and Δp equal to zero to reflect particular company policy towards cost recovery. It is a substantial advantage of our model that it provides great flexibility in the choice of which cost recovery strategy to apply.

As regards the required rate of return on investment, it is often the case that a set policy exists in this regard a corresponding value of the rate of return has been determined. If not, WIK-Consult stands ready to advise also on the determination of this parameter. In general we would recommend the use of the WACC.

Also, concerning the economic life times of the various equipment items, which are as important as the interest rate for the level of capex, we will provide advice based on our knowledge from comparable modelling exercises.

A.2.2 Opex

The determination of opex is in all bottom-up modelling approaches still underdeveloped which is mainly due to the complexity of the business processes involved, in particular the network management tasks, and the non-availability of relevant information. To really model the functions that give rise to operating and maintenance expenses would require on the one hand that one knows in detail the complex processes by which these (normally very company specific) activities are carried out, and that on the other hand one is able to give expression to these relationships in a standardised way so that they could be incorporated in a cost model. Corresponding studies have so far not been done or at least have not been made available to the interested public. Therefore, in all telecommunications bottom-up modelling exercises known to us, even the ones that have been developed on behalf of operators, the practice is being followed of expressing opex as a percentage mark-up on top of the value of the network elements where the value is expressed in current prices. Not only is this commonly used in bottom-up cost modelling but is often also the approach used by operators in their own business case planning.

Opex will thus be determined in the model by the following equation:

$O_i \quad = \quad ocf_i \, I_i.$

where

O_i = opex for equipment item i,

ocf_i = the operating cost factor relevant for equipment item i.

The availability of this information will depend on the willingness of operators concerned to provide relevant information from their accounting systems. In case of default we use international benchmarks for which we can draw on our data bank compiled in the course of previous studies.

A.2.3 Cost Implications of use of leased lines or integrated fixed-line network infrastructure

Parts of an MNO's network may consist either of leased lines, instead of stand-alone own infrastructure, or of the infrastructure of a fixed-line network if the MNO is part of an integrated operator. In both cases, what would otherwise be the capex and opex of an own infrastructure would now be the charges for wholesale services procured either externally or internally. The SNPT will provide for this option. If leased lines are used, or the equivalent provided internally from the fixed network branch of the operator, the corresponding charges will be included instead of what would otherwise be opex and there would be no capex.

A.2.4. Total costs and cost per service

Adding up capex and opex gives the total annual costs of all network elements and thus of running the entire network and of providing all services. Information gained during the planning stage is then used to determine to what extent the various network elements are on average being used for the delivery of the particular services under study. This information comes in the form of so-called routing factors on the basis of which the costs (capex plus opex) of the network elements are distributed to the various services provided. Dividing a particular service's share of total cost so derived by the number of units delivered, usually minutes of calling, one obtains the per-unit long-run average incremental cost (LRAIC) of this service.

Routing factors represent the intensity with which the different services use the network elements. The model determines these routing factors endogenously in deriving them from the traffic distribution on the basis of which the network has been dimensioned. The costs of the network elements are thus distributed to the various services using the values of these factors that will be listed in a routing factor table. The table below shows the general structure of such a routing factor table.

Service	Cells	Base Station Subsystem (BSS)		Network Subsystem (NSS)			Registers	
		BSCs	Trans-mission	MSCs	BB Links	Rest of NSS	HLR	VLR
On-net								
Termination								
Origination								
……								
……								

To obtain the figure on which to base the price for the service under review, one needs to add a mark-up to cover common costs, i.e. that part of total cost that is not driven by the volumes of services provided over the network. We will propose to determine this mark-up according to the equal proportionate mark-up (EPMU) rule. Mainly common cost in the sense of overhead arising at the company level will be so included. To determine this mark-up, we will also here use information from the cost accounting records of the operating companies. Cost categories that might be considered network common cost will in general be included with the costs of the relevant network elements and distributed in accordance with the routing factors discussed above.