Methodologies for Valuing Spectrum: Review of the Experts' Report

A report for Vodafone

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Summary

Vodafone commissioned Plum to provide a critique of the approach to valuing frequencies at 1800 MHz proposed in the report produced by four experts for the TRAI titled "Report on the 2010 Value of Spectrum in the 1800 MHz Band" and dated January 30, 2011 (called hereafter the Experts' Report). This document addresses the economic analysis undertaken by the four experts which sought to estimate a value for incremental spectrum at 1800 MHz.

The paper is written by Phillipa Marks and Ken Pearson, who are both Directors of Plum Consulting. Phillipa Marks is an economist who is expert in the application of market mechanisms to the management of radio spectrum. She advised the New Zealand government on creating the first ever national market in spectrum in 1989, and since then has developed the approach to spectrum pricing now applied in the UK, and advised regulators in many countries on auctions, pricing and trading issues (e.g. Australia, Canada, Hong Kong, Ireland, Singapore, the UK). She is a member of the Ofcom Spectrum Advisory Board.

Ken Pearson is a Director of Plum with more than 20 years of experience in telecommunications regulation, licence bids and financial, market and technical analysis of mobile and broadband wireless opportunities. He has extensive experience in undertaking business, economic and technology strategy analysis for operators. He has also undertaken business analysis of high technology industries, and advised on the implication of technology-driven change. He has valued spectrum licences used to provide cellular mobile services in Australia, Canada, Hong Kong and the UK. He has also worked on many other spectrum auctions processes for regulatory authorities and operators in Austria, Bahrain, Ireland, Switzerland and the UK. These projects have included assessment of spectrum value and financing.

First and foremost, the lack of transparency and incomplete disclosure of the models used to estimate the values stated in the Experts' Report is a serious concern that limits our ability to provide a fully informed analysis of the Report. We have been involved in spectrum valuation regulatory processes in many countries, including the UK, Australia, New Zealand, Hong Kong and Ireland. The current TRAI process is the only regulatory process we have been involved with that has not disclosed sufficient information to facilitate a fully informed debate on the merits of the valuation.

Economic principles suggest that the spectrum fees set by regulators should be based on opportunity cost. This implies a value that lies between a cost reduction value (i.e. the value arising from using spectrum to reduce network deployment costs) and a value based on the discount cash flows earned from a given amount of spectrum. In theory the cost reduction value should always be less than the value based on discounted cash flows because the latter also takes account of incremental revenues.

International best practice favours the use of a cost reduction approach because:

- Values based on cost savings rather than cash flows are generally simpler to calculate and more robust, because less information on the future development of services is required.

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- It is good practice to have a downward bias in the fees set so as to minimise potential economic losses.

The cost reduction approach is based on the use of spectrum to engineer networks in capacity constrained cells. If the operator has less spectrum then it must investment in additional base stations in order to carry the traffic generated by its customers.

The Experts' Report estimates a cost reduction value based on the assumption that a Cobb Douglas production function characterises the relationship between capacity, spectrum and the number of base stations. This approach is unsound and erroneous because the Cobb Douglas production function has no clear foundation in network engineering or the economics of network deployment. In particular:

- The production function is mis-specified. The dependent variable should be the level of traffic (or ideally busy hour traffic) in congested area in a circle *not* the total number of subscribers across all the area in a circle as is used in the Experts' Report. This is a fundamental error.
- The production function approach assumes that operators can optimise their spectrum and base station inputs at any point of time to meet the demands of their subscriber base. However, this is clearly not practical.

We conclude that neither the cash flow nor the cost reduction methods proposed in the Experts' Report provide reliable estimates of the value of spectrum. The analysis in our expert opinion is fundamentally flawed. We recommend that the international best practice approach described in Table 2 (below) should be adopted.

1 Introduction

Vodafone commissioned Plum to provide a critique of the approach to valuing frequencies at 1800 MHz proposed in the report produced by four experts for the TRAI titled "Report on the 2010 Value of Spectrum in the 1800 MHz Band" and dated January 30, 2011 (called hereafter the Experts' Report). The Experts' Report presents separate technical and economic analyses of the capability and value of the 1800 MHz band respectively. This document addresses only the economic analysis presented in the Experts' Report.

The Experts' Report follows on from the TRAI report of May 2010 titled "Recommendations on the "Spectrum Management and Licensing Framework" in which The Authority indicated (para 3.82) that it would initiate an exercise to study the issue of the "current price" of spectrum in the 1800 MHz band.

The "current price" of spectrum in the 1800 MHz band is a one-off payment that is to apply to incremental spectrum held beyond 6.2 MHz in the case of GSM and 5 MHz in the case of CDMA (para 3.28). It is intended to reflect the present value of the spectrum (para 3.74) over a 20 year period. The TRAI has ruled out the use of auctions for the assignment of incremental 1800 MHz spectrum (para 3.46).

In Section 2 of this document we summarise international best practice on spectrum valuation for the purpose of setting prices. Section 3 compares the best practice approach with the two approaches used in the Experts' Report. Section 4 contains our conclusions on the valuation method that should be used to set the value of incremental 1800 MHz spectrum.

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2 International best practice

2.1 Transparent and open consultative process

Regulatory decisions should be made in an open and transparent manner.[1] Openness means that there should be public consultation on decisions so that interested parties can put forward their views and decisions are based on all relevant information. Transparency requires the regulator to be clear about the objectives it is seeking to achieve and the model and evidence used to reach decisions, and then to consult with all parties. This is to ensure that decisions are made in a way that is consistent with the regulator's statutory objectives and is fully informed.

The process undertaken by the TRAI in relation to the derivation of values for 1800 MHz spectrum does not conform to these principles. Table 1 sets out the steps taken in a good practice process, and compares these with the situation in India and a recent spectrum pricing consultation in the UK.

[1] See for example, OECD Guiding principles for regulatory quality and performance, OECD 2005; Regulatory effectiveness: The impact of regulation and regulatory governance arrangements on electricity outcomes, Jon Stern and John Cubbin, December 2003. http://www.london.edu/facultyandresearch/research/docs/No56.pdf

Table 1: Steps in a transparent and open process for setting spectrum prices

Good practice activities undertaken by Regulator	1800 MHz valuation – India 2010/2011	Ofcom (UK) review of spectrum pricing 2009/10
Pre-consultation discussions with major players	**No** TRAI writes to inform operators that study initiated. (21 May 2010)	**Yes** Meetings with stakeholder groups held in 2009 to discuss terms of reference for the review[2]
Publish consultation document covering – method, information and results – asking questions on aspects of the findings.	**No** Experts submit report to RAI (31 January 2011). It is sent to DoT (8 February 2011).	**Yes** Consultation document published 29 March 2010
Time for stakeholders to respond of at least 3 weeks. The more major the decision the longer the time period.	**No**	**Yes**[3] Responses to consultation due 21 June 2010
For major issues - Public meeting(s) at which regulator presents proposals and these are discussed	**No**	Yes[4] Stakeholder discussions held during consultation period
Regulator publishes non-confidential consultation responses	**No**	**Yes**
Publish document giving decision including reasons and comments on how consultation responses impacted on decisions.	**No**	**Yes**

It is clear that the process in India falls a long way short of good practice in that there has been no consultation on the methodology or the information used to derive values. Furthermore the version of the Experts' Report that has been published is incomplete in that the methodology is not fully described, the results of the econometric analysis are not fully reported and the information underpinning the analysis is not fully disclosed. This falls well short of the standards expected of a regulatory body.

2.2 Economic principles

Best practice spectrum policy is founded on the overriding objective of managing the spectrum so as to maximise the economic and social benefits from spectrum use.[5] To support this objective regulators are increasingly using financial incentives such as pricing and auctions to promote efficient spectrum use.

[2] http://stakeholders.ofcom.org.uk/spectrum/spectrum-pricing/documents/

[3] http://stakeholders.ofcom.org.uk/consultations/srsp/

[4] http://stakeholders.ofcom.org.uk/binaries/spectrum/spectrum-policy-area/spectrum-pricing/SRSP_stakeholder_workshop_s1.pdf

[5] For Australia see http://www.acma.gov.au/WEB/STANDARD/pc=PC_311103; For Canada see http://www.ic.gc.ca/eic/site/smtgst.nsf/eng/sf08776.html; For the see EU http://ec.europa.eu/information_society/policy/ecomm/radio_spectrum/index_en.htm

This is also the case in India. The TRAI's May 2010 report makes it clear that for radio spectrum policy (para 3.70):

"the primary objective is to maximise the net benefits to society that can be generated from the resource such that there is an efficient distribution of resources resulting in maximum benefits to society. Prices are used as an important mechanism to ensure the spectrum resources are used efficiently by users".

The TRAI also mentions generating revenue for the public purse as an objective but this appears to be secondary to the achievement of efficiency objectives[6].

The overriding objective of efficiency has important implications for the approach to setting a price for spectrum. In particular, economic theory tells us that efficient resource use is achieved when prices reflect opportunity cost.[7] The opportunity cost is the value of the opportunity forgone by current spectrum use (i.e. it is the value to the next best alternative use or user of the spectrum) and equals the market price if spectrum was tradable or auctioned. In the absence of a spectrum auction at the beginning of a licence period, the market value can be observed through a functioning secondary market for spectrum – that is, by allowing operators to trade spectrum and observing the resulting market prices.[8]

We note that this optimal market-based solution has been rejected by the TRAI, as the 1800 MHz spectrum in India is not tradable.[9] In principle there is merit in market trading of this spectrum to facilitate a more efficient allocation between operators and provide incentives to reduce hoarding. However, this approach has been rejected by the TRAI. It is therefore necessary to calculate the appropriate price based on sound economic principles.

2.3 Applying economic principles to derive valuation methods

To derive an estimate of the opportunity cost or market value of spectrum, two general approaches can be used:

- Derive values from market benchmarks
- Derive values from bottom-up calculations using business and network modelling.

We discuss each of these in turn.

2.3.1 Market benchmarks

As markets reveal the opportunity cost of resources, it might be thought that the best approach is to use values revealed by market processes, such as the prices of other spectrum that has been

[6] Para 3.45, "Recommendations on the "Spectrum Management and Licensing Framework", TRAI, May 2010

[7] Spectrum is an input to production and if it is underpriced there is a de facto subsidy on an input. It can be shown that subsidising inputs is inefficient and that policy should be focussed on outputs. http://www.ofcom.org.uk/research/radiocomms/reports/independent_review/spectrum_pricing.pdf Peter Diamond and James Mirrlees (1971) "Optimal taxation and public production 1: Production efficiency and 2: Tax rules", *American Economic Review*, vol. 61. This is discussed in "An Economic Study to Review Spectrum Pricing", Indepen, Aegis Systems and Warwick Business School, Ofcom, February 2004.

[8] This may require obligations on operators to disclose prices.

[9] The fact that the spectrum is not tradable means that there is a risk that the balance of holdings between operators will not be efficient as there is no mechanism whereby spectrum can transfer to high value operators.

auctioned and/or traded. This is problematic, as the TRAI and other regulators have found, because prices vary according to:

- The frequency range and the size of the blocks sold
- The technologies and services that can use the band
- The existing spectrum holdings of bidders
- Local economic, competitive and demographic circumstances
- Expectations of and confidence in future revenue growth which varies from time to time

When deriving prices from market benchmarks it is difficult to control for the impact of all of these factors. Hence regulators have tended to use a bottom-up approach to estimating market prices or opportunity costs by considering how operators themselves value spectrum.

For example, in a recent review of its approach to setting spectrum prices Ofcom considered the use of market information and concluded:

> "AIP Principle 7: use of market valuations
>
> We will take account of observed market valuations from auctions and trading alongside other evidence where available when setting reference rates and AIP fee levels. However, such market valuations will be interpreted with care and not applied mechanically to set reference rates and AIP fees."[10]

In the Indian context market benchmarks could have a role in providing an upper bound on calculated values.

2.3.2 Bottom-up approaches

An increase in spectrum holdings has value to a mobile operator because it could allow the operator to:

- Increase revenues: Additional revenues may be earned because additional spectrum allows service quality to be improved and/or more traffic (for new and existing services) to be supported.
- Reduce costs: Access to additional spectrum allows operators to reduce costs because fewer base station sites are needed to provide a given amount of traffic capacity.

It is important to note that once sufficient spectrum is acquired to achieve a basic level of coverage additional spectrum is used to support traffic growth. Therefore additional spectrum only has value in locations where an operator's base stations are capacity constrained. This fundamental point underpins bottom-up approaches to spectrum valuation. It is a point that appears to have been missed in the Experts' Report.

There are two bottom-up approaches to estimating the value of spectrum:

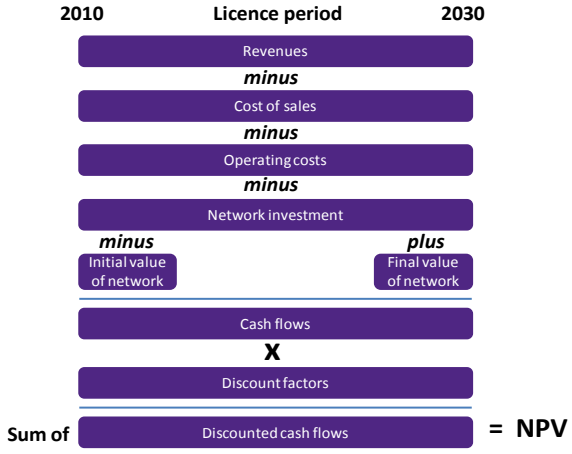
- Discounted cash flow value
- Cost reduction value.

[10] Page 4, SRSP: The revised Framework for Spectrum Pricing, Statement, Ofcom, December 2010.

Discounted cash flow value

A rational firm can be expected to value access to spectrum based on the expected net present value (NPV) of future cash flows where these are calculated valuing all other inputs (including capital) at their market price – for convenience we call this the **discounted cash flow value**[11]. This is the maximum an operator would be prepared to pay for the given amount of spectrum – any higher payment means the operator would not make a reasonable return on its investment (see Figure 1).

Figure 1: Calculation process for estimating discounted cash flows



This approach results in highly uncertain estimates because it is reliant on forecasts of future revenues over the next 20 years and an uncertain relationship between revenue and network capability.

Cost reduction value

At a minimum incremental spectrum can be used by an operator to reduce its costs. Revenues may be earned on top of this but these are not counted in the cost reduction approach. The value occurs in capacity constrained areas where additional spectrum can be used instead of additional base stations to increase capacity – this is called the **cost reduction** value. The steps involved in implementing this approach are shown in Table 2.

[11] In principle mobile operators are also likely to value the investment and operating flexibility that access to additional spectrum provides when faced with uncertainty over future technology and market performance – this is often called the option value of spectrum. In practice the option value is only known by the operator and so regulators do not attempt to estimate its value.

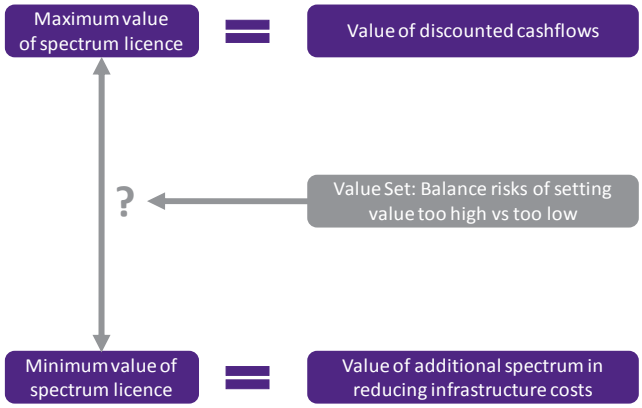
Table 2: Steps in applying the cost reduction method

Step	Action	Comments
Step 1: Determine network and technology situation to be modelled	Make assumptions concerning future network coverage and technology	Transitions between technologies must be considered in a practical manner
Step 2: Determine "typical operator characteristics	Make assumptions concerning forecast traffic, number of base stations (actual or modelled based on link budget and propagation assumptions), and base line spectrum assignment.	Traffic should be split between urban, suburban and rural areas and each of these locations separately modelled. This is crucial to ensure that the impact of spectrum supply on capacity constrained areas is isolated.
Step 3: Determine spectrum increment/decrement	Make assumptions about amount of spectrum to add/take away from base line allocation. This is the minimum amount that can technically can be used to enhance/reduce capacity	Typically this could be the spectrum associated with removing a carrier from each sector. It depends on the carrier size and frequency re-use pattern.
Step 4: Determine the number of base station sites and amount of network equipment to deliver traffic	Either model network or use data from operators to identify initial number of base stations affected that are capacity constrained initially. Model impact of traffic growth on network quantities in future.	Increases in base station numbers will typically be required in urban areas, though some suburban areas may also experience capacity constraints
Step 5: Estimate number of base stations required network costs to support traffic forecasts with and without additional spectrum	Model network with and without spectrum in areas that are capacity constrained	Where areas are capacity constrained, fewer base station sites will be required with additional spectrum
Step 6: Estimate network costs to support traffic forecasts with and without additional spectrum	Change in the number of base stations will results in change in base station and backhaul costs.	The future deployment costs are discounted back to a net present value. Costs include both capital and operating costs such as site rental and maintenance, which may vary by area. With additional spectrum the costs of adding carriers must be taken into account.
Step 7: Estimate value of spectrum increment/decrement	Calculate difference between network costs with and without spectrum	

Relationship between value measures

The cost reduction value should *in theory* always be less than the discounted cash flow value because the operator has the option either to reduce costs only (keeping capacity constant) or to enhance profits further by increasing capacity and possibly also reducing costs (and so increasing cash flows) – see Figure 2. In practice the way the calculations are done may mean this relationship does not always hold. Hence it is necessary to check the cost reduction value does not exceed the cash flow value.

Figure 2: Range of spectrum value measures



If estimates of cost reduction value do exceed the discounted cash flow value, this indicates that the business case would not support the increase in network costs associated with a reduction in spectrum. In these circumstances a network operator would not rationally increase network capacity if denied access to additional spectrum since to do so cannot be justified by incremental revenue. This point is missed in the Experts' Report resulting in an error. This should be corrected.

It also follows that where the two methods generate values that are close, they are subject to the same uncertainties inherent in the discounted cash flow approach and a conservative approach to setting prices is called for.

2.3.3 Choice of operator characteristics

To implement both the discounted cashflow and cost reduction approaches it is necessary to make assumptions about the business and network characteristics of the operator whose spectrum value is being calculated. Values for a "typical" or average operator could be chosen but it should be recognised that this results in an average valuation and may be above the value of spectrum to weaker operators. This might suggest that characteristics of weaker operators should be chosen. The choice depends on whether the allocation of spectrum between operators is thought to be reasonably efficient or not:

- If the allocation of spectrum between operators is thought to be inefficient then setting an average value may be seen as beneficial as it could encourage reallocation of spectrum between operators.
- If allocations between operators are reasonably efficient then setting an average value risks leaving spectrum idle. It is for this reason that values are sometimes set based on the characteristics of the weakest or weaker operators.

We note that the second situation is analogous to the way efficient auctions work - the auction price is at or just below the value of the resource to the lowest winning bidder.

2.4 Examples of best practice

Examples of best international practice in setting spectrum fees to promote efficient spectrum use are given by:

- The approach adopted by the UK regulator Ofcom to setting Administered Incentive Pricing (AIP)
- The approach used by the New Zealand Government to set fees that applied on renewal of spectrum licences used to provide cellular mobile services

The subsections below describe the approaches taken and provide a summary of our findings.

2.4.1 UK approach[12]

Spectrum fees in bands that have not been auctioned are set by Ofcom based on opportunity costs calculated at the margin.[13] These fees are charged on an annual basis and are called Administrative Incentive Pricing (AIP). As well as being applied in the UK, the approach is discussed in the ITU's ICT Regulation Toolkit.[14]

Opportunity cost estimates have been calculated by considering the impact of a hypothetical marginal change in spectrum on the costs of an "average firm" in the sector assuming the level of output and service quality are kept constant. For example, suppose the average firm was denied a unit of spectrum then the marginal cost equals the minimum additional costs the firm would incur to maintain the same level of capacity. These additional costs were calculated by examining the least cost alternative action an "average firm" might take when denied access to a small amount of spectrum.[15] In the case of cellular services this involves investing in more network infrastructure to achieve the same quantity and quality of output with less spectrum.

This approach assumes output and service quality are both fixed – so revenue effects and other non-cost aspects of value (e.g. convenience) do not need to be considered. This is similar to the cost reduction method described in the previous section.

In the case of mobile services values were calculated for spectrum at 900MHz and 1800MHz. If the spectrum available to the operator was increased (decreased) and it was assumed the operator would react by decreasing (increasing) the number of sites used so that the same amount of capacity was offered by the network. These calculations were undertaken for locations known to be capacity constrained.

The following table shows the annual values/MHz estimated and fees applied to 900 MHz and 1800 MHz spectrum in the UK. Actual fees were set at half the estimated value on the grounds that:

- There is uncertainty concerning the opportunity cost estimates (because these are based on forecasts and an "average operator")

[12] This approach is also proposed in Australia http://www.acma.gov.au/webwr/_assets/main/lib310867/ifc12-09_final_opportunity_cost_pricing_of_spectrum.pdf and Hong Kong http://www.ofta.gov.hk/en/freq-spec/suf.html.

[13] This approach was first recommended in Study into the Use of Spectrum Pricing, NERA and Smith System Engineering, Radiocommunications Agency, April 1996 and then applied by the regulator from 1998 on. In 2002 it was endorsed in a review undertaken by Professor Martin Cave http://www.ofcom.org.uk/static/archive/ra/spectrum-review/2002review/1_whole_job.pdf

[14] http://www.ictregulationtoolkit.org/en/Section.1280.html

[15] Usually the smallest change in spectrum use that is technically feasible.

- The economic losses from setting prices too low (spectrum not being allocated to the highest value use/user) are less than those from setting prices too high (spectrum being underused).[16]

New estimates obtained in 2004 were not applied on the grounds that fees would be reviewed three years later because of uncertainty over policy in respect of the frequency bands.[17]

Table 3: Annual fees and value estimates (£/MHz) for 900 and 1800 MHz bands in the UK[18]

	Fees applied since 2002	2004 estimates
900 MHz	£356k/MHz	£840k/MHz
1800 MHz	£277k/MHz	£840k/MHz
Comments	Fees were set at 50% of values estimated in 1996	Fees were not changed based on new estimates

In a recent review of Spectrum Pricing, Ofcom examined the pros and cons of using cost reduction (termed least cost alternative - LCA) method and a discounted profit approach (reproduced in the following table)[19]. It concluded that "the LCA method is generally fit for purpose and propose to continue using it but acknowledge that the discounted profit (DP) method offers a useful alternative in certain circumstances"[20]

Table 4: Advantages and disadvantages of the LCA and DP methods

	Advantages	Disadvantages
LCA method	Information requirements are not demanding Easy to implement	Not applicable if output cannot be assumed constant/revenue implications cannot be ignored Sensitive to assumptions, will produce a range of values Requires judgement to choose from range of values estimated
DP method	Method used by users to estimate values in an auction Is applicable if output cannot be assumed constant/if revenue implications cannot be ignored	Same as LCA except for first point Requires more cost information and uncertain revenue forecasts than LCA

Source: Table 1, SRSP The revised Framework for Spectrum Pricing, Consultation, Ofcom, March 2010

[16] This is discussed more fully on p180 of "Essentials of Modern Spectrum Management", Cave, Doyle and Webb, CUP 2007 and in "An Economic Study to Review Spectrum Pricing", Indepen, Aegis Systems and Warwick Business School, Ofcom, February 2004. http://www.ofcom.org.uk/research/radiocomms/reports/independent_review/spectrum_pricing.pdf

[17] Para 3.17, Spectrum Pricing: Statement, Ofcom, February 2005. The future policy for the bands is still under consideration.

[18] "An Economic Study to Review Spectrum Pricing", Indepen, Aegis Systems and Warwick Business School, Ofcom, February 2004. http://www.ofcom.org.uk/research/radiocomms/reports/independent_review/spectrum_pricing.pdf

[19] P56, SRSP The revised Framework for Spectrum Pricing, Consultation, Ofcom, March 2010.

[20] Para 4.22 SRSP The revised Framework for Spectrum Pricing, Consultation, Ofcom, March 2010.

2.4.2 New Zealand Approach

In New Zealand the government needed to set licence fees on expiry of existing 20-year spectrum licences at 800/900MHz. Licensees were to pay a single upfront fee on licence renewal. The government's objectives were to maximise the value of spectrum to society and provide a fair return to the Crown and so the market value of spectrum needed to be estimated[21].

A study for the New Zealand government examined options for estimating market value was commissioned. This study considered approaches based on: (1) benchmarking;(2) earnings or project values; and (3) avoided costs or deprival value. [22] Benchmarking was rejected on the grounds that there are few, if any, like-for-like comparators. Earnings-based approaches suffer from the uncertainties about future revenue growth and service/technology change and so the consultants recommended an approach based on the "incremental optimal deprival" value (IODV)[23].

The implementation of the methodology by Network Strategies[24] involved modelling:

- A generic operator with an efficient nationwide mobile network, where the network had the optimal number and placement of sites to deliver a constant coverage and quality level[25] and used the most efficient technology (i.e. LTE) and not the actual technology deployed);
- A generic operator assumed to have between 2x10 and 2x15 MHz (at 800/900 MHz) and 2x15 MHz at 2.1 GHz, an average market share and traffic/customer forecasts based on market trends.
- The impact of depriving the generic operator of 2x2.5 MHz at 800/900 MHz. Network costs (in particular base station and backhaul costs) with and without the 2x2.25 MHz were estimated. Network costs in areas[26] that are capacity constrained increase as a result of the spectrum deprival because more base stations sites have to be installed to support the forecast traffic growth.

This approach follows the steps shown in Table 2 for the cost reduction approach. It is the same as the UK AIP approach except that calculations assume a hypothetical network which uses the most efficient technology (in this case LTE). The UK approach is based on actual networks where sites are not always optimally located, because of planning constraints and the historical evolution of the network.

2.5 Conclusions on international best practice

The findings on spectrum valuation based on economic analysis and our examination of international best practice are that:

[21] http://www.rsm.govt.nz/cms/policy-and-planning/current-projects/radiocommunications/cellular-rights/past-consultation-and-documents/international-peer-review-1/2-the-crown-s-objectives

[22] Renewal of Spectrum Rights for Cellular Services pricing methodology, Discussion paper, July 2006, PriceWaterhouseCoopers and NZIER, Ministry for Economic Development, http://www.med.govt.nz/templates/MultipageDocumentTOC____20766.aspx;

[23] Renewal of Spectrum Rights for Cellular Services pricing methodology, Discussion paper, July 2006, PriceWaterhouseCoopers and NZIER, Ministry for Economic Development, http://www.med.govt.nz/templates/MultipageDocumentTOC____20766.aspx

[24] http://www.rsm.govt.nz/cms/pdf-library/policy-and-planning/radio-spectrum/rights-at-expiry/network-strategies-report

[25] Although the starting point for the network was calibrated against the actual number of base stations.

[26] Urban, suburban and rural areas were modelled based on operator data concerning the split between the three types of area.

- The market clearing price of spectrum should lie between a cost reduction value and a value based on the discount cash flows earned from a given amount of spectrum. The cost reduction value should be less than the value based on discounted cash flows.
- Values based on cost savings rather than cash flows are more robust and generally simpler to calculate, because less information on the future development of services is required.
- It is good practice to have a downward bias in the fees set so as to minimise potential economic losses.
- The cost reduction approach is based on the use of spectrum to engineer networks in capacity constrained cells. If the operator has less spectrum then it must investment in additional base stations in order to carry the traffic generated by its customers.
- The AIP and IODV approaches are the same except in respect of the network and technology assumptions made:
  - The AIP approach: This approach uses actual network data on numbers of base stations and information on likely technology migration paths to forecast the future network configuration.
  - The IODV approach: This approach assumes an optimal network configuration (to achieve a given coverage level) and optimal technology is deployed. When this approach was implemented in New Zealand actual numbers of base stations were used to calibrate the model making the approach more like the AIP approach.

3 Comparison of best practice with the proposals in the Experts' report

Chapter II of the Experts' Report proposes taking the average the results from two proposed methods for estimating the economic value of incremental 1800 MHz spectrum above the initial 6.2 MHz. The two methods comprise:

- Method 1: Cash flow from spectrum. This involves estimating the NPV of the additional cash flow an operator would earn over 20 years from an increment of 1.8 MHz of spectrum.
- Method 2: The substitution approach. This involves estimating the price of spectrum based on the savings in base station costs as a result of having additional spectrum at a given number of subscribers.

In both cases we have been unable to provide a full critique of the approaches used due to the non-disclosure of the actual models used to estimate the value of spectrum. The non-disclosure of the actual model used is inconsistent with international best practice and limits the analysis that can be undertaken. As such, the analysis below is limited to what can be read in the Experts' Final Report which gives contains sufficient information to indicate a number of basic errors.

3.1 Cash flow approach

The cash flow approach proposed in the Experts' Report appears to follow the standard approach to cash flow valuation. However, the assumptions used are not reasonable. Consequently, the results are not credible.

As noted above, the non-disclosure of the actual model and the resulting lack of transparency limits the analysis, but from what can be observed it appears that the revenues and costs for three years are forecast and then assumed constant for the remaining 17 years. [27] While the outlook for the mobile industry is uncertain, one thing that does appear certain is that the market is likely to change significantly over the next 20 years. The cash flow model should capture a range of plausible future scenarios.

In addition, the following detailed points can be made:

- The model assumes consistent average revenue per user (ARPU). This assumption is highly unrealistic as the TRAI Performance Indicator Reports show a quarterly all-India ARPU decline of around 10% and a year-on-year decline of 33%.[28] This should be factored into the model.
- The model does not take into account interconnect cost. ARPU should have been adjusted to take into account the interconnection costs associated with calling other networks. As such, the model should be based on average margin per user (AMPU).[29] Using September 2010 data, adjusting for interconnection costs reduces ARPU by 16% in A, B and C circles and by 19% in metro circles. The all India ARPU is reduced by 17%.[30]
- No cost trend included for future operating cost per base station. Base station opex accounts for 90% of total yearly base station costs in the model described in the Experts' Report. The cash flow model assumes that the operating cost would not change throughout the next 20 years. This is highly unrealistic. The main components of base station opex (land rental, labour and diesel/electricity) are increasing each year. It is reasonable to assume that these costs would be significantly higher in 20 years time.
- Unrealistic financial lifetimes of base stations. The model assumes that a base station has a financial lifetime of 20 years. This assumption is inconsistent with the accepted regulatory lifetimes used throughout the world. For example, recent UK and Dutch cost models assume 8 year lifetime for BTS equipment.[31]
- Unrealistic subscriber growth. It can be expected as in other markets that penetration of mobile phones in India will approach saturation in the next 20 years.

Due to the non-disclosure of the actual model a sensitivity analysis cannot be undertaken. However, these are fundamental flaws that are likely to results in erroneous forecasts of value

In addition to inappropriate input values, the value per MHz of incremental spectrum in all areas, with the exception of Kolkata, is found to be larger than that of 6.2 MHz. It would normally be expected that the relationship would be around the other way, i.e. incremental spectrum above 6.2 MHz would be worth less than the value of the initial 6.2MHz. This is because:

- Efficient operators acquire the most profitable customers first, business customers and affluent individuals on contracts, and then expand capacity and their service offering to attract other less profitable customers
- The initial spectrum holding is used to provide coverage as well as capacity.

[27] See p 28 of the Experts' Report.

[28] TRAI, *The Indian Telecom Services Performance Indicators July – September 2010*, Table 2.1.

[29] ARPU is adjusted in the following way: AMPU = ARPU – (outgoing MOU * % of outgoing MOU to other mobile networks * MTC).

[30] TRAI, *The Indian Telecom Services Performance Indicators July – September 2010*, Tables 2.1, 2.4 & 2.5.

[31] See http://stakeholders.ofcom.org.uk/consultations/wmctr/ and http://www.opta.nl/nl/wat-doet-opta/markten/mobiele-telefonie/

The authors discuss their unusual findings (p37-38), and attribute them to various aspects of their attribution of costs[32]. However, this simply highlights the fact that the analysis should have used alternative assumptions.

In summary, the cash flow model: (1) does not reflect actual market data; (2)does not properly reflect the range of possible outcomes over a 20 year period; and (3) gives results that do not pass the common sense test (that incremental spectrum should be of less value than initial 6.2 MHz of spectrum). Hence, the cash flow model as currently specified is not suitable for estimating the value of spectrum.

3.2 Substitution approach

The substitution approach is based on the concept that there is a trade-off between spectrum and base station costs, which is similar to the cost reduction approaches described above. However, the Experts' Report seeks to estimate the relationship between spectrum and base stations using a Cobb Douglas production function rather than using well established engineering relationships that underpin the international best practice examples that were applied in New Zealand and the UK.

The production function approach is incorrect because the Cobb Douglas production function has no clear foundation in network engineering or the economics of network deployment. In particular:

- The production function is mis-specified. The dependent variable should be the level of traffic (or ideally busy hour traffic) in congested area in a circle, *not* total number of subscribers across all the area in a circle as is used in the Experts' Report.
- The production function approach assumes that operators can optimise their spectrum and base station inputs at any point of time to meet the demands of their subscriber base. This is clearly not practical.

As can be seen in Table 5 the model in the Experts' Report does not conform to international best practice.

For these reasons we would expect the model used in the Experts' Report to give unreliable results. This is the case in fact. For example, the Experts' Report finds:

- The incremental value of spectrum is lower in the Metro areas as compared Category A and B areas. This does not seem correct. Incremental spectrum would be expected to be more valuable on a cost reduction basis in the Metro areas given their greater population density and hence higher traffic density in future
- The value estimated for Mumbai is over 3 times that estimated for Kolkata. This does not look correct. We would expect values to be similar because[33]:
  - The number of subscribers per base station is almost identical in each case (4578 and 4635 for Kolkata and Mumbai respectively)
  - The amount of spectrum per base station is almost identical in each case (0.0174MHz and 0.0176MHz for Kolkata and Mumbai respectively).

[32] For example, not taking account of trunking efficiencies derived from the production function estimates derived in Method 2 and the higher allocation of administration, marketing and salary costs to the initial 6.2 MHz - 28% of revenue as compared with 22% for the incremental spectrum.

[33] Based on data provided in the Annex to the Experts' Report.

- The incremental value of spectrum from the cost reduction approach is greater than that from the cash flow approach. If the cash flow approach is a correct representation of the revenue and cost saving potential of the spectrum then this should give the maximum the operator would be prepared to pay for the incremental spectrum. This tells us the operator would not pay the cost reduction value for incremental spectrum – it is simply not profitable to do so.

The authors attribute the variation in values to differences in population distribution in urban and rural areas. This simply highlights the deficiency in the method. It is important that the model takes account of these differences to obtain a realistic cost reduction value.

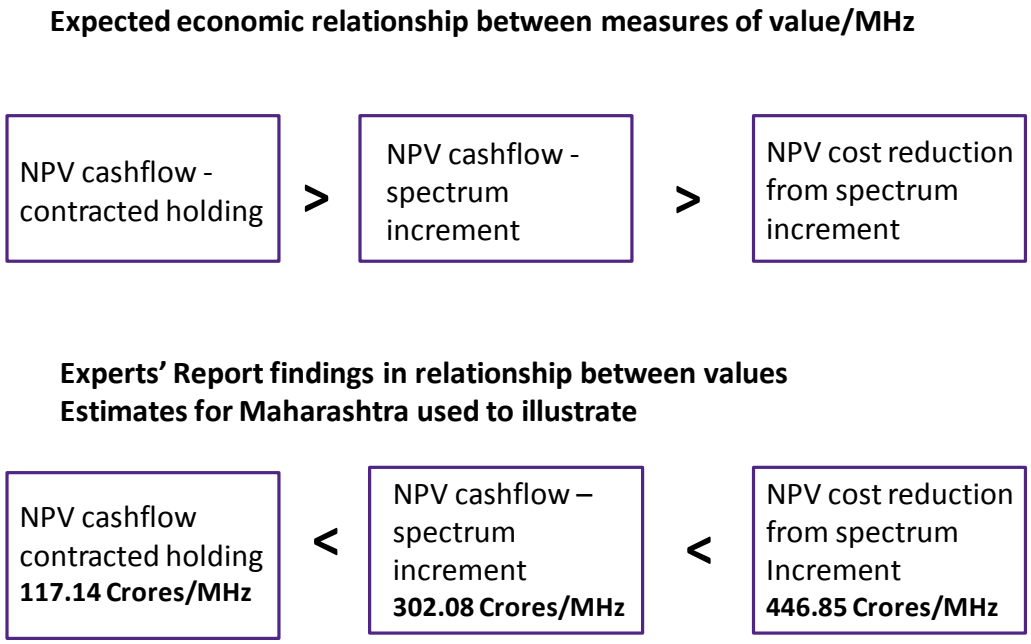
Table 5: Assessment of Experts' Report Cost Reduction Approach Compared with International Best Practice

Step	Action	Model in Experts' Report
Step 1: Determine network and technology situation to be modelled	Make assumptions concerning future network coverage and technology	**No**. Relationship is based on historic investment. No forward looking adjustments are made.
Step 2: Determine "typical operator characteristics	Make assumptions concerning forecast traffic, number of base stations (actual or modelled based on network assumptions), base line spectrum assignment	**No**. Only reflects three operators out of a market of up to 12. Reflects neither average nor marginal operator.
Step 3: Determine spectrum increment/decrement	Make assumptions about amount of spectrum to add/take away from base line allocation. This is the minimum amount that can technically can be used to enhance/reduce capacity	**No.** Production function determines average relationship not marginal relationship. Model does not represent marginal cost.
Step 4: Identify areas and number of base stations that are capacity constrained	Either model network or use data from operators to identify number of base stations affected that are capacity constrained initially. Model impact of traffic growth on capacity constraints in future.	**No.** No adjustment for capacity constrained cells made.
Step 5: Estimate number of base stations required network costs to support traffic forecasts with and without additional spectrum	Model network with and without spectrum in areas that are capacity constrained	**No.** Model regresses against subscribers not traffic.
Step 6: Estimate network costs to support traffic forecasts with and without additional spectrum	Change in the number of base stations will results in change in base stations costs and possibly also costs of backhaul.	**Yes** Model calculates cost. Although not enough information to assess how model treats future costs over lifetime of network.
Step 7: Estimate value of spectrum increment/decrement	Calculate difference between network costs with and without spectrum	**Yes** Although relationship between spectrum, network costs and traffic is mis-specified

3.3 Conclusion

Neither the cash flow nor the cost reduction method proposed in the Experts' Report is of adequate rigour (in either methodological approach or in the data used) to provide reliable estimates of the value of spectrum. It is not surprising therefore that the relative values obtained do not follow economic logic – in fact they reveal values that are the reverse of those expected by economic logic as shown in Figure 3.

Figure 3: Relationship between values



This reinforces the view that no reliance at all can be placed on the estimates contained in the Experts' Report. If these values are used there is a significant risk of overpricing spectrum[34] which could result in spectrum potentially left idle and negative results on the development of the sector and the wider Indian economy.

4 What value should apply?

We conclude that the approaches proposed in the Experts' Report should not be used to determine the market or opportunity cost value of incremental spectrum at 1800 MHz. The market value of spectrum can be directly observed through auctions or market trading of the spectrum concerned. In the absence of a spectrum auction at the beginning of a licence period, the market value can be observed through a functioning secondary market for spectrum – that is, by allowing operators to trade spectrum and observing the traded prices for spectrum. We note that this optimal market-based solution has been rejected by the TRAI.

[34] The fact that incremental and cost reduction values are in general higher than the 3G auction values (see para 2.60 of the Experts' Report) reinforces the view that spectrum could be overpriced.

The market price can be estimated through an appropriate economic valuation methodology. The international best practice approach, based on a cost reduction methodology and described in Table 2 should be adopted for the estimation of market value for following reasons:

- It is based on sound economic and engineering principles
- It provides a robust estimate of spectrum value as it reflects the way operators plan network deployment and value additional spectrum to cater for traffic growth
- Values should be set on the low side because all estimates have some uncertainty. It is desirable to avoid setting prices too high to avoid the risk that spectrum is otherwise left idle or there is excessive pressure on operators to consolidate thereby reducing competition to the detriment of customers.
- It is practical to implement.

It is for all these reasons the cost reduction method has been used by other regulators.