NETWORK COMMON COSTS

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Introduction

1. In Oftel's LRIC model there are few common costs. At a meeting with Competition Commission staff Oftel was asked whether this was the result of its choice of two broad increments - all traffic and all customers – rather than separate increments for each service, such as incoming calls (termination) and outgoing calls. This paper sets out and explains Oftel's view that common costs are relatively small even with separate increments for each service. Wherever possible, the arguments are illuminated by including information on mobile network costs from the LRIC model.

Small Common Costs Between Broad Increments of Traffic and Customers

2. In Oftel's LRIC model of mobile network costs there are relatively small common costs, comprising only about 3-5% of total network costs, as shown in Table 1. They consist of the costs of a network management system and of acquiring, preparing and leasing the number of sites needed to meet the coverage requirements. Such costs are referred to as the costs of minimum coverage presence (MCP).

Table 1: Common costs (MCP) as a proportion of total network costs in 2005/06

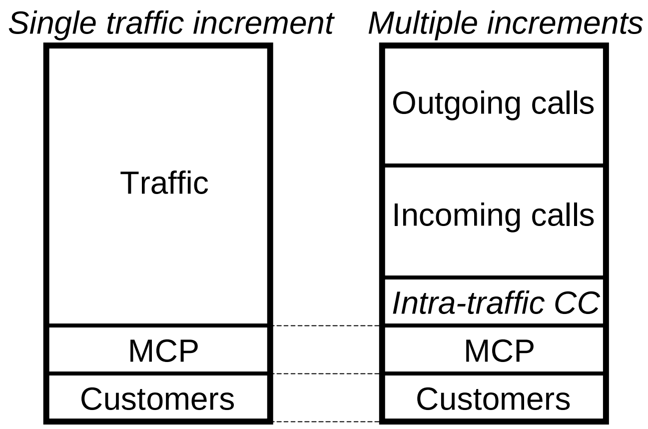
	900 operator (£m)	% split	1800 operator (£m)	% split
Traffic	1,606.6	96.2%	1,782.4	94.6%
Customers	8.5	0.5%	8.5	0.4%
MCP (common costs)	54.3	3.3%	92.4	4.9%
Total	1,669.3	100.0%	1,883.2	100.0%

Small Common Costs between Incoming and Outgoing traffic

3. The Competition Commission staff asked at the meeting on 28 January whether the common costs are small because of Oftel's choice of broad increments in the model: traffic and customers. In particular, how much larger would the common costs be if incoming traffic (termination) and outgoing traffic were defined as separate increments?

4. In principle, since the increment is defined more broadly in the model as all traffic, any common costs that exist between incoming and outgoing calls would be included in Table 1 within the LRIC of traffic. Such costs will be referred to as 'intra-traffic' common costs – see Figure 1. As explained below, in practice, however, there are few sources of economies of scale and scope in mobile networks (apart from short run modularity effects). Consequently, common costs between incoming and outgoing traffic are relatively small.

Figure 1: Common costs



Note: Not drawn to scale

Results from earlier modelling work

5. In earlier modelling work Analysys built and compared single-increment and multi-increment versions of the model. The multi-increment version had separate increments for incoming calls, off-net calls, on-net calls, SMS, GPRS, HSCSD and customers. The results are shown in Table 2.

6. As a proportion of total network costs, intra-traffic common costs in the multi-increment version were very small at only 0.7%. On this basis there are few additional common costs even if separate increments are defined for each service.

Table 2: Comparison of single- and multi-increment models for 900 MHz operator in 2000/01 (using versions of the LRIC model in March 2001)[1]

	Multi-increment		*Single increment*	
	£m		£m	
Stand-alone cost of coverage	215.9	20.9%	215.9	20.9%
Total cost of increments	809.2	78.4%	816.2	79.1%
Intra-traffic common costs	6.9	0.7%	n/a	n/a
Total	1,032.0	100.0%	1,032.1	100.0%

Note: MCP costs were included within the stand-alone cost of coverage in these figures.

Treatment of coverage costs

7. There is, however, a complication to be explored. At the time that the modelling work reported in Table 2 was undertaken, coverage costs were being treated separately from the incremental costs of traffic and customers. The model was set up first to derive the stand-alone costs of a coverage network. This was defined as the cost required to build a network that provides full geographic coverage and is capable of carrying traffic, but is only dimensioned to carry the minimum amount of traffic. From Table 2 it can be seen that such costs constituted a significant proportion of total costs at about 21%. The incremental cost of traffic was then derived as the additional cost required to provide a network that carries the traffic demanded.

8. In April and May 2001, subsequent to the analysis in Table 2, Oftel refined its thinking about the appropriate treatment of such costs. There is a minimum deployment of traffic-handling capacity at each base station (and in the backhaul and backbone conveyance networks[2]). Until the volume of traffic exceeds this level no additional capacity needs to be installed. Such capacity costs constitute a large proportion of the so-called 'stand-alone costs (SAC) of coverage', more than 80% - see Table 3.

9. The term 'SAC coverage' is misleading, because the traffic-handling capacity is not needed for coverage purposes – instead it reflects a 'lumpiness' or modularity in the deployment of capacity. In other words, in the absence of the modularity, the costs of traffic-handling capacity would not be incurred in the (hypothetical) stand-alone coverage network (or such costs would be minimal). Following discussion of

[1] The figures in Table 2 are derived from page 5 of *Issues surrounding mobile LRIC model*, Analysys, 28 March 2001, paper 5t attached to Oftel's submission of 22 January 2002. It should be noted that the figures in £m are not the same as in the final version of the model. This is because the final version includes improved modelling of economic depreciation. However, Oftel would not expect the final version of the model to have substantially different relative sizes of incremental and common costs than Table 2 between single- and multi-increment versions.

[2] Backhaul connects bases station sites to Base Station Controllers (BSCs). The backbone network links together switches: BSCs and MSCs.

this issue with mobile and fixed operators in the 'LRIC Working Group'[3], it was concluded that a better reflection of cost causation would be provided by regarding those coverage costs that relate to traffic-handling capacity as being part of the incremental cost of traffic.

Table 3: Breakdown of costs in 'SAC coverage'

	900 operator	*1800 operator*
'SAC coverage'		
NMS	2%	1%
Site acquisition, preparation and lease	16%	16%
Capacity costs[4]	82%	83%
Total	100%	100%
Capacity costs		
Macrocell equipment	81%	84%
TRXs	6%	6%
Backhaul	8%	5%
BSCs	4%	3%
Other	2%	1%
Total	100%	100%

Note: Figures may not sum to 100% due to rounding.

10. The breakdown of the capacity or traffic-related costs in the 'SAC coverage' is shown in the lower half of Table 3. There are two types of cost at base station sites: macrocell equipment and transceivers (TRXs). Macrocell equipment is needed for each site and includes towers, antennas, Base Transceiver Stations (BTS) and power. The minimum capacity deployment at a site also involves one TRX per sector (coverage sites are configured with 1 sector; highway sites have 2 sectors; and urban/suburban sites have 3 sectors). The first TRX deployed provides 7 traffic channels (allowing 7 simultaneous voice calls in the busy hour). Additional TRXs can be added to provide further traffic capacity up to a limit depending on the network design assumptions (on average, 4 TRXs per sector for 900 operators and 4.5 TRXs per sector for 1800 operators). Beyond this limit an additional site needs to be deployed to expand traffic-handling capacity. The other traffic-related costs in the 'SAC coverage' relate to the costs of a minimal backhaul and backbone conveyance network.

11. The remaining, non-capacity costs of the coverage network comprise the costs of acquiring, preparing and leasing the number of sites needed to meet the coverage requirements and the cost of a network management system. Together they form the minimum coverage presence costs, ie the common costs between customers and traffic which Oftel has proposed should be recovered using an equal proportionate mark-up of 3-5%.

[3] See the minutes of the LRIC Working Group meetings of 24 April and 11 May 2001.

[4] Nearly all of the capacity costs are traffic-related, although a very small proportion (less than 1%) are customer-related.

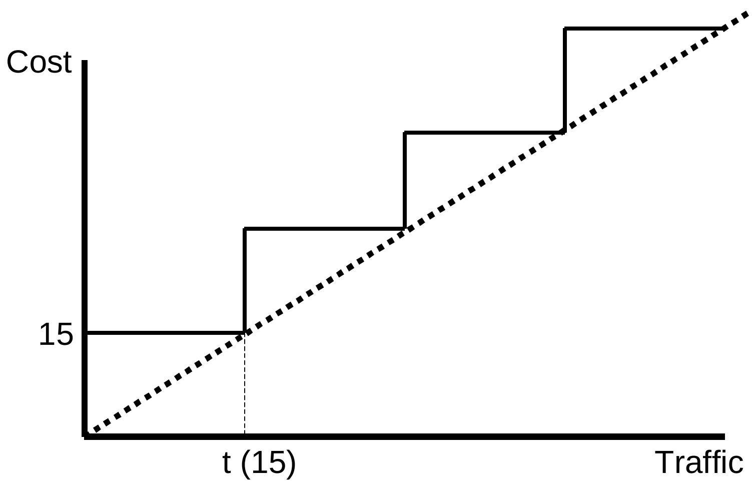
Sources of Common Costs and Economies of Scale

12. Common costs arise when there are economies of scope, ie it is less costly to provide the two increments together than for two separate firms each to provide one of the increments on its own. When services (eg incoming and outgoing calls) share the use of a facility (eg base station sites), economies of scope exist if the cost function for that facility displays economies of scale. Economies of scale can arise:-

- because the marginal cost of increasing capacity is below the average cost; or
- in the short run from lumpiness or modularity in the addition of capacity.

Capacity in the radio network displays modularity as illustrated in Figure 2.

Figure 2: Costs of traffic capacity at base station sites



13. Figure 2 can be interpreted for each of TRXs and site equipment. For TRXs the vertical axis measures the cost of traffic capacity at a base station and each step represents an additional TRX. For site equipment the costs of sites are measured on the vertical axis and each step represents the deployment of an additional base station site.

14. If the modularity effects are smoothed, the radio network displays constant returns to scale. In the underlying cost function the average cost does not fall as output increases (diagrammatically, this means that the steps in the cost function are connected by the dotted line through the origin). To double the traffic-handling capacity at a site the number of TRXs would need to be doubled. When the maximum limit on TRXs per sector has been reached, doubling the capacity requires that the number of sites is doubled. Site equipment and TRXs account for a large proportion of the total network costs, 48%-55% – see Table 4.

Table 4: Total network costs by network element[5] in 2005/06

	900 operator	1800 operator
MCP – NMS, coverage site acquisition, preparation & lease	3%	5%
Site acquisition, preparation and lease (non-coverage sites)	6%	5%
Macrocell equipment	34%	40%
Micro and picocell equipment	2%	2%
TRX	12%	13%
Backhaul	5%	3%
BSC	7%	6%
MSC	6%	5%
Backbone transmission	6%	5%
GPRS dedicated infrastructure	17%	15%
Other (HLRs, spectrum fee)	2%	2%
Total	100%	100%

Note: Totals may not sum to 100% due to rounding.

15. In other parts of the mobile network (apart from modularity effects), there are few sources of economies of scale:-

- Some economies of scale arise in backhaul. If there is sufficient traffic to justify the use of a 8 Mbit/s link rather than 2 Mbit/s, economies of scale are exploited, because the cost per Mbit/s of the larger transmission system size is cheaper. Such economies of scale are reflected in the LRIC model, but the effect is small because backhaul only accounts for 3-5% of total network costs.

- There may be some economies of scale in the core or backbone network (which are not captured in the LRIC model, because of lack of information about their importance). The backbone network accounts for 16-19% of network costs (BSCs, MSCs and backbone transmission).

- There may be some economies of scale in site acquisition, eg arising from increased purchasing power. On the other hand, it is also possible that there are diseconomies of scale, ie that as suitable locations become more scarce, it becomes more expensive to acquire sites at the margin. (The LRIC model assumes neither economies nor diseconomies of scale in site acquisition, again because of lack of information[6]). Site acquisition, preparation and leasing accounts for 9-10% of network costs.

- The LRIC model allows for economies of scale arising from the Network Management System (NMS) and spectrum fees, because both are treated as fixed costs that do not increase with scale. However, they account for less than 2% of network costs. In any case it is arguable that either is a true source of

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[5] A more detailed cost breakdown is available in the LRIC model.

[6] It is assumed, however, that site acquisition costs rise over time (in real terms) – see, for example, Figures 11 and 12 in Oftel's paper, *Additional information concerning Oftel's LRIC model*, 12 February 2002.

economies of scale, because in reality such costs are likely to rise and fall with the volume of traffic and customers.

16. This discussion of the lack of sources of significant economies of scale provides further support for the conclusion that small common costs exist between incoming and outgoing traffic.

Apparent Common Costs (Short Run Costs)

17. In apparent contradiction to the above conclusion, if short run costs are analysed, ie reflecting the modularities and steps in the cost function shown in Figure 2, there appear to be significant intra-traffic common costs. Oftel's view is that this relies upon a contrived view of costs that uses a short run perspective, when the long run view is more appropriate. Nevertheless, it illuminates the debate to set out the argument in this section, which is then critically evaluated in the next section.

18. Figure 2 above sets out the way in which the costs of providing traffic-handling capacity arise at base station sites. To assist understanding, simple and purely illustrative figures are used for volumes and costs. The cost of each capacity deployment is assumed to be 15. Over a range of traffic no additional capacity needs to be installed beyond the initial deployment to serve the level of traffic, ie up to the volume denoted by 't' in Figure 2 or traffic volume of 15. Thereafter, additional traffic requires an additional 'lump' of capacity (eg an additional site) and so costs increase by 15. The cost line is therefore flat in the ranges between capacity deployment and step up by 15 with each additional deployment.

19. Let us first consider a base station site that has a small volume of traffic, ie total traffic is less than t=15 (the point at which the first kink occurs). Such sites are often referred to as 'coverage sites'. The argument that the minimum capacity deployment constitutes intra-traffic common costs between incoming and outgoing calls would run as follows. The incremental cost of incoming calls is derived by assuming that outgoing calls are already provided and considering the increase in cost caused by adding incoming calls. The increase in capacity cost would be zero, because there would be no need to add any capacity beyond the minimum deployment. Exactly the same line of argument would apply to the incremental cost of outgoing calls. The conclusion would appear to be that the incremental cost of each service is zero and the minimum capacity deployment represents a common cost (equal to 15 using the illustrative figures).

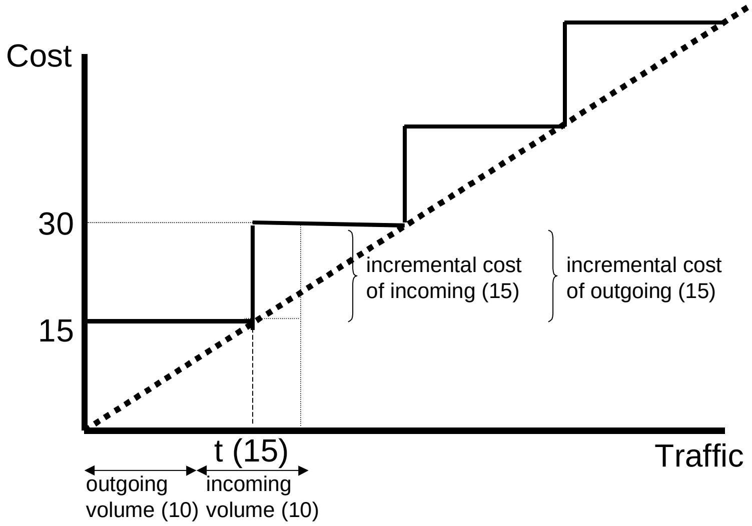
20. Similarly, common costs could apparently arise at higher traffic volumes, if the addition of, for example, incoming traffic would not require an additional capacity deployment beyond that already required for outgoing traffic. In other words, if the excess capacity on any step could be used to serve the incoming traffic, then the incremental cost appears to be zero and common costs appear to arise.

21. But it is not always the case that there would be common costs. If each of incoming and outgoing calls required additional capacity to be installed, there would be no common costs. This case is illustrated in Figure 3. The incremental cost of

each of incoming and outgoing calls would be 15 and the total cost would be 30, so common costs would be zero.

22. In summary, the existence of lumpy or modular capacity deployment can in some cases give rise to some apparent common costs in the short run between incoming and outgoing calls. This arises where the additional increment of traffic does not trigger any additional capacity deployment, such as for coverage sites.

Figure 3: Costs of traffic capacity at base station sites (no common costs)



Differences Between Short Run and Long Run Costs

23. The source of intra-traffic common costs in the argument in the previous section is not a true long run economy of scale. Instead it only arises from the lumpiness in the deployment of capacity and consequently the finding of intra-traffic common costs is a contrived conclusion. This becomes apparent if the underlying economic issue is considered, ie the difference between short run and long run costs and which should be reflected in economically efficient prices.

24. The differences between short run and long run costs are set out below and then the implications of using each as the basis for pricing are discussed.

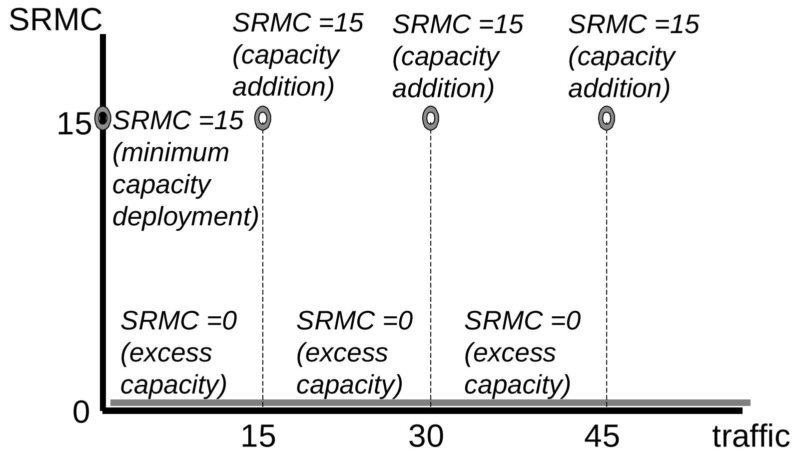
Short run marginal costs

25. Figure 4 shows the cost function for base station sites for short run marginal cost (SRMC). The modularity effects result in SRMC that is either: -

- zero, if the horizontal portion of the cost function at the current level of traffic in Figures 2 or 3 is used on any of the steps, ie there is excess capacity; or

- large, if a capacity addition is required at the margin (SRMC is 15 using the illustrative figures).

Figure 4: Short run marginal costs of base station sites

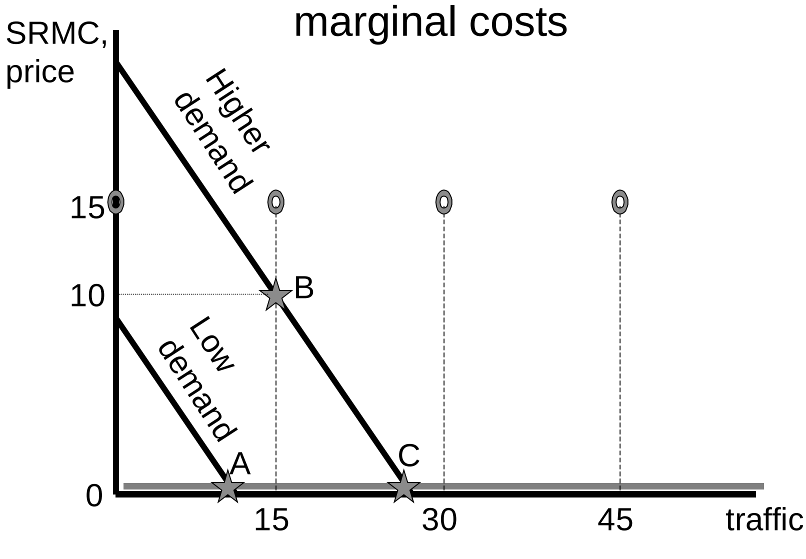


SRMC pricing

26. Reflecting this structure of costs, if prices were set using SRMC they would either be:-

- zero, if the capacity deployed had not yet been fully utilised; or
- at a level sufficient to ration demand - any number of rationing prices may exist depending on the position of the demand curve.

Figure 5: Prices based on short run marginal costs



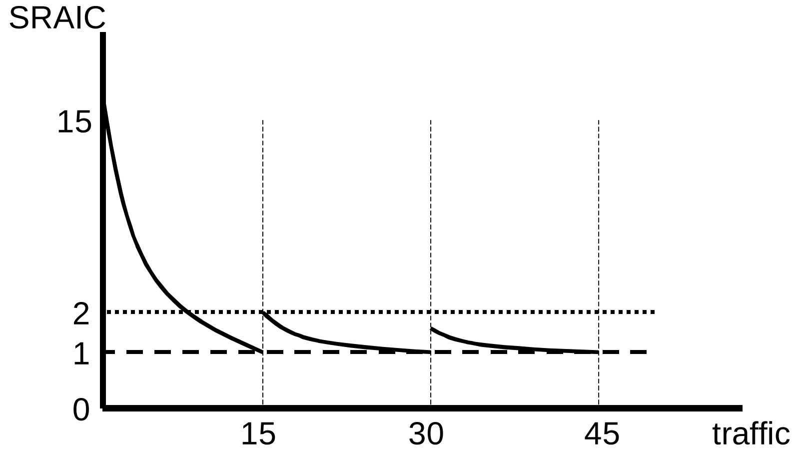
27. The derivation of prices using SRMC is illustrated in Figure 5. At a low level of demand, the traffic level does not exceed the minimum capacity deployment (even at price equal to zero). The appropriate SRMC price is zero, in order to encourage as much use as possible of the capacity that has been deployed. The outcome is shown by point A in Figure 5.

28. Let us now assume that there is an increase to a higher level of demand. The immediate effect would be for the price based on SRMC to rise to a level that rations demand so that it fills up, but does not exceed, the capacity deployed, ie point B. For illustration it is assumed in Figure 5 that this rationing price is 10. If an additional 'lump' of capacity was added, the SRMC price would fall back to zero (at point C), as before to stimulate as much usage of the excess capacity as possible.[7]

Short run average incremental cost

29. Short run average incremental cost (SRAIC) is shown in Figure 6. The SRAIC cost function also reflects the modularity of capacity deployment. The first unit of volume requires the minimum capacity deployment, which costs 15. The SRAIC falls quickly and then more slowly until it reaches 1 at traffic volume of 15. At this volume the initial capacity deployment is entirely filled up (cost of 15 to serve volume of 15). The next unit of traffic causes the SRAIC to jump up, reflecting the cost of the additional capacity deployment that is required (cost rises to 30 for volume of 16).

Figure 6: Short run average incremental costs



Long run costs

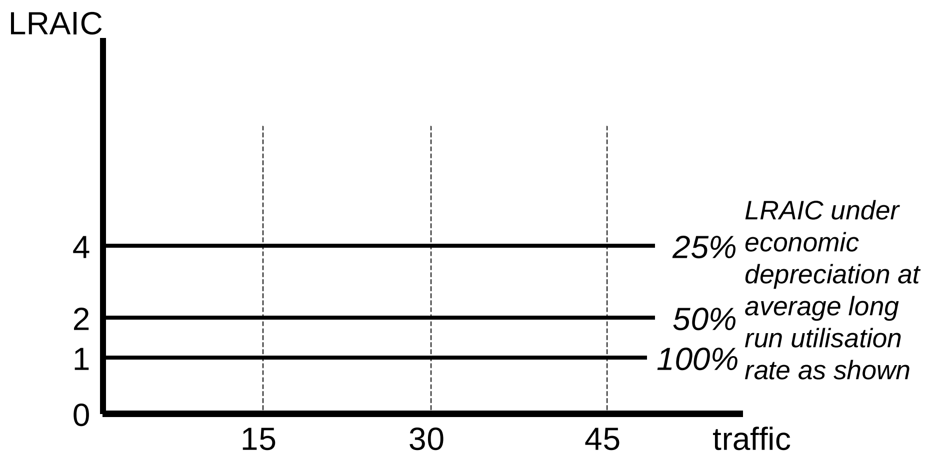
30. In analyses of long run cost functions the lumpiness tends to be smoothed by allowing all input factors to be fully variable over this time horizon. The implication of such an approach would be to derive a constant long run marginal cost (LRMC)

[7] It is efficient to add capacity if the additional willingness to pay of consumers for the additional capacity (the area of the triangle under the demand curve between points B and C) is larger than the cost of the additional capacity, 15.

equal to long run average incremental cost (LRAIC). This is because, apart from the modularity effects, the cost function for capacity at base station sites displays constant returns to scale (as discussed in paragraph 14 above). With such a long run cost function base station costs would give rise to no common costs among traffic services.

31. The approach to long run costs in the LRIC model is slightly different. It is assumed that the lumpiness in the deployment of capacity remains even with the long run perspective. But there is smoothing of the effects of modularity across years through economic depreciation. Average costs under economic depreciation do not vary between years because of differences in utilisation, but only because of differences in input costs (prices of assets and operating costs that new entrants would incur).[8] Therefore, for a given average utilisation over the long run, there is a constant LRAIC with respect to traffic volume - the cost function has this flat shape where, as for base station capacity costs, there are no economies of scale (other than modularity effects). The position of the cost line depends on average utilisation: the lower the average utilisation, the higher the level of LRAIC – see Figure 7.

Figure 7: Long run average incremental costs



32. An increase in traffic volume in one year can lead to lower LRAIC (ie LRMC is less than LRAIC) if it results in an increase in average utilisation over the long run. One circumstance in which this will occur is for coverage sites, because an increase in traffic will result in improved utilisation of the minimum capacity deployment. Such economies of scale are still present to some extent in the 1800 MHz networks, because in the LRIC model their average rural site is still coverage-driven. But this source of economies of scale has been exhausted[9] in the 900 MHz networks,

8 See, for example, the graphs and explanation of economic depreciation profiles over time for the 5 most important assets in Oftel's paper, *Additional information concerning Oftel's LRIC model*, 12 February 2002.

9 Or such economies have been largely exhausted. The LRIC model derives the utilisation of the average rural site (in the absence of information about the distribution of traffic in rural areas). Some rural sites with below-average traffic might still be coverage sites.

because their average rural site is traffic-driven at current traffic volumes (the change for the average rural site in the LRIC model from coverage site to traffic site occurred in 2000/01 for the 25% operator).[10]

33. For sites with capacity in excess of the minimum deployment, a volume increase in a given year could result in higher or lower utilisation, depending on whether existing excess capacity is used or an additional lump of capacity needs to be added (as illustrated in Figure 3 above).

Efficient pricing

34. Should economically efficient prices reflect short run or long run costs? Efficient pricing is a multi-faceted issue - see, for example, the discussion in Chapters 3-4 of *The Economics of Regulation* by Alfred Kahn (MIT Press, 1970). In Kahn's view the theoretical starting point for the analysis of efficient prices is short run marginal costs, but there are various factors which typically make the use of long run incremental costs more appropriate:-

> "…short-run marginal costs (SRMC).. are the place to begin. There are situations in which it both efficient and practical to base rates on them….. Typically, this is not the case; principle must be compromised in various ways in the interests of practicality, for a number of interrelated reasons" [page 83]
>
> "Partly for this reason [that SRMC may more often be less than average total cost], and partly because of the infeasibility of permitting prices to fluctuate widely along the SRMC function, depending on the immediate relation of demand to capacity, the practically achievable benchmark for efficient pricing is more likely to be a type of average long-run incremental cost, computed for a large, expected block of sale, instead of SRMC, estimated for a single additional sale." [pages 84-85]
>
> "It is important to recognize that all these reasons for compromising principle with practicality make sense even in purely economic terms…" [page 86]

35. The considerations set out by Kahn are relevant in the context of mobile pricing. The purpose of the price signal based on SRMC would be to stimulate demand at a site where there existed excess capacity, ie SRMC (and price) equal to zero, and deter it where capacity at a site was fully utilised. Pure SRMC pricing would therefore involve:-

- a different price for each base station site, reflecting its particular cost function and demand conditions; and

- volatile prices over time for each base station site as it moves from excess capacity to fully utilised capacity and then back again to excess capacity as an additional lump of capacity is added - for example, the discontinuities in the

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[10] In earlier years, such as when the CC previously investigated in 1998, economies of scale were much more important because of the significant number of coverage sites at that time (and so average costs were much more sensitive to volume forecasts).

SRMC function in Figure 4 mean that the SRMC jumps from 0 to 15 using the illustrative figures; and the rationing price when capacity is filled up is determined by the demand conditions, as illustrated in Figure 5.

36. This raises three major difficulties. First, the volatility in prices is likely to involve confusing pricing arrangements and high transactions costs for suppliers and consumers in identifying which are the relevant prices for a given base station site on a given day. Even if it were possible for such complexity in prices to be implemented, it is unlikely that consumers would in practice make efficient demand responses, because of the confusion over the applicable prices.

37. Second, it is not practical to implement separate prices for each base station. In reality, prices are set averaging across base stations. Given this, it is far from clear that reflecting SRMC on average across base stations would encourage efficient decision-making by consumers. The outcome might be to stimulate traffic at sites where there was no excess capacity and not stimulate it where it was under-utilised.

38. The third difficulty is that SRMC pricing might not allow the operators to recover their costs, or might allow revenues in excess of costs. Whether there is under- or over-recovery depends on the level of the rationing prices and their frequency relative to the periods when the SRMC price is zero because of excess capacity. If the level of demand were known for every base station at all times, it would be theoretically possible to apply mark-ups (or abatements) to the SRMC prices to ensure full and exact cost recovery. However, such mark-ups (or abatements) would distort the original purpose of SRMC pricing, which is to provide signals to consumers about whether there is an excess or a shortage of capacity in the short run.

The practical alternative: prices based on long run costs

39. All three difficulties are avoided by basing prices on long run costs, which are not volatile, are practical to implement, and allow full cost recovery.[11] Furthermore, long run costs provide a reasonably efficient price signal that reflects the cost of the resources consumed. This suggests that the use of long run cost as the basis for prices would compromise pure principle with practicality, but that this would make sense even in purely economic terms (to paraphrase Kahn).

Conclusion on differences between short run and long run costs

40. It seems far more appropriate in the circumstances for prices to reflect long run than short run costs. Implementation of short run marginal cost pricing in its pure form is impractical, because for example it would require separate prices for each base station site. But if prices reflect short run costs averaged across base stations, it is unclear that the pricing signals would enhance economic efficiency. By contrast,

[11] Full cost recovery is ensured by the use of economic depreciation. The discounted cash flow analysis under economic depreciation includes all of the capital investment in the capacity that is deployed. The level of costs derived under economic depreciation reflects the average level of utilisation over the long run and so allows all costs to be recovered (including a reasonable return on investment).

prices based on long run costs are practical, allow full cost recovery and provide a reasonably efficient price signal.

41. Since long run costs provide a more appropriate basis for pricing, the analysis of incremental and common costs should be conducted using a long run perspective. This implies that the common costs of mobile networks are relatively small, because of the relative absence of economies of scale and scope.

Summary

- Common costs between the broad increments of traffic and customers are small at only 3-5% of total network costs. Common costs between incoming and outgoing calls are also small, especially for 900 MHz operators at current traffic volumes. Therefore, the result in Oftel's LRIC model that common costs are small is not an artefact of the choice of broad increments. It is a consequence of taking a long run, not a short run, perspective on costs.

- This is not a surprising result given that there are few sources of economies of scale or scope in mobile networks other than lumpiness (or modularity) in the deployment of capacity. In particular, the underlying function for capacity costs at base station sites, which account for around one-half of total network costs, displays constant returns to scale.

- Modularity of capacity deployment is only a source of substantial common costs if a short run view of costs is taken. But this reflects a contrived view of costs, because pricing based on short run marginal costs is impractical and unlikely to be economically desirable. It suffers from three major difficulties. Short run marginal cost is volatile, zero (or close to zero) if there is excess capacity at a site, or large (ie well above average costs) if capacity needs to be added at the margin. Since averaging of costs/prices across base stations occurs, it is not clear that the price signals provided would promote efficient decisions by consumers. In addition, prices based on short run marginal costs might not allow the operators to recover their costs (or might allow revenues in excess of costs).

- In this context it is more appropriate to take a long run view of costs as the basis for prices. Under economic depreciation the level of long run average incremental cost depends on the average utilisation over the long run. Economies of scale at base stations (marginal costs below average costs) only arise to the extent that a volume increase in a given year results in an increase in average utilisation over the long run.

- One circumstance in which this will occur is for coverage sites, because an increase in traffic will result in improved utilisation of the minimum capacity deployment. Such economies of scale are still present to some extent for the 1800 MHz operators, but this source of economies of scale has been entirely or largely exhausted by the 900 MHz operators.

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19 February 2002