COMPETITION
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GROUP

Wholesale broadband cost drivers

January 2013

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1 Overview

1. We have been asked by Chorus to provide our views as to the cost drivers for the bitstream service. This work is relevant to the benchmarking of the incremental costs of providing the regulated unbundled bitstream access (UBA), service since it should lead to identifying means to screen for comparable benchmarks and/or adjust benchmarks for identifiable cost drivers.

1.1 Cost drivers for the UBA service

2. In this report we consider in some detail the importance of line density as a cost driver for bitstream services. By way of broad summary, in relation to line density we find that:

- it is an important cost driver because it has a significant impact on the per customer usage of the network elements that make up the cost of providing the services;
- differences in spatial density characteristics within and across jurisdictions explain a significant amount of the divergence in observed prices for wholesale broadband services across jurisdictions; and
- it is appropriate and practical to adjust benchmarked prices of bitstream services to reflect differences between New Zealand's spatial density characteristics and those of the benchmark jurisdictions.

1.2 Adjusting prices to reflect cost conditions in New Zealand

3. The observed relationship between spatial density characteristics and bitstream prices provides a sufficient basis to pursue benchmarking the incremental costs of the bitstream service as a function of the unbundled copper local loop prices (what might be termed 'ratio benchmarking'). This approach would import the normalisation approach (i.e., the established relationship between cost and proxies for line density) adopted in the UCLL proceedings into the benchmarking of UBA prices.

4. We also consider an adjustment based on the relationship between costs and spatial density characteristics identified from within the cost models used by the Swedish and Danish regulators. We use econometric analysis to quantify how the benchmark UBA incremental costs would differ if those countries had the lower line density observed in New Zealand.

5. Applying this 'normalisation' based on our preferred econometric model indicates that the benchmark UBA incremental cost should be adjusted upwards by 53.9%

from 41.7 Kr to 64.1 Kr per month in Denmark[1] and by 14.1% from 60.5 Kr to 69 Kr per month in Sweden. Using the Commission's exchange rates from its draft modelling this increases the median incremental bitstream cost from $10.22 per month to $13.50 per month.

6. We note that this represents a smaller increment than what is indicated by a ratio benchmarking approach ($15.25 per month), i.e., where the increment is benchmarked as a percentage of the local loop price. However, the calculated adjustment returns a result that is more similar to the ratio benchmarking approach than the Commission's proposed unadjusted approach.

7. Table 1-1 below compares the outcome of the unadjusted approach, the econometric approach and the ratio benchmarking approach.

Table 1-1 Comparison of benchmarked UBA incremental unit costs

	Unadjusted (NZD)	Econometric approach (NZD)	Ratio benchmarking (NZD)
Sweden	11.22	12.80	14.68
Denmark	9.22	14.19	15.81
Median	10.22	13.50	15.25

Source: CEG analysis

8. Given the data available to us we conclude that an adjustment should be made to the benchmarked UBA increments to reflect differences in spatial density characteristics. We consider that the econometric approach and the ratio benchmarking approach both provide a reasonable basis for such an adjustment.

1.3 Selecting the benchmark price from each jurisdiction

9. The benchmark prices applied in the Commission's draft determination are *not* the correct starting point, because:

- the Commission's benchmark prices are set based on the slowest speed available in each of the benchmark jurisdictions; whereas
- the regulators in those jurisdictions use an allocation gradient to allocate costs between different speeds, and so selecting the price associated with the slowest speed will not allow for full cost recovery.

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[1] Our confidence in this adjustment is reasonably high. However, it should be noted that we are extrapolating outside the range of the Danish cost model to reflect the greater variability in line density observed in New Zealand.

10. The appropriate starting point from which to make adjustments to reflect the factors noted in section 1.2 is the *average* price from each of the cost models in the benchmark jurisdictions, weighted by demand in that jurisdiction (or directly sourced from the price list/cost model).

1.4 Structure of this report

11. The remainder of this report is set out as follows:

- Section 2 discusses the factors driving the deployment of network elements used to provide bitstream services;
- Section 3 provides an analysis of the relationship between spatial density characteristics and the additional elements used to provide the UBA in New Zealand;
- Section 4 discusses how bitstream service network elements are dimensioned and allocated in cost models used by regulators in other jurisdictions and identifies relationships between bitstream prices and cost drivers (including spatial density characteristics);
- Section 5 proposes adjustments based on a relationship between costs and spatial density characteristics; and
- Section 6 explains why the Commission should use an average price as opposed to the price for the slowest speed as the benchmarked price from other jurisdictions.

12. In preparing this report we have investigated available public cost models developed for regulators in Europe. We have also had extensive discussions with engineering personnel from Chorus. In drawing conclusions regarding the cost drivers for the bitstream services we have relied on technical information drawn from those sources. Throughout this report we set out the technical information and assumptions we have relied on in reaching our conclusions.

13. Note that the analysis in this report relies on cost models from the Danish and Swedish regulators used to set prices from 1 January 2013. These represent an update on the costs collated by the Commission last year which were derived from earlier versions of these cost models that were used to set prices in 2012.

2 Factors driving service elements

2.1 The regulated service

14. The UBA service is defined as[2]:

> *A digital subscriber line enabled service (and its associated functions, including the associated functions of operational support systems) that enable access to, and interconnection with, that part of a fixed PDN that connects the end-user's building (or, where relevant, the building's distribution frame) to a first data switch (or equivalent facility), other than a digital subscriber line access multiplexer (DSLAM).*

15. The UBA service requires Chorus to transport the service to a handover point in the coverage area with which the DSLAM is associated. The UBA service:[3]

> *… transports Access Seeker's internet traffic from the ETP at an End User's premises to the Handover Point (as described in clause 3.19 below) for the Coverage Area which hosts the DSLAM*

16. In Chorus' existing network, the UBA service is provided in two ways: (i) over cabinetised lines (cabinet-based UBA); and (ii) from the exchange (exchange-based lines or non-cabinetised lines). This is illustrated in Figure 2-1 below.

17. Figure 2-1 illustrates that the broad network elements of the UBA service include, in the case of non-cabinetised lines:

- the DSLAM;
- the local exchange building and associated infrastructure (e.g., power and air conditioning);
- the local aggregation path; and
- Chorus' Ethernet switches.

18. For cabinetised lines, the broad network elements include:

- the DSLAM;
- the cabinet and associated infrastructure (e.g., power and air conditioning as appropriate);

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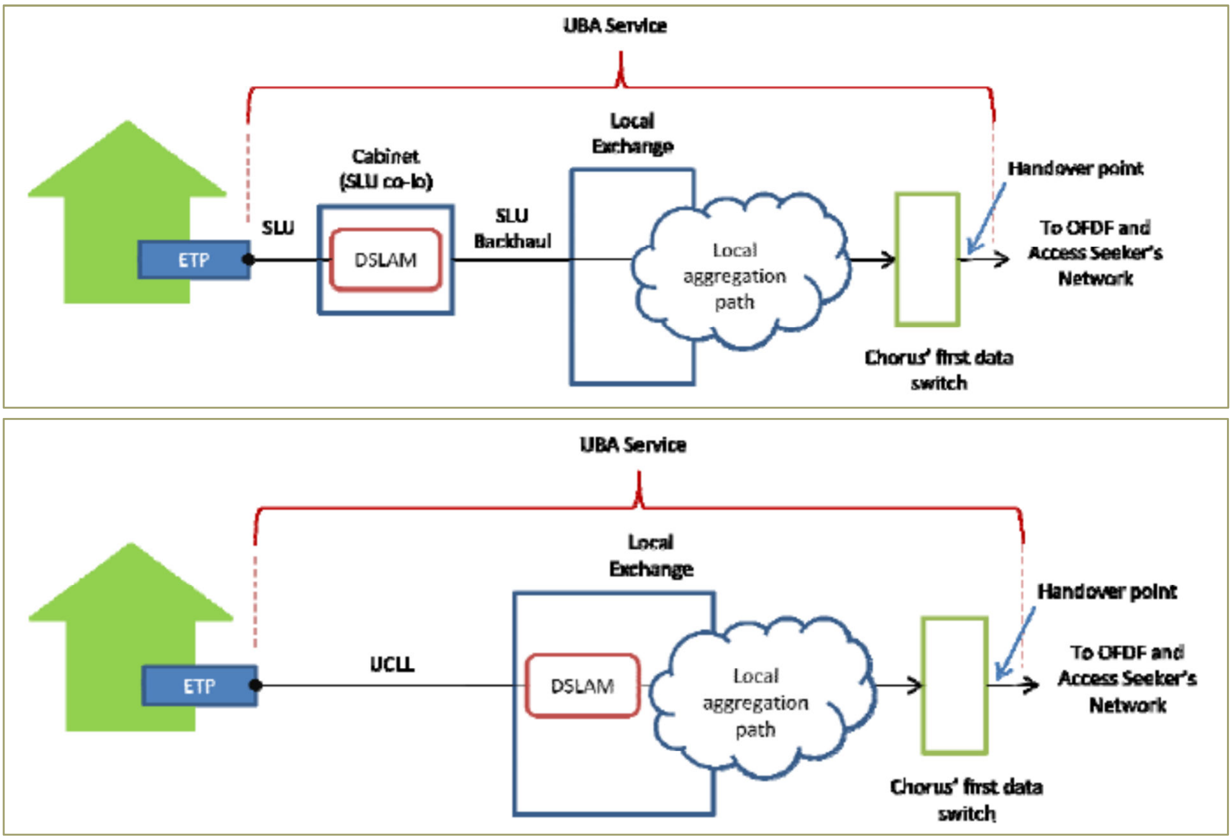
[2] Commerce Commission (2012), Unbundled Bitstream Access Price Review Consultation, p. 7

[3] Commerce Commission (2007), Standard Terms Determination For Unbundled Bitstream Access Service, Schedule 1, Public Version, p. 5

- the local aggregation path; and
- Chorus' Ethernet switch.

Figure 2-1 UBA over cabinetised and non-cabinetised lines



Source: Commerce Commission (2012), Unbundled Bitstream Access Price Review Consultation

19. We understand that the UBA has four variants, each of which is available with or without telephony services. These include a basic UBA service, Enhanced UBA 40 kbps, Enhanced UBA 90 kbps and Enhanced UBA 180 kbps. The basic UBA service is specified with a single class of service - a best-efforts un-throttled service (i.e., whatever the line is capable of). The enhanced UBA services provide two classes of service, one with an internet grade service best-efforts un-throttled and one with a real-time class of service (for voice over internet protocol).

2.2 The modern equivalent version of the regulated service

20. Chorus provides UBA over its cabinetised access network. We understand that it does not carry mass market voice services over its DSL network (including its Ethernet backhaul network). This voice traffic is predominantly managed by Telecom over the copper access network using legacy technology switches and line cards.

2.2.1 European networks

21. There are some differences in modern equivalent technologies between the network in New Zealand and that used in the models developed by regulators in Europe – including Denmark and Sweden (the jurisdictions of most interest for present purposes). The modelled networks in Europe based on Ethernet technology appear to deploy IP based digital subscriber line access modems (DSLAMs) to carry both voice and data services over Ethernet technology in the access network. Chorus does not carry voice services over its Ethernet network.

22. An alternative implementation of the UBA service may be over a fibre-to-the-premise (FTTP) access network. Modelling of this approach is increasingly being adopted in other jurisdictions, e.g., this is currently the case in Sweden and has been foreshadowed in Denmark and Switzerland. An FTTP interpretation presents some challenges in the context of the UBA service in New Zealand, given that the pricing principle requires benchmarking of the additional cost of providing the UBA on top of that allowed for in the copper unbundled local loop service. That is because there may be some costs that shift between the access and the core networks when moving between technologies that may need to be accounted for in either the local loop or bitstream service prices. We deal with these issues in later sections of this report.

2.2.2 Terminology differences between Europe and New Zealand

23. There are some important differences between the terminology that is used in New Zealand and in the cost models that are used by regulators in Europe (including in Denmark and Sweden) that are worth clarifying.

24. The UBA service in New Zealand is carried from the DSLAM to a handover point over a fibre transmission service. A data switch is located at the handover point. At this point the traffic is routed to the relevant access seeker's network. The data switch at the handover point may not be the first data switch through which the traffic is carried. In some areas of New Zealand there may be switches that perform a traffic aggregation function (rather than a switching function). Notwithstanding this different function, we understand that similar equipment is used at these first data switches and the handover points.

25. Similar network architecture is found in the cost models developed in European jurisdictions. There are data switches located on fibre transmission rings that aggregate traffic from DSLAMs in an area. The term used for these switches in the regulatory models is 'aggregation switches' (or 'metro switches'). The number of aggregation switches is either exogenously determined or based on the number of DSLAM locations.

26. The data switching function performed at the handover points in New Zealand appears to be performed at the location of the 'edge routers' in the European cost models.[4]

27. In addition, we note that the European models are broken down into a number of modules including an 'access' module and a 'core' module. The incremental costs of providing bitstream (or UBA equivalent) services are modelled in both the access and core network modules. We understand that the 'core network' in New Zealand would typically refer to the network above that used to supply the UBA services, i.e., long distance transmission between handover points and other points of interconnection.

2.3 Identifying cost drivers

28. An efficient network configuration for the delivery of the modern equivalent version of the UBA service will be driven by the expected demand for the service. Put another way, the dimensioning of the network elements needed to provide the UBA service is primarily a demand driven exercise.

29. In the case of the UBA, this demand has a number of characteristics including:

    i. its location - where customers are physically located and how they are dispersed relative to the points where the service terminates;

    ii. the number of customers who take the service; and

    iii. the amount of throughput and the quality of service provided for that throughput in peak periods of demand.

30. Each of the major network elements (depicted in Figure 2-1) will be dimensioned based on one or more of these demand characteristics. The factor that ultimately determines the dimensioning of each element is its relevant cost driver. It is this factor that pushes the network element to its full capacity and/or causes more network elements to be deployed. For this reason, it is unlikely that the same cost driver will be relevant to all network elements.

31. The cost of the bitstream service will also be influenced by the existing network architecture and the extent to which this is retained in the modern equivalent implementation of the service. Retaining the location of network nodes in network cost modelling (sometimes termed a 'scorched node' approach) is common practice. It may also be 'required' (mandated) by the legislation. In the case of the UBA, the service is defined to end at the handover point in a coverage area. For that reason,

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[4] We understand that edge routers provide greater service functionality than is provided by the UBA service.

the location of Chorus' handover points should be retained in analysing the cost of the UBA service.

32. In addition, the extent to which demand characteristics for the UBA service drive costs will be affected by the extent to which network elements are shared with other services. These might include voice (if relevant) and other non-regulated broadband services (such as business grade services).

33. Also, some cost allocations may be determined by regulatory convention. In particular, the cost of the local loop is typically allocated to voice services and only to broadband if no voice service is taken. An important consideration in the costing process is the extent to which the cost of trenching and cable costs in the feeder network (between the cabinetised DSLAMs, exchange-based DSLAMs and the data switches) is allocated to the unbundled copper local loop (UCLL) service.

34. For example, if the Commission determines a UCLL price for all loops (cabinetised and non-cabinetised), it may reason that it has captured all of the cost of the feeder network in the UCLL price. However, although all of the prices used by the Commission for benchmarking UCLL are 'all loop' prices, some prices reflect an allocation of feeder trenching costs between voice and fibre services, e.g., Denmark and Germany. In this case, it is important that the benchmarked price for the UBA increment appropriately captures the element of the feeder network allocated to the bitstream service.

35. Finally, the cost of providing bitstream service - and telecommunications services more broadly - is influenced by a number of supply-side factors. For example, the cost of physically installing equipment is influenced by:[5]

- input costs - the cost of labour, land and financing costs;
- topological factors - geology, geography and climate, including the type of terrain, e.g., soil, rock; and
- regulation - the extent to which lines/cabinets have to be installed, e.g., street-side or underground.

36. In the following sections we consider the cost drivers for the major network elements used to supply the bitstream service in a partially cabinetised network using Ethernet technology.

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[5] For a good account, see Productivity Commission, *Population Distribution and Telecommunications Costs*, Staff Research Paper, August 2000.

2.4 Drivers of cost for the DSLAM equipment and housing

37. DSLAMs are typically installed at exchange buildings or in street-side cabinets. The number of DSLAM locations is therefore dependent on the architecture of the local loop network and the extent of cabinetisation, i.e., the proportion of customers that are served via cabinets and the proximity of cabinets to the home.

38. If one assumes a constant level of cabinetisation, one would expect that a more geographically dispersed line population would require a greater number of DSLAM locations (and vice versa). This would be correct if lower line density correlated with fewer lines per exchange (or cabinet), which we expect it might, since:

- in rural areas, customers will be more geographically dispersed, resulting in a relatively small number of lines per DSLAM; and
- if cabinets are placed close to the home in urban areas (i.e., as in fibre to the curb) there may be a small number of lines per cabinet in these areas as well.

39. We would expect that the average cost of providing bitstream service would be higher in jurisdictions with a more geographically dispersed line population (other things being equal). This observation holds for a constant level of cabinetisation and broadband coverage/penetration across jurisdictions. As we discuss further below, cabinetisation would raise the average cost of providing bitstream services because it requires a greater number of locations (essentially duplicating some of the fixed costs associated with the bitstream service).

40. Installing DSLAMs at exchanges or cabinets involves fixed costs, e.g., associated with the power, air conditioning, housing, installation, space, land etc. These fixed costs must be defrayed across the number of DSL lines requested by customers. We understand that the variable costs associated with the DSLAMs include the cost of line cards and additional outgoing transmission ports to manage the bandwidth demanded by customers.

41. More bitstream customers therefore drive a requirement for additional line cards which, in turn, require additional racks and eventually additional chassis', as well as additional power. Additional bandwidth requested by those customers may drive additional network facing transmission costs (depending on the increments in which transmission is provisioned and/or the need for additional data switches). Additional transmission costs are also incurred, depending on the distance over which that data must be transmitted, i.e., between the DSLAM, switches and handover points.

42. The importance of the fixed costs of the DSLAM equipment and its housing to the average cost of providing the bitstream services diminishes as the demand for bitstream services increases. In order to investigate whether broadband subscribers and their locations are cost drivers we must first understand the 'modular' nature of

the investment at exchanges and cabinets and whether economies of scale are likely to be achieved at most DSLAM locations.

2.5 Drivers of cost of transmission to the handover point

43. The bitstream service is defined to terminate at a handover point within a coverage area. Data must be therefore transported to and from the DSLAM equipment to the handover point, which we understand involves carrying data over a transmission path through one or more data switches to the handover point. This transmission is almost universally provided over fibre optic cable and the dimensioning of this fibre cable (i.e., the maximum bandwidth capacity) will, ultimately, determine the cost of this major network element.

44. The geographic proximity of DSLAM equipment to the handover point will consequently determine a large proportion of the cost of transmission. In a network in which the ratio of DSLAM locations to customers is relatively high (because of low line density) we would expect that additional fibre cable (and trenching) would be required to connect to aggregation/data switches and on to handover points. However, this will depend to a material extent upon the number of handover points. The greater the number of handover points in a network, the less physical cable (and trenching) that will be required to connect the DSLAM equipment to the data switches to those handover points. Trade-offs abound, for example:

    - there will be a trade-off between the cost of additional transmission equipment in the network and the cost of installing additional data switches; and
    - there will also be a trade-off in total costs (for Chorus and access seekers) because additional data switches/handover points mean that data is handed over to access seekers in more locations and they must incur the cost of transporting that data within New Zealand and to international gateways.

45. If a 'scorched-node' approach is adopted, the locations of Chorus' handover points might be 'taken as given' in the modelling – together with the 'trade-off' implied by those locations, i.e., between transmission and switching costs. However, we would expect this trade-off to change over time. We understand that developments in IP core networks mean that more centralised switching is leading to reduced costs.

46. We note that in the STD, Chorus has some discretion to determine the number of handover points according to certain criteria:

> *The locations of Handover Points and Coverage Areas <u>are determined by Chorus</u> taking into account various factors including:*
>
> *(a) network architecture and design requirements including network robustness and logical and physical diversity requirements;*
>
> *(b) the availability of local and national backhaul capacity by technology;*

> *(c) the number of data switches required to support the required volume of End User services; and*
>
> *(d) DSLAMs and throughput capacity and the location of the DSLAMs in the network. [Emphasis added]*

47. When comparing costs across jurisdictions it may be difficult to determine whether a jurisdiction has balanced the trade-off between transmission costs and switching costs in the same way as Chorus. Moreover, there may be differences in the nature of the equivalent of the UBA service, such that data may be handed over at a second or third data switch. This would need to be accounted for in cross-country comparisons of prices.

48. Hitherto, we have established that the physical distance between DSLAM locations and handover point will be a major cost driver – this might be termed a 'locational factor'. This is not only because of the physical infrastructure required to lay the fibre cable but also because the electronic equipment must be powered to cover the required distances (including repeaters if necessary). Put simply, the greater the geographic dispersion between the key network elements described above, the greater costs associated with providing the service.

49. The level of data throughput may also have an important bearing on costs. In particular, the transmission path between the DSLAM locations and the data switch/handover points must be provisioned to handle the throughput demanded by customers. In network design and bottom-up cost modelling the transmission equipment will be dimensioned to meet the peak load traffic demand at the required level of service quality. It is important to note that the transmission path will carry the traffic from a range of customers with different service classes. The range of services will include traffic for;

    - mass-market bitstream services on a 'best efforts' basis, e.g., the UBA service;
    - business and commercial grade bitstream and perhaps fibre services; and
    - it may also include voice services and other services requiring committed bandwidth.

50. The combination of each services' requirements in terms of (i) quality of services (e.g., latency, jitter and packet loss); (ii) committed bandwidth; (iii) number of users; and (iv) demand profile, in particular, simultaneous requirements creating a peak period will drive the dimensioning of transmission equipment and, ultimately, the costs for these network elements. The extent to which lower bandwidth contributes to lower average costs will depend on:

    - the relative importance of bandwidth costs; and
    - the differential in costs between greater and lesser bandwidth provisioning.

51. We have been informed by Chorus that the minimum provisioning for data switches provides more than sufficient bandwidth in the aggregation network to meet busy hour demand for the entire country at the present time but this may change in the future as demand grows. This ultimately is an empirical question but, if it is the case that the minimum provisioning of data switches is more than sufficient to meet demand (and forecast demand), then bandwidth would not be an important cost driver. The primary determinant of costs will instead be the aforementioned locational factors that drive the number of data switches.

2.6 Drivers of cost for data switches/handover points

52. Data switches are required in order to manage and aggregate Ethernet traffic from DSLAMs. In addition to aggregation switches, data switches will be located in the network in order to undertake traffic switching. Data switches are typically located on transmission rings, with multiple switches per ring providing redundancy.

53. The number of data switches providing the aggregation function is a product of network geography. It will be determined by the geographic dispersion of the DSLAM locations and the requirements to route traffic to established handover points. As discussed in the section below, in other jurisdictions, the locations of these switches are included as parameter inputs to the regulatory cost models - meaning the number and location of the switches are 'fixed' (and are not based on bandwidth/processor demand).

54. It follows that the historical decisions of Chorus in relation to the location of switches and its requirements to aggregate from geographically dispersed DSLAM locations to regional handover points are likely to be key cost drivers for the bitstream service. In comparing bitstream prices across jurisdictions a relevant consideration is the number of aggregation switches per DSLAM location. This will be particularly important:

- if, in less urban areas, the more geographically dispersed DSLAM locations require a greater number of aggregation switches; and
- if the more dispersed DSLAM locations of a less line dense population result in a greater number of IP routing switches per subscriber.

55. In terms of cost structure, we understand that at the present time:[6]

- the data switches' costs are primarily driven by the fixed costs of the chassis as well as transmission port costs;
- the "backplane" on just one chassis could carry all the Chorus traffic;

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[6] These figures were provided to us based on demand at November 2012.

- the smallest data switch Chorus purchases an ESS-7 can carry 200Gbps of traffic in the busy period;
- broadband traffic during the busy period is around 120Gbps; and
- total traffic in the Chorus network (business, mass market services and mobile backhaul is 160Gbps during the busy period.

56. This implies that peak period traffic at present is unlikely to be an important cost driver of additional costs for these network elements, i.e., the network equipment is provisioned to meet current peak demand. This is consistent with i our analysis below of cost models in other jurisdictions where the deployment and total cost pools of data switches and routers is unchanged by traffic volumes. We note, for example, that the total busy hour traffic in Denmark is around 300Gbps which, as noted above, can theoretically be switched by just two of Chorus' small data switches, and there are over 100 in the modelled network.

57. However, if bandwidth grows exponentially, busy hour demand may be increasingly a driver of cost in providing the UBA service. For example, it may require additional deployment of switches within the network.

3 Line density as a cost driver in Chorus' network

3.1 Line density as a cost driver for bitstream services

58. The Commission's draft decision on UBA assumes that, unlike for UCLL, spatial density factors are unlikely to be important drivers of bitstream costs:[7]

> *The UBA service is largely comprised of active network infrastructure. For instance, DSLAMs are major cost components of UBA networks. Accordingly, spatial density factors are less likely to be major cost drivers of UBA networks.*

59. In our opinion, this preliminary conclusion significantly understates the importance of spatial density factors. In particular, there are local scale-related factors at play in the cost structure of the UBA which mean that line density is an important driver of unit costs for this service.

60. The Commission rightly recognises that DSLAMs are major cost components of the UBA service. These costs are largely fixed across customers connected to each DSLAM location. It may be the case that in densely populated areas it is relatively easy to structure the network such that every DSLAM location achieves high utilisation (and therefore low unit costs).

61. However, the Commission appears not to have recognised that in regional and rural areas there may not be enough customers to allow for this, increasing average costs in these locations. In these circumstances, spatial density will become an important driver of the unit costs of providing the UBA service, as was the case for the UCLL service.

62. The Commission has also not considered the potential relevance of the trench distance between DSLAM locations, data switch(es) and handover points. Again, in dense urban environments, we might expect this distance to be modest, reducing total and unit costs. However, in rural areas, these distances are likely to be considerably larger, increasing unit costs.

63. In this section, we test these hypotheses using data provided by Chorus on exchanges, cabinets, handover points and mappings between statistical mesh-block areas and exchange service areas.

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[7] Commerce Commission (2012) Draft Determination Unbundled Bitstream Access Service Price Review, p.19

3.2 Relationship between cost drivers and customer density in New Zealand

3.2.1 Average customers per DSL location against customer density

64. In this section we explore the relationship between:[8]

- line/customer density in bespoke geographic locations throughout Chorus' network, i.e., the number of customers per square kilometre; and
- the average number of customers per DSLAM site in those same locations, i.e., the number of lines in situ at exchange buildings or in cabinets.

65. Intuitively, one might expect that:

- in urban areas like, say, central Auckland, where there is a higher degree of 'line density' (more customers per square kilometre), that each exchange/cabinet will serve more customers, i.e., the average number of lines per DSL site will be relatively high; and
- in rural areas like, say, central Otago, where there are far fewer customers per square kilometre (a sparser/less dense customer base), that each exchange/cabinet will serve far fewer customers, i.e., the average number of lines per DSL site will be lower.

66. If that is the case then one might expect that the average/unit costs of providing the UBA service will be higher in rural areas, where the fixed costs associated with deploying the DSLAM infrastructure must be defrayed over fewer customers. (Note that this is before any consideration is given to the additional costs that may be associated with greater trench distances, which we consider subsequently).

67. Figure 3-1 and Figure 3-2 below confirm that intuition. Both figures suggest a positive relationship between line density and customers per DSLAM location i.e., as the number of customers per square kilometre (line density) increases/decreases, the number of lines/customers connected to each exchange (Figure 3.1) or cabinet (Figure 3.2) increases/decreases (note that the axes are in a logarithmic scale). This suggests strongly that the unit cost of supplying the regulated bitstream service will be higher in less densely populated rural areas.

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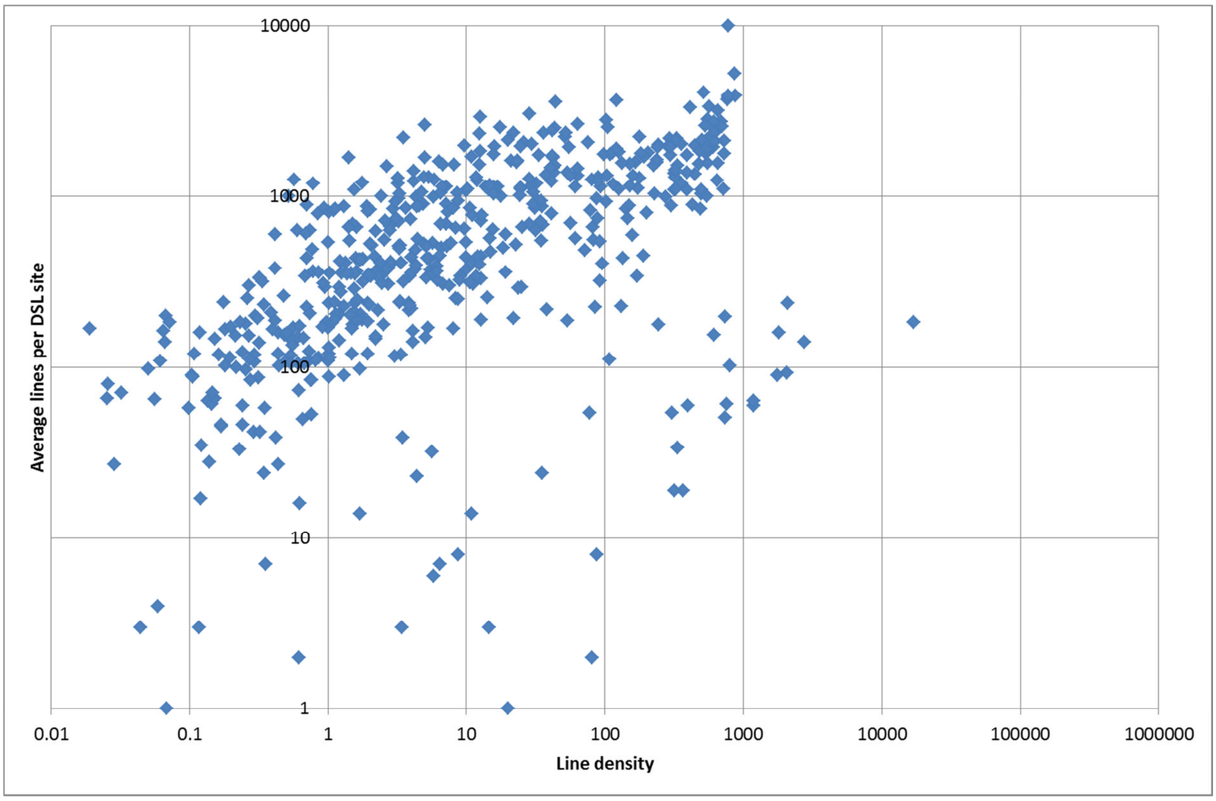
[8] This analysis is based on mesh-block analysis that matches Chorus' exchange service areas to locations throughout New Zealand.

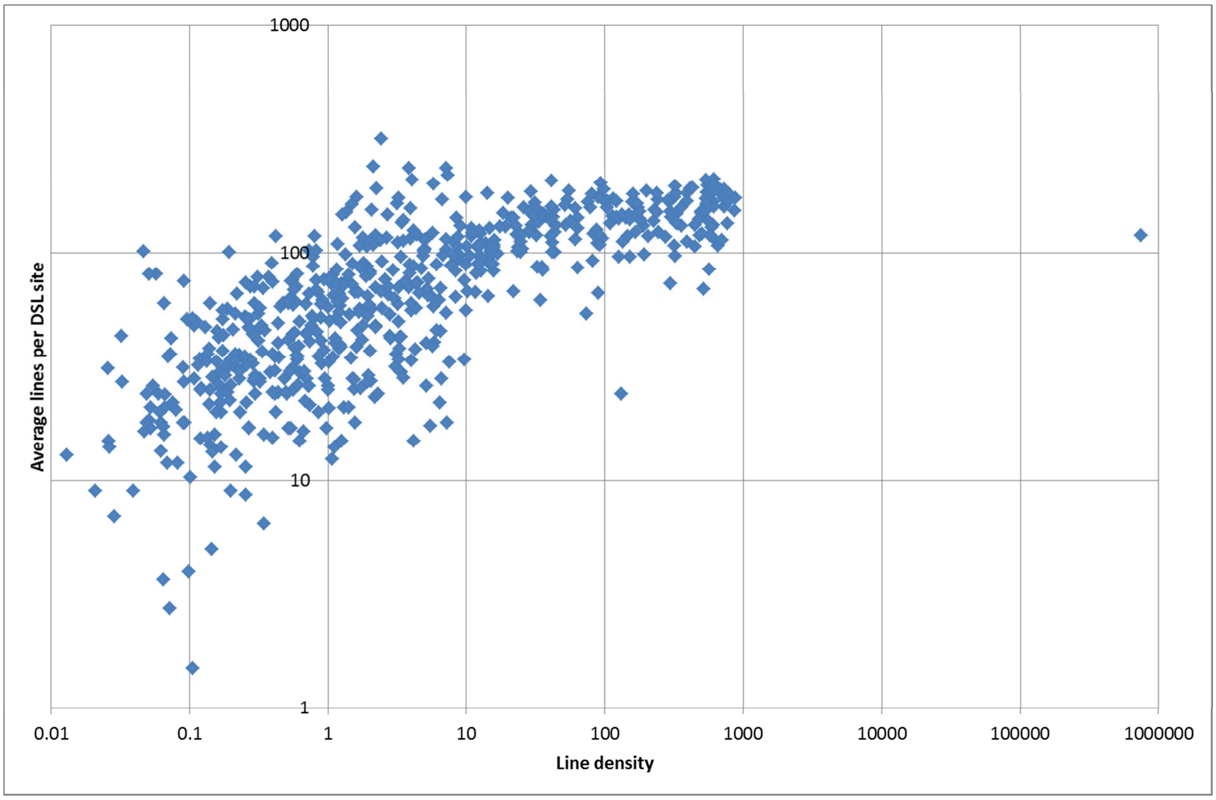
Figure 3-1 Average customers per DSLAM site versus customer density for customers connected to exchanges



Source: Chorus data, CEG analysis

68. Note that, on average, the number of customers per DSL location is significantly greater at exchanges than it is at cabinets. This is unsurprising. The number of customers per DSL location at cabinets is predominantly between 100 and 500. In contrast, the number of customers per exchange site is commonly in the thousands. This is reflected in Figure 3-2 below.

Figure 3-2 Average customers per DSLAM site v. customer density for customers connected to cabinets



Source: Chorus data, CEG analysis

69. In Table 3-1 the elasticity of average lines per exchange DSLAM site to customer density is 0.289. This implies that for every 1% increase in line density, the average lines/customers per exchange will increase by 0.289%. The p-value indicates a very high level of statistical significance (it implies statistical significance at the 1% level). The R-squared for this regression is 0.285. The full results of the regression are shown at Table 3-1 below.

Table 3-1 Regression results of average lines per DSLAM location against line density for exchange-served lines

Regression Statistics	
Multiple R	0.534
R Square	0.285
Adjusted R Square	0.284
Standard Error	1.216
Observations	555.000

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1.000	326.130	326.130	220.385	0.000
Residual	553.000	818.342	1.480		
Total	554.000	1144.472			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	5.395	0.066	81.169	0.000	5.264	5.525
Ln(line density)	0.289	0.019	14.845	0.000	0.251	0.327

Source: CEG analysis

70. In Table 3-2, the elasticity of average lines per cabinet DSLAM site to customer density is 0.221. This implies that for every 1% increase in line density, the average lines/customers per cabinet will increase by 0.221%. The level of statistical significance is very high (the p-value is statistically significant at the 1% level). The R-squared for this regression is 0.550. More details of these regression results are shown at Table 3-2 below.

Table 3-2 Regression results of average lines per DSLAM location against line density for cabinet-served lines

Regression Statistics	
Multiple R	0.742
R Square	0.550
Adjusted R Square	0.550
Standard Error	0.546
Observations	633.000

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1.000	230.208	230.208	771.973	0.000
Residual	631.000	188.169	0.298		
Total	632.000	418.377			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	3.852	0.024	160.225	0.000	3.805	3.900
Ln(line density)	0.221	0.008	27.784	0.000	0.205	0.236

Source: CEG analysis

71. These results suggest that there is a significant link between customer/line density and the number of customers per DSL location (exchange or cabinet). This is likely to be a very important cost driver for the regulated UBA service. In particular:

- in urban locations, because the costs of providing DSLAM infrastructure can be defrayed over more customers, on average, the unit costs of providing the UBA service will be lower; and
- in comparison, in rural locations, because the costs of providing DSLAM infrastructure must be recovered from fewer customers, on average, the unit costs of providing the service will be higher.

72. In other words, there is a link between spatial density and the costs of providing the UBA service. This suggests that an adjustment should be made to the prices observed in benchmark jurisdictions to account for any relevant divergences in this factor. That is, if New Zealand exhibits lower customer density, this would necessitate upward adjustments to the prices observed in these countries.[9]

3.2.2 Average distance from the DSLAM location to the handover point against customer density

73. In this section we explore the relationship between:[10]

- line/customer density in bespoke geographic locations throughout Chorus' network, i.e., the number of customers per square kilometre; and
- the average distance from the DSLAM site (the exchange or cabinet) to the handover point in those same geographic locations.

74. Intuitively, one might again expect that:

- in urban areas, where there is a higher degree of line density, the exchange or cabinet (as the case may be) will be relatively proximate to the handover point; and
- in rural areas, where there are far fewer customers per square kilometre (lower line density), the exchange or cabinet might be further away from the handover point.

75. Figure 3-3 and Figure 3-4 below confirm that there is indeed a negative relationship between line/customer density and the average distance from a DSLAM site to the

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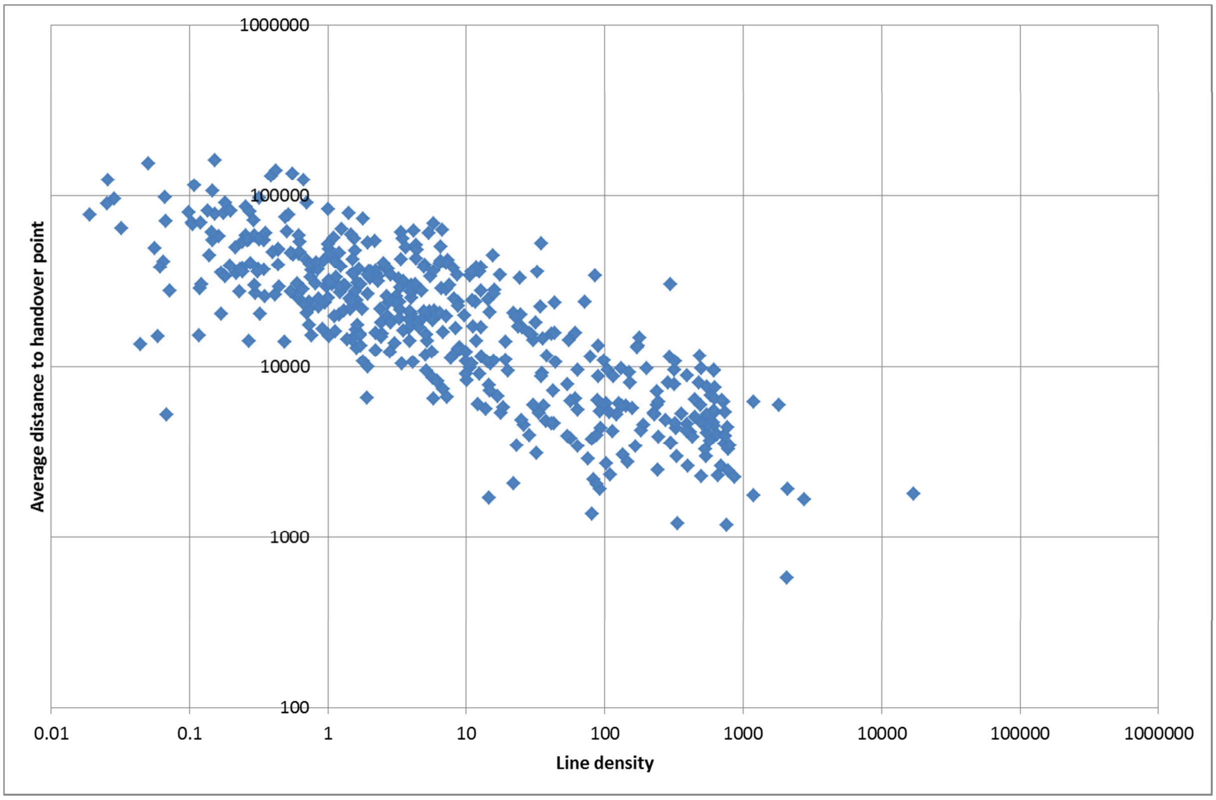
[9] In this respect, it is worth noting that an elasticity of around 0.2–0.3 is a relatively strong relationship. By way of comparison, the elasticity of national population density was measured in the Commission's revised 2007 regression of UCLL prices as being 0.076.

[10] This analysis is based on mesh-block analysis that matches Chorus' exchange service areas to locations throughout New Zealand.

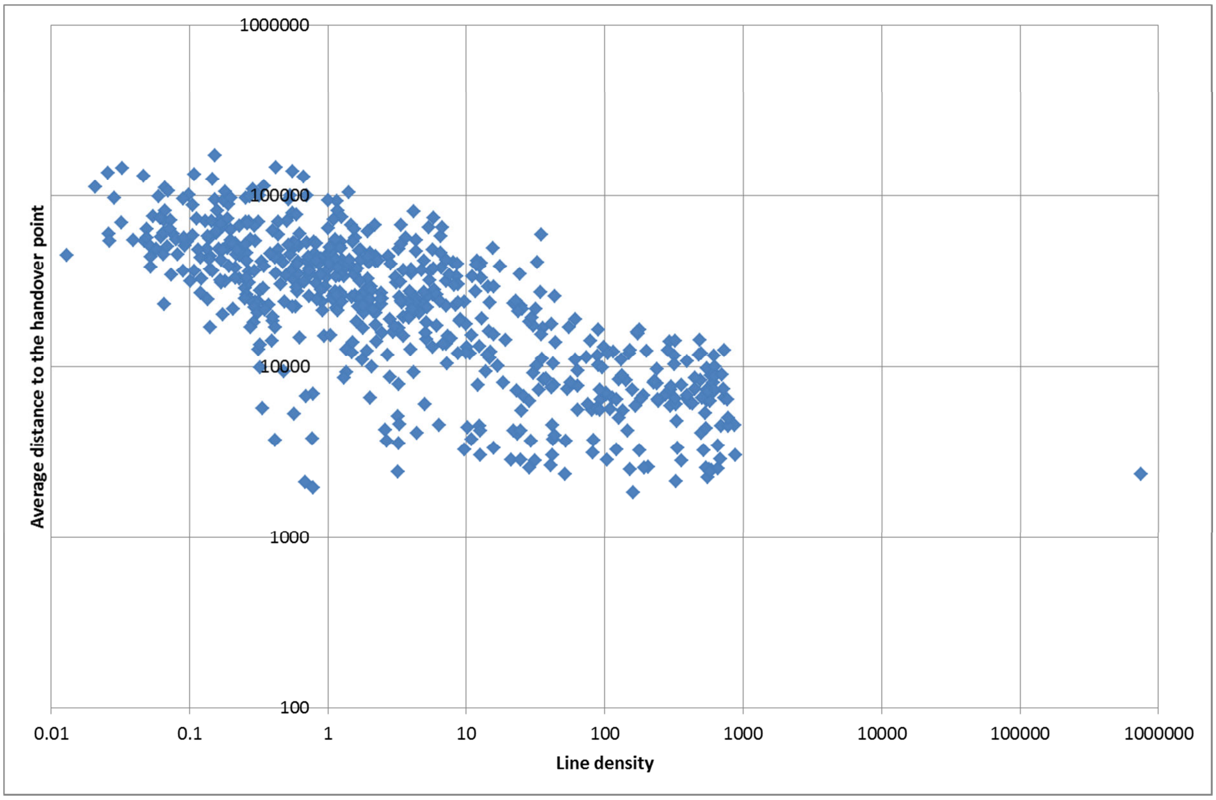
handover point. In other words, areas of greater line density have shorter distances between DSLAM locations and handover points. Figure 3-3 illustrates the relationship for DSLAMs located in exchange buildings, and Figure 3-4 for equipment located in cabinets. The axes are, again, in a logarithmic scale.

Figure 3-3 Average distance to the handover point v. customer density for customers connected to exchanges



Source: Chorus data, CEG analysis

Figure 3-4 Average distance to the handover point v. customer density for customers connected to cabinets



Source: Chorus data, CEG analysis

76. In Table 3-3 the elasticity of average distance to the handover point against customer density is -0.31. This implies that for every 1% reduction in line density, the average distance from the exchange to the handover point will increase by 0.31%. The level of statistical significance is very high (the p-value is statistically significant at the 1% level). The R-squared for this regression is 0.643. A comprehensive set of results for this regression are displayed in Table 3-3 below.

Table 3-3 Regression results of average distance to the handover point against line density for exchange-served lines

Regression Statistics	
Multiple R	0.802
R Square	0.643
Adjusted R Square	0.643
Standard Error	0.615
Observations	475.000

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1.000	323.166	323.166	853.781	0.000
Residual	473.000	179.036	0.379		
Total	474.000	502.202			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	10.352	0.035	292.608	0.000	10.283	10.422
Ln(line density)	-0.310	0.011	-29.220	0.000	-0.330	-0.289

Source: CEG analysis

77. In Table 3-4 the elasticity of average distance to the handover point to against density is -0.269. This suggests that for every 1% reduction in line density, the average distance from the cabinet to the handover point will increase by 0.269%. There is, once again, a very high level of statistical significance (the p-value is statistically significant at the 1% level). The R-squared for this regression is 0.550. The results of this regression are shown at Table 3-4 below.

Table 3-4 Regression results of average distance to the handover point against line density for exchange-served lines

Regression Statistics	
Multiple R	0.742
R Square	0.550
Adjusted R Square	0.549
Standard Error	0.670
Observations	617.000

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1.000	337.510	337.510	752.052	0.000
Residual	615.000	276.003	0.449		
Total	616.000	613.513			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	10.315	0.030	344.211	0.000	10.256	10.373
Ln(line density)	-0.269	0.010	-27.424	0.000	-0.289	-0.250

Source: CEG analysis

78. The analysis above suggests that in rural areas there is typically a significantly greater distance between the DSLAM and the relevant handover point than for urban areas. One might expect that this would increase yet further the average/unit costs of providing the UBA service in those areas. This is because there are likely to be significant additional costs associated with building longer trenches to connect those more geographically dispersed points.

4 Cost drivers in benchmarked jurisdictions

79. As discussed above, the Commerce Commission's draft decision starts from a conclusion that the costs of providing the UBA service are unlikely to be directly affected by spatial density factors:[11]

> *The UBA service is largely comprised of active network infrastructure. For instance, DSLAMs are major cost components of UBA networks. Accordingly, spatial density factors are less likely to be major cost drivers of UBA networks.*

80. This reference above underpins the Commission's approach to benchmarking the incremental costs of UBA. However, our analysis of the structure of Chorus' network at section 3 above shows that spatial density is very closely associated with important cost drivers for the UBA service, including lines per DSLAM location and average trench length per line. This indicates that the link between spatial density and UBA costs is closer than suggested by the Commission.

81. In this section, we deepen our review of the importance of spatial density factors to incremental UBA costs by reviewing in more detail the nature of the benchmarks relied upon by the Commission. This involves undertaking a close examination of the publicly available cost models that produce the benchmarked prices from Denmark and Sweden.

82. In these models, costs are mostly generated using a bottom-up methodology based on traffic requirements at various locations. These costs are averaged across the network and part of the overall sum is allocated to bitstream services (or the UBA increment) through the use of routing tables to generate an overall average bitstream cost.[12]

83. Since these models already contain a great deal of information about the underlying demand and assets provisioned at the locations that comprise the average cost generated by the model, this information can be extracted to inform the calculation of an average cost at each such location. We do this for 108 edge router locations in the Danish model, which represent the entirety of that network. We similarly do

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[11] Commerce Commission (2012) *Unbundled Bitstream Access Service Price Review,* p.19

[12] As discussed at section 6 below, the output of the Danish cost model is an average bitstream unit cost, not the schedule of prices differentiated by speed benchmarked from by the Commission, which are generated by subsequent allocation rules that are not cost-based. However, the Swedish model incorporates an allocation gradient, and therefore generates a schedule of prices differentiated by speed in the model. The allocation gradient can be 'neutralised' to achieve an average bitstream unit cost.

this for 64 out of 139 edge locations in the Swedish model (the 'sampled' edge locations), which are used to provision trenching, ducting and fibre within the model.

84. Analysis of costs from the Danish and the Swedish cost models at this level shows that, as expected, there is a strong relationship between average incremental UBA costs and cost drivers canvassed in section 3 such as number of lines per DSLAM location and trench length per line. We express these relationships as equations using standard econometric techniques. The equations derived from this analysis have strong explanatory power because they represent a codification of the Danish and Swedish cost models into an econometric form that can be applied to other jurisdictions with different density characteristics.

85. We have focused our analysis of the effect of spatial density factors on the core network module of the cost models, which represents the bulk of the bitstream incremental costs. The core network cost models contain the 'active network infrastructure' that the Commission believes will not be substantially affected by spatial density factors. We believe that it is reasonable to assume that the access network part of the bitstream cost increment will be at least as sensitive to spatial density factors as the core network part.

4.1 The Danish cost model

86. The telecommunications market in Denmark is regulated by the Danish Business Authority. The Danish Business Authority uses LRAIC as its primary pricing methodology, including for the fixed network. The pricing method is based around what the prospective cost should be if the network is based on the latest technology.

87. Although locational information is used in the bottom-up build of costs within the Danish model, it is subsumed in the final outputs of the model which are network-wide average unit costs. However, it remains available to be used in the calculation of average unit costs at each edge router location. That is, there is no need to make any changes in order to generate average unit costs at each edge router – all this information is already contained in the cost model. The only task is to compile that information.

88. In the Danish cost model, the total cost of the UBA equivalent - layer 2 ADSL bitstream access - is 872 Kr per annum. This consists of 518 Kr from the access network and 354 Kr from the core network.

89. The Danish regulator has stated that its bitstream access cost includes the cost of a shared access loop. The shared access loop is costed in the model at 372 Kr per annum. This means that the incremental cost of the bitstream product, over the shared access loop, is 500 Kr (872 Kr – 372 Kr = 500 Kr). This consists of 354 Kr from the core network and 146 Kr from the access network (we assume that the shared access loop costs are from the access network, 518 Kr – 372 Kr = 146 Kr).

90. This means that the majority of the incremental bitstream cost is derived from the core network (354/500 = 70.1%), confirming the observation made above that the bulk of the incremental bitstream costs are derived from the core network.

91. The core network module of the Danish cost model contains a large number of cost categories. However, only a subset of these is relevant to bitstream services. These relevant cost categories receive routing factors allocating them, at least in part, to bitstream services. A list of relevant cost categories is shown at Appendix B.

92. The model already contains calculations at each edge router location and its child nodes that seek to provision the relevant asset categories by location. However, the final model result does not use this node-specific information because it is a network-wide average unit cost. Within the model, the assets provisioned at each edge router location and child nodes associated with that router are summed and a mark-up for spares applied to the network total.[13]

93. From this total asset provisioning, unit costs and specific mark-ups for each cost component are used to calculate:

- equipment and materials capital costs;
- installation capital costs; and
- maintenance and annual supplier support operating costs.

94. The capital costs are annualised and added to the operating costs to form the annual cost base for each cost category, with these costs allocated across the various services using a routing table.

95. To estimate the average core network unit bitstream cost at each edge router location, we have taken the assets provisioned by the model at these locations and uplifted them by any mark-ups used by the model, such as spares.[14] This number of assets is multiplied by the unit price from the model to calculate the equipment and materials capital costs. Installation capital costs and maintenance and annual supplier support operating costs are calculated from this amount using the same multipliers applied by the model at the network-wide level. Finally, the capital costs are annualised, consistent with the process used for total costs, and the annual costs are added together to form a total annual cost for each cost component at each edge router location.

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[13] The bottom-up provisioning can be found in the core network module in the “A5_I_Node_Equipment”. Mark-ups to the totals are subsequently applied in the “B5_C_Equipment” sheet. These calculations are conducted on the sheet “B5_C_Trenching_Local” for transmission path costs.

[14] This can result in fractional parts of assets at specific edge router locations. However, this is consistent with the overall result of the model, since the spares are effectively a common cost that can be allocated across all edge router locations.

96. The final routing table in the core network model contains information about the relative allocation of each cost component to bitstream services.[15] We use this routing table to calculate the total annual bitstream cost at each edge router location, relative to the total annual bitstream cost across all edge routers.

97. The unit bitstream cost at each edge router location is calculated as:

$$Unit\ cost\ of\ edge\ router\ i = Network\ unit\ cost \times \frac{\left(\frac{Annual\ cost\ of\ edge\ router\ i}{Annual\ cost\ of\ network}\right)}{\left(\frac{xDSL\ demand\ of\ edge\ router\ i}{xDSL\ demand\ of\ network}\right)}$$

98. That is, the unit cost of bitstream at the network level is scaled up (or down) by the cost of bitstream per xDSL line at the edge router relative to the cost of bitstream per xDSL line over the entire network. In this equation, relative xDSL line numbers takes the place of relative bitstream demand because the model does not contain information about bitstream demand by edge router. Rather, it effectively assumes, consistent with the formula above, that this demand is distributed proportionately with broadband demand across the network.[16]

4.1.1 Variability in bitstream network elements across Denmark

99. We begin our analysis by examining the breakdown of network elements into each area served by an edge router.

100. This breakdown allows us to examine the variability in scale across areas at the current level of broadband penetration. As illustrated in Figure 4-1 there is significant variability in the number of bitstream customers per DSLAM location in Denmark. Figure 4-1 shows that the number of bitstream customer per DSLAM location (which may be a cabinet or an exchange) varies significantly. In around 75% of areas there is less than 1000 bitstream customers per site (with 20% below 200 bitstream customer per site) whilst 14% of areas have more than 2000 bitstream customers per DSLAM site.

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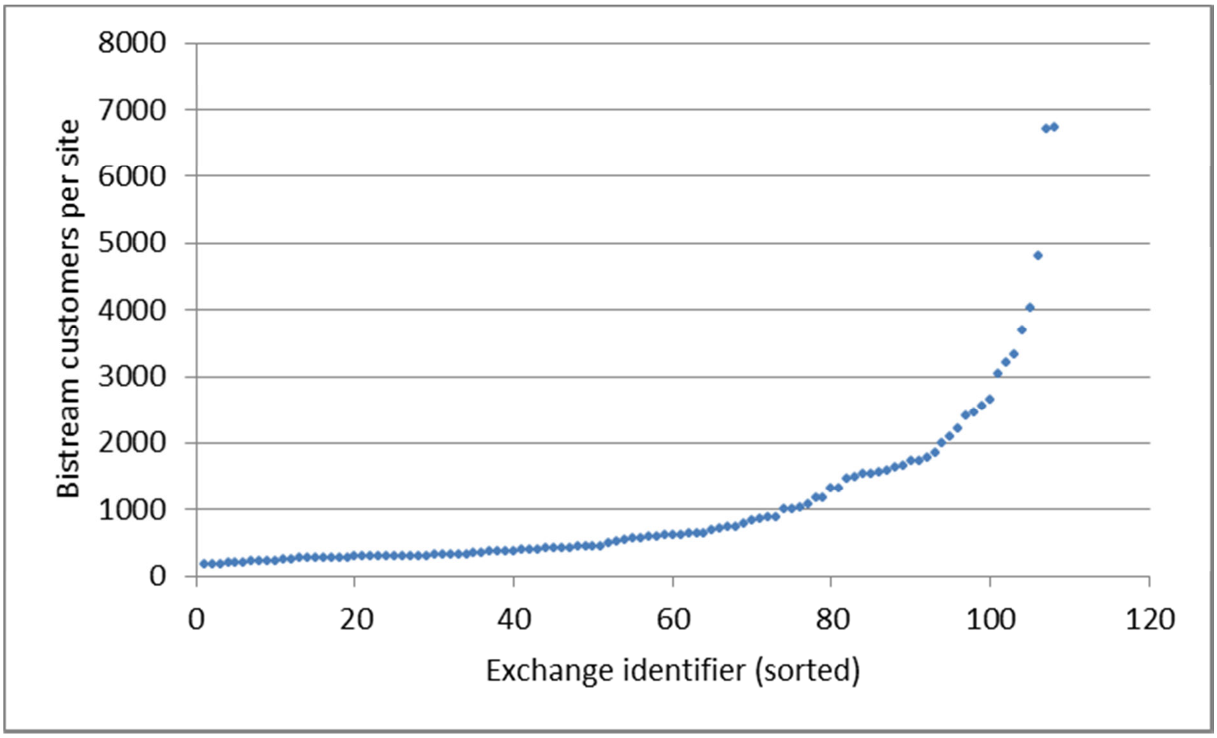
[15] We use the "Adjusted route table for consolidation model" in the "A3_C_Route_Table" worksheet.

[16] This must be the case since the model does not take into account the location of bitstream demand in provisioning assets.

Figure 4-1 DSL customers per DSLAM location in Denmark

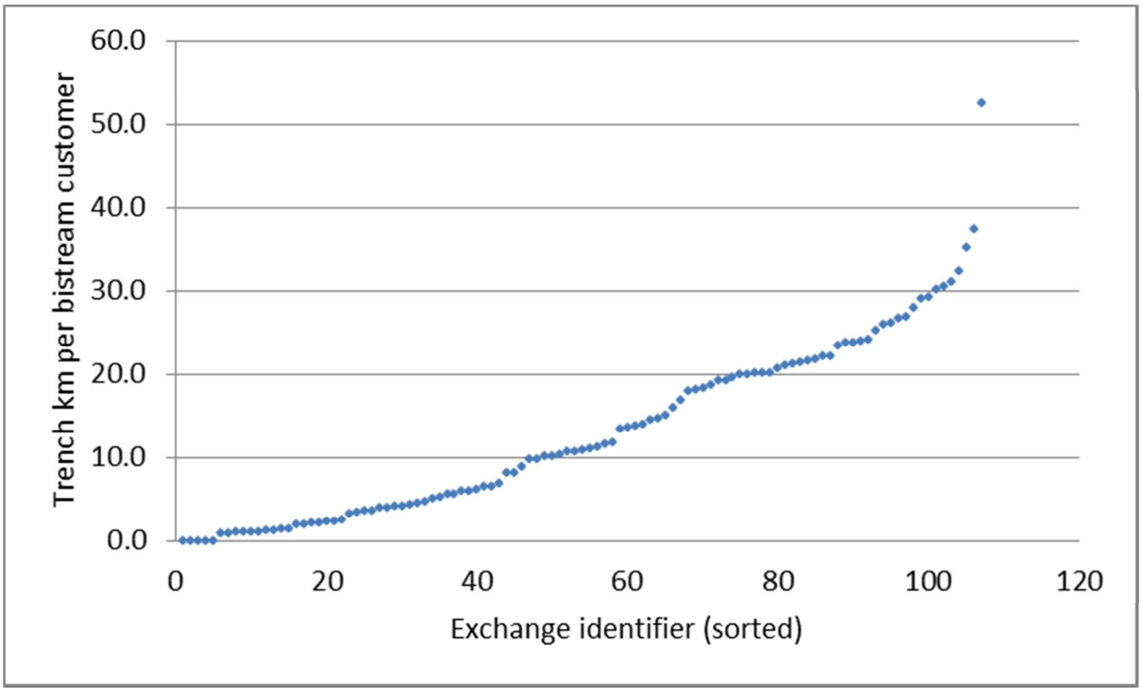


Source: Danish cost model, CEG analysis

101. A reasonable hypothesis is that the exchange areas with lower bitstream customers per DSLAM location are in rural areas (as is the case in the Swedish model, discussed below). We cannot confirm this without line density data for Denmark. However, the data does show very large variability in scale across exchanges and therefore potentially very high unit costs in areas with lower scale and low unit costs in areas with high scale.

102. Similarly, Figure 4-2 shows the variability in local trenching kilometres in areas within the Danish model, where trenching kilometres is a mapped distances between each site containing a DSLAM and the edge rout. These data again demonstrate a high degree of variability across areas.

Figure 4-2 Trench km per customer in Denmark



Source: Danish cost model, CEG analysis

4.1.2 Regressions on cost drivers in the Danish model

103. In this section we described how we extracted the average unit cost of bitstream services by edge router location from the Danish cost model.

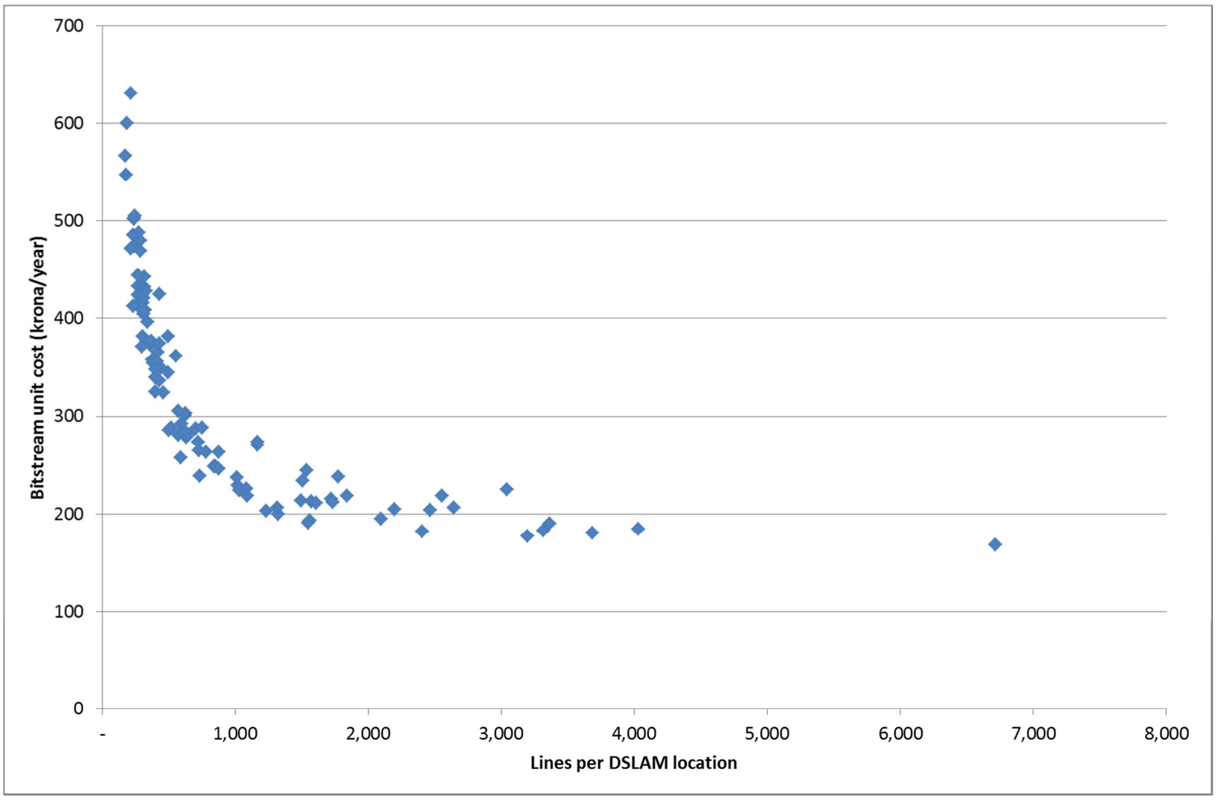
104. We do not have direct information about the population density and urbanisation of the areas in which each edge router is located in these models. However, the models themselves contain information about cost drivers of the core elements of the bitstream service, which we have shown at section 3 above are themselves closely related to spatial density factors.

105. In this section we use the Danish model to investigate the effect of two cost drivers, being:

- the average number of xDSL lines per DSLAM location; and
- the trench distance at each edge router.

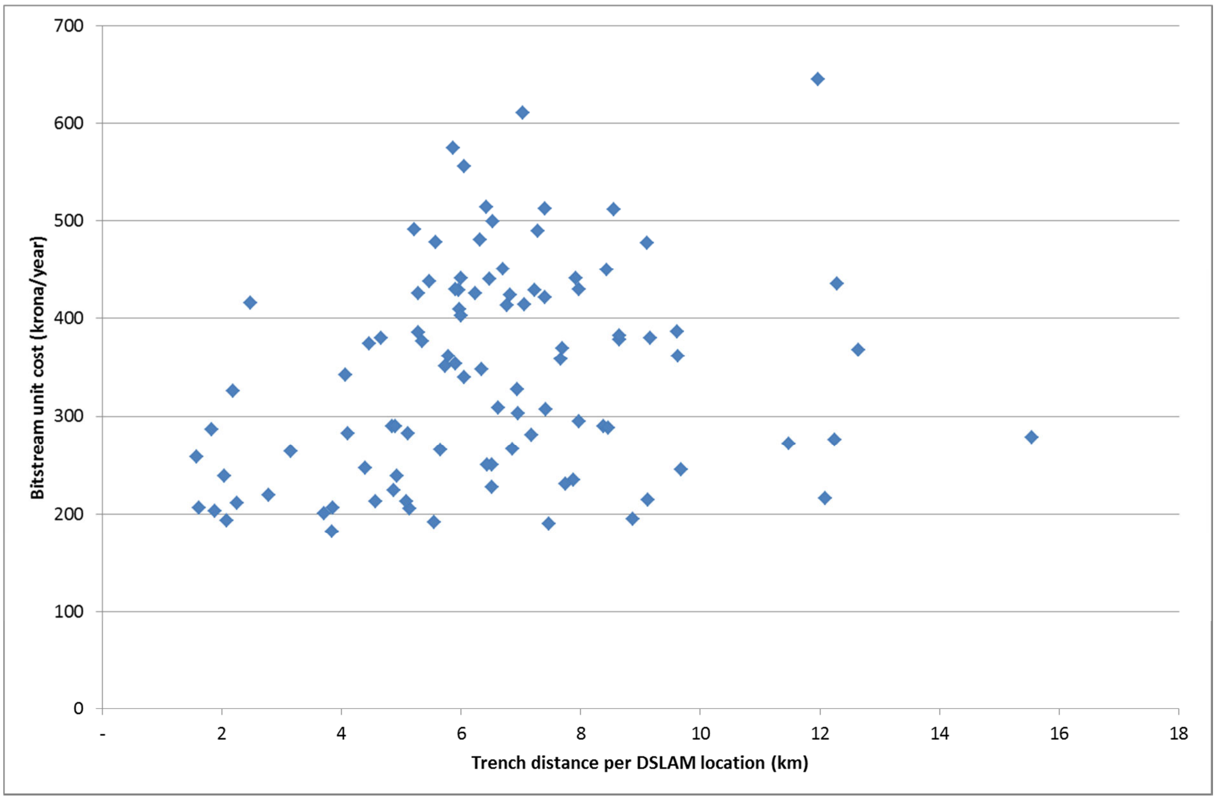
106. Figure 4-3 and Figure 4-4 below plot these cost drivers against core network bitstream unit cost at each edge router location in the Danish cost model.

Figure 4-3 Lines per DSLAM location against core network bitstream cost in Danish cost model



Source: Danish cost model, CEG analysis

Figure 4-4 Trench distance per DSLAM location against core network bitstream cost in Danish cost model



Source: Danish cost model, CEG analysis

107. The figures above suggest that the factor that exhibits the strongest relationship to localised cost is lines per DSLAM location. Trench distance per edge router does not appear to exhibit as strong a relationship.

108. Table 4-1 below investigates these relationships by regressing both of these factors onto bitstream unit cost, testing alternative functional forms.

Table 4-1 Econometric regressions onto bitstream unit cost from Danish cost model

Parameter	Linear-Linear	Linear-Log	Log-Linear	Log-Log
Lines per DSLAM location	-0.135***	-136.030***	-0.000432***	-0.416***
Trench distance per DSLAM location	7.513***	38.834***	0.0229***	0.122***
Constant	391.328***	1132.148***	5.951***	8.199***
Adjusted R-squared	0.6132	0.8716	0.7214	0.9409

Source: Danish cost model, CEG analysis
*Note: *** indicates significance at the 1% level*

109. It is not possible to directly compare R-squareds between models with different dependent variables. However, it appears that using logged independent variables produces a closer fit than linear dependent variables. This is consistent with the strongly non-linear relationship indicated in Figure 4-3 above. We also note that when the R-squared for the log-log regression is re-calculated on the basis of its predictions of the unlogged dependent variable, it performs better than the linear-log model.[17] On this basis, we prefer the log-log model.

4.2 The Swedish hybrid model

110. In Sweden, the incumbent operator, TeliaSonera, is considered by the regulator (PTS) to have significant market power in the market for bitstream access. The regulator consequently sets a cost-based priced for bitstream based on a long-run incremental cost (LRIC) model ("the hybrid model").

4.2.1 Customer density effect on bitstream elements in Sweden

111. As with the Danish model, the Swedish model does not produce geographically differentiated prices. However, it does use sample edge locations in different geographic areas in order to build up a representation of the network across the whole of Sweden. The sample edge locations are divided across four *urbanisation categories*. These include:

- Category A for Stockholm;
- Category B for other major cities;
- Category C for the remainder of Northern Sweden; and
- Category D for the remainder of Southern Sweden.

112. Once information has been obtained for each of the sample edge locations, the sample is 'scaled up' based on these four urbanisation categories to reflect the total network. To ensure that the result is as representative as possible, that adjustment is based on the number of sampled edge locations relative to the total population in each urbanisation category.

113. Table 4-2 below proves a breakdown of the number of network elements per customer in each of the urbanisation categories within the Swedish cost model.[18]

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[17] The log-log model returns an unadjusted R-squared for the unlogged cost of 0.9360, as against the linear-log model which achieves 0.8743.

[18] Note that the number of bitstream customers is not directly observable for each area, so line card modules are used as a proxy.

114. In Stockholm, on average, more customers are served per site relative to less dense areas, and sites are also associated with less trench distance.

115. For example Stockholm has on average 1935 xDSL customers per site and only 3.3 km of trench per site. In comparison, Northern Sweden has on average only 208 xDSL customers per site and as much as 11.0 km of trench per site.

116. This suggests that the distribution of lines across areas of varying line density will have a significant effect on the amount of equipment per customer needed to provide the bitstream service.

Table 4-2 Network elements by urbanisation category in Sweden

Urbanisation category	# xDSL customers per site	Trench (km) per site
A – Stockholm	1935	3.3
B – Other major cities	862	2.6
C – Remainder of Northern Sweden	208	11.0
D –Remainder of Southern Sweden	463	6.9

Source: Swedish cost model, CEG analysis

4.2.2 Sensitivity to a change in subscribers

117. Figure 4-5 below illustrates how the incremental bitstream unit cost changes from its original 60.5 Kr[19] as a result of changing the number of broadband subscribers/penetration. The red marker reflects the original input into the model. The figure shows that the unit cost falls as the number of subscribers' increases.

118. This reduction in unit cost is in part due to an increase in scale[20] and also the result of changes in the allocation of costs within the model between services.

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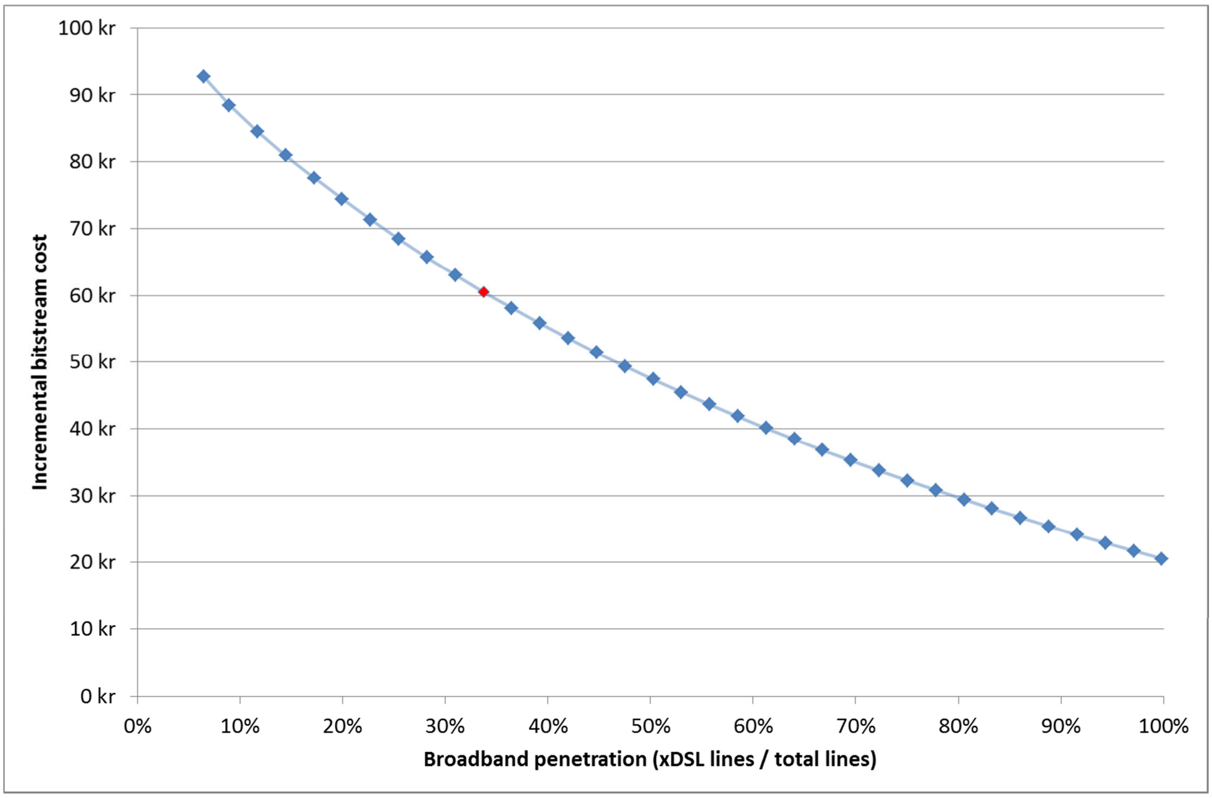
[19] This is the average cost/price across all broadband speeds.

[20] We note for example that the total cost pool for the core network elements used to provide the bitstream service is insensitive to the change in the number of subscribers.

Figure 4-5 Effect of a change in broadband subscribers on the bitstream service unit cost



Source: Swedish cost model, CEG analysis

4.2.3 Regressions on cost drivers in the Swedish model

119. The Swedish cost model does not rely on locational information at the edge location to the same extent as the Danish cost model. However, it does provide a sufficient amount of information by edge location for us to be able to estimate average unit costs at each edge location with some simplifying assumptions.

120. We have focused this analysis on the portion of bitstream costs derived from the core network module of the model, which is 63.7 Kr per month.[21]

121. The core network module of the Swedish model contains a large number of cost categories. As was the case in the Danish cost model, only a sub-set of these cost categories is relevant to the bitstream service. A portion of the total cost for these cost categories is allocated to the bitstream service by way of routing factors.

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[21] This is the sum of the unit costs allocated to bitstream from the four network elements in paragraph217 in Appendix C. This number is slightly higher than the incremental costs to the local loop, which as per the Commission's methodology is given by the bitstream price less the price of the full local loop (157.4 Kr – 96.9 Kr = 60.5 Kr)

122. Of these costs, only those associated with the trenching and ducting are allocated by edge location in the model. In the model, 64 of the 139 edge locations are sampled and scaled up to estimate a total cost for the network (rather than using information from all the edge locations). We have therefore estimated total costs for these sampled edge locations.

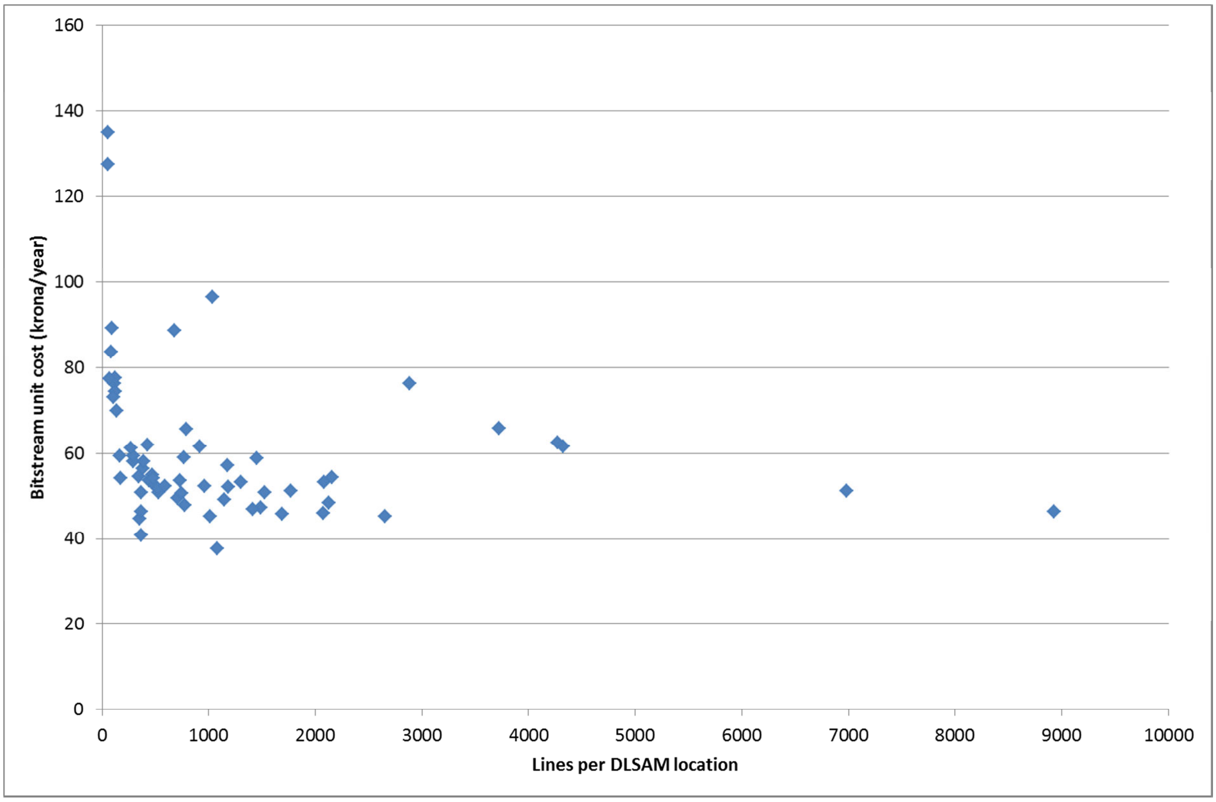
123. The total costs for fibre access switches are provisioned by way of the design rules implemented in the model. The model determines the total number of fibre access switches based on summarised information across the network, and not information on an edge location basis. To calculate provisioning at each edge router location, we have assumed that all nodes associated with an edge location are the same size (i.e. has the average number of lines of that sampled edge location) and used the design rules implemented in the model to determine the number of fibre access switches on a per sampled edge location basis.

124. We have allocated the costs for aggregation switches to sampled edge locations in proportion to the fibre access switches, consistent with the design rules implemented in the model. The costs associated with metro switches, the management system and the edge routers and repeaters (Layer 3 Edge) have been attributed equally between the sampled edge locations. This reflects the fact that the design rules implemented in the model set the total units for these elements with no regard to other factors (i.e. envisage a constant distribution across locational areas).

125. This analysis of the Swedish cost model is described more fully in Appendix C.

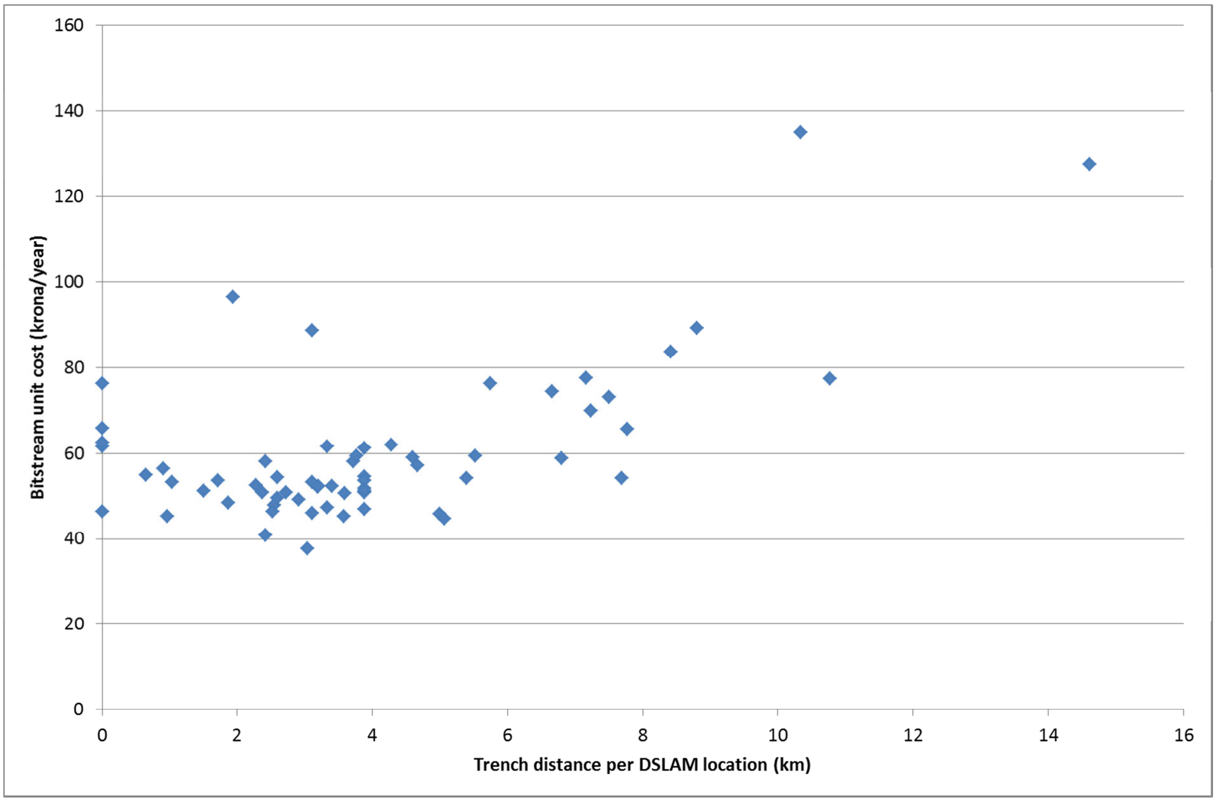
126. As with the Danish model, we have used the cost per sampled edge location (as well as the demand per edge location) to calculate a unit cost per sampled edge location. Figure 4-6 below plots these cost drivers against core network bitstream unit cost at each edge router location in the Swedish cost model.

Figure 4-6 Lines per DSLAM location against core network bitstream cost in Swedish cost model



Source: Swedish cost model, CEG analysis

Figure 4-7 Trench distance per DSLAM location against core network bitstream cost in Swedish cost model



Source: Swedish cost model, CEG analysis

127. Table 4-3 below investigates both of these relationships by regressing lines per DSLAM location and trench distance per DSLAM location against bitstream unit cost, testing alternative functional forms.

Table 4-3 Econometric regressions onto bitstream unit cost from Swedish cost model

Parameter	**Linear-Linear**	**Linear-Log**	**Log-Linear**	**Log-Log**
Lines per DSLAM location	0.001	-8.515***	0.00000854	-0.121***
Trench distance per DSLAM location	4.156***	7.336**	0.0538***	0.098**
Constant	42.618***	103.986***	3.840***	4.691***
Adjusted R-squared	0.3698	0.4317	0.3323	0.4543

Source: Swedish cost model, CEG analysis
*Note: *** indicates significance at the 1% level, ** indicates significance at 5% level*

128. As noted previously in the context of the Danish cost model is not possible to directly compare R-squared statistics between models with different dependent

variables. However, we note that when the R-squared for the log-log regression is re-calculated on the basis of its predictions of the unlogged dependent variable, it performs better than the linear-log model.[22] This conclusion appears consistent with the non-linear relationship indicated in Figure 4-6 above. On this basis, we prefer the log-log model in the case of Sweden also.

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[22] The log-log model returns an unadjusted R-squared for the unlogged cost of 0.4868, as against the linear-log model which achieves 0.4516.

5 Adjusting for line density

129. Based on the analysis in sections 2 to 4, we believe that it is appropriate to adjust the prices of bitstream services from the benchmark jurisdictions to reflect an differences in the density of lines relative to New Zealand.[23]

130. This could be achieved by benchmarking the additional costs of the bitstream in proportion to the unbundled copper local loop prices. An alternative is to base any adjustment on the econometric analysis undertaken in the section 4.

5.1 Relationship between prices and line density

131. The cost of providing the copper local loop varies considerably with the density of lines at an exchange.[24] The Commission found this when it employed econometric analysis to identify a relationship between UCLL prices and proxies for distribution of line densities within jurisdictions (national level population density, urbanisation rates, and teledensity).

132. An important part of the relationship between average UCLL prices in a jurisdiction and the distribution of line densities is the high cost of serving low density areas. The Australian Productivity Commission found that:[25]

> *… low density areas are estimated to account for some 25 per cent of the total cost of providing local telephone service, despite having only about 5 per cent of the total number of lines.*

133. The Commission did not rely on sub-national line density distributions in informing its UCLL prices. It established an econometric relationship between UCLL prices and proxies for this distribution. Using this relationship it was able to adjust (or normalise) the benchmark prices to reflect the characteristics of New Zealand.

5.1.1 UBA costs also expected to vary with line density

134. In the previous sections of this report we have established that a strong relationship exists between the utilisation of network elements used to provide bitstream services and the density of lines.

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[23] In section 6 below we consider the appropriate price to benchmark is the average price reported for each jurisdiction. For the purpose of this analysis we use the average price as the appropriate starting point for any adjustment.

[24] Productivity Commission, *Population Distribution and Telecommunications Costs*, Staff Research Paper, August 2000.

[25] Ibid, p. IX

135. This relationship was unsurprising based on what we know about the cost drivers for each network element. Specifically, we found that the spatial density of customer, DSLAM locations, data switches and handover points was a key driver of the scale that could be achieved on each network element. In particular, the number of customers per DSLAM site, the number of DSLAM sites per data switch/handover location and the number of customers per kilometre of trench were all driven by the spatial density of the network.

5.1.2 Reconciling the relationships between UCLL and UBA prices

136. The extent to which the differences in costs of providing bitstream services across different line densities mirrors the differences in costs of providing the UCLL across different line densities is an empirical question that could only be answered through cost modelling or econometric analysis. Nevertheless, the density of lines, reflected in proxies such as national population density, urbanisation rate and fixed penetration, is likely to be an important cost driver for the provision of the bitstream service. It is also likely to explain differences in the observed prices for bitstream services across jurisdictions.

137. As such, we believe it would be appropriate for the Commission to adjust benchmarked bitstream prices to reflect differences in line densities observed between New Zealand and its benchmark set.

138. An obvious solution is to benchmark the additional cost of providing the bitstream services as a percentage mark-up on top of the local loop price in each jurisdiction. This approach would effectively import the normalisation adjustment used in the UCLL pricing determination into the UBA pricing determination.

139. In our view benchmarking bitstream prices based on a ratio of local loop prices is a potentially pragmatic solution in the absence of more reliable information on the relationship between bitstream costs and line density. We recognise that would require the reasonably strong assumption that the relationship is the same as that found to exist for local loop prices. Nevertheless, in our opinion, there is evidence that, like the local loop service, the costs of the bitstream will vary considerably with line densities, and the high expected unit costs in remote areas will strongly influence average costs in all areas.

5.2 Econometric adjustment to benchmarks

140. In section 3 above, we introduced a dataset of observations from Chorus' network of lines per DSLAM location. In section 4 we developed econometric relationships between the incremental cost of the bitstream service and the cost drivers explored in section 3. Using this dataset and the econometric relationships, we can normalise the average incremental costs reported by the Danish and Swedish cost models. By doing so, we can produce benchmark prices that better reflect New

Zealand's characteristics including, most notably, its different spatial density factors.

5.2.1 Normalising the UBA increment in Denmark and Sweden

141. The normalisation process involves applying the econometric relationships derived above to estimate a cost for each DSLAM location in New Zealand. Given that the relationship was established at the edge router level in both Denmark and Sweden, we use the New Zealand data at the first access switch level (rather than the cabinet level or the exchange level).

142. In the case of Sweden the UBA increment is 60.5 Kr; that is, 157.4 Kr for the average UBA service per month less 96.9 Kr for the cost of the full local loop per month.

143. In the case of Denmark, the UBA increment is 500 Kr. We note the reported prices of the UBA equivalent in Denmark - layer 2 bitstream access - already includes the cost of the shared loop. Therefore, the incremental cost of the bitstream service, over the access loop (in this case a shared access loop rather than a full access loop), is given by the average bitstream cost (872 Kr per annum) less the cost of the shared access loop (372 Kr per annum). This gives an incremental cost for the bitstream above the shared access loop of 500 Kr per annum.

144. Both of these UBA incremental costs are based on average costs from the cost models, as opposed to the cost for the slowest speed. The reasoning behind this is discussed in more detail in section 6.

145. Due to the sparser nature of New Zealand's demand for telecommunications infrastructure, we find that this adjustment, based on our preferred econometric model, increases the benchmarked UBA increment costs from 500 Kr to 769.5 Kr per annum in Denmark (an increase of 53.9%).

146. The equivalent adjustment for Sweden is much smaller, which reflects the fact that Sweden's telecommunications infrastructure may more closely resemble that of New Zealand. The adjustment increases the benchmarked UBA increment costs from 60.4 Kr to 69.0 Kr in Sweden (an increase of 14.1%).

147. We note that this represents a smaller increment than would be allowed under a ratio benchmarking approach (i.e., where the increment is benchmarked as a percentage of the local loop price). Adopting the ratio benchmarking approach would in effect adopt the same normalisation model for the UBA increment that applied for the local loop. This is reasonable given the relationship observed between bitstream network elements and line density and the robust information contained in the UCLL normalisation adjustment.

148. Given the data available to us we conclude that an adjustment should be made to the benchmarked UBA increments. We consider that the econometric approach and

the ratio benchmarking approach each provide a reasonable basis for such an adjustment.

5.2.2 Normalising prices in other jurisdictions

149. In the previous section we showed how locational cost information contained within the Danish and Swedish cost models can be used to normalise their respective UBA increments to reflect the characteristics of Chorus' network.

150. We have not conducted this analysis using cost models for other jurisdictions. However, we can approximate the adjustment that would be implied by this approach by comparing the spatial density characteristics of these jurisdictions to Denmark and Sweden. That is, if Denmark's denser line locations and shorter trench lengths necessitate a 53.9% adjustment, and Sweden's require a 14.1% adjustment, then we can use approximate the adjustments that would be needed for other jurisdictions. Specifically, we can:

- take the Commission's fitted UCLL prices, derived using its 2007 regression model of spatial density factors (being national population density, urbanisation and tele-density); and
- using the adjustments for Denmark and Sweden implied by the fitted UCLL prices for those jurisdictions, approximate the mark-ups that would be required these jurisdictions, based on their fitted UCLL prices and a straight line interpolation/extrapolation between the Danish and Swedish observations.

151. Table 5-1 below illustrates the effect of this spatial density proxy. In our opinion, given the information available from the Denmark and Sweden models, the suggested adjustments for Belgium, Greece and Switzerland are reasonable. However, we have not reviewed the UBA prices or models that generate the prices from these jurisdictions.

Table 5-1 Estimated mark-ups for other jurisdictions

Jurisdiction	Fitted UCLL price	Estimated mark-up based on fitted UCLL price
Denmark	16.35	+53.9%
Sweden	18.40	+14.1%
Belgium	14.84	+83.3%
Greece	19.75	-12.2%
Switzerland	15.98	+61.1%

Source: Commerce Commission UCLL modelling, CEG analysis

5.3 Comparing the econometric approach and the ratio benchmarking approach

152. We find that using ratio benchmarking offers a pragmatic alternative to the Commission. While taking into account the fact that the UBA increment does have a relationship with spatial density, it avoids the need to go to the modelling presented above in computing the exact nature of this relationship.

5.3.1 Comparing the econometric approach and ratio benchmarking approach for Denmark

153. The Danish model estimates a full loop cost of 744 Kr per annum (or 62.0 Kr per month). The unadjusted bitstream increment is 500 Kr per annum (or 41.7 Kr per month). This means that the unadjusted bitstream cost is equal to 67.2% of the full loop cost.

154. The Commission has recently set the price of the unbundled copper local loop service at $23.52 per month per line. Using ratio benchmarking therefore implies in an incremental bitstream cost of $15.81 (67.2% of $23.52), and a total bitstream cost of $39.33 per month ($23.52 + $15.81).

155. Alternatively, if the adjustment described above were to be made instead, the Danish UBA increment would be 64.1 Kr per month (as calculated earlier). At the Commission's exchange rate of 4.52 Kr/NZD, this amounts to a UBA increment of $14.19 per month per line and a total UBA price of $37.71 per month per line.

156. We note that there are some limitations to our econometric approach in that it is based solely on the core cost component in the case of Denmark. That is, it excludes the access cost component from the bitstream price in Denmark. Benchmarking of the access cost component may lend itself more readily to the ratio approach depending on the nature of these costs.

5.3.2 Comparing the econometric approach and ratio benchmarking approach for Sweden

157. The incremental bitstream cost in Sweden of 60.5 Kr is equal to 62.4% of the full local loop cost of 96.9 Kr. Therefore, applying ratio benchmarking, the equivalent incremental bitstream cost in New Zealand is $14.68 (62.4% of the full loop cost in New Zealand of $23.52).

158. Alternatively, if the adjustment described above were to be made instead, the Danish UBA increment would be 69.0 Kr per month (as calculated earlier). At the Commission's exchange rate of 5.39 Kr/NZD, this amounts to a UBA increment of $12.80 per month per line and a total UBA price of $36.32 per month per line.

5.3.3 Conclusion on the econometric approach vs. ratio benchmarking approach

159. The following table summarises the outcome of the econometric approach, ratio benchmarking for Sweden and Denmark and the scenario in which no adjustment is made.

Table 5-2 Comparison of results

	Unadjusted (NZD)	Econometric adjustment (NZD)	Ratio benchmarking (NZD)
Sweden	11.22	12.80	14.68
Denmark	9.22	14.19	15.81
Median	10.22	13.50	15.25

Source: CEG analysis

160. In our opinion, the results implied by both of these methodologies are reasonable.

6 Selection of benchmark price

161. The benchmark prices applied in the Commission's draft determination are not the correct starting point, because:

    - the Commission's benchmark prices are set based on the slowest speed available in each of the benchmark jurisdictions; whereas
    - the regulators in those jurisdictions use an allocation gradient to allocate costs between different speeds, and so selecting the price associated with the slowest speed will not allow for full cost recovery.

162. In its draft determination, the Commission notes that in New Zealand there is no differentiation in line speed: the basic UBA service is a full speed service, subject to throughput limitations.[26] However, different prices for different speeds are common in other jurisdictions, including Sweden and Denmark.

163. Drawing upon the WIK report, the Commission comments that a higher line speed over the local access network does not result in any additional cost relative to a lower line speed. Rather, in a cost based model, the higher price for a higher speed reflects increased variable common costs (mostly transport):[27]

> *A higher line speed over the local access network (the copper pair) does not incur any additional cost when compared to a lower line speed service. A higher price for a higher speed, in a cost-based model, is therefore reflective of the increased variable cost of the shared resource, mostly transport costs.*

164. The Commission consequently concludes that the slowest speed service indicates the minimum level of fixed costs that are required to provide this service. Any additional costs are said to only be required in providing a higher speed service. It reasons that because the basic UBA service in New Zealand (with 32 Kbps minimum throughput) is at the lower end of the spectrum of speeds available overseas , it is appropriate for it to select the price corresponding to the slowest speed in the benchmarked countries:[28]

> *The slowest speed service therefore provides an indication of the minimum level of fixed costs necessary to provide the service. Additional costs are incurred by the additional transport required for a higher speed service.*
>
> *The price for the Basic UBA service represents the cost of providing the service with a 32kbps minimum throughput which puts it at the low end*

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[26] Commerce Commission (2012) *Unbundled Bitstream Access Service Price Review,* p.22

[27] Ibid.

[28] Commerce Commission (2012) *Unbundled Bitstream Access Service Price Review,* pgs.22 - 23

> *when compared to other services overseas. The price point for the slowest speed should therefore be selected in the benchmarked countries.*

165. We disagree. In our opinion, it is inappropriate for the Commission to select the price associated with the slowest speed in the benchmarked countries for two reasons:

- in benchmark jurisdictions, a greater proportion of the costs that are common to all service speeds are allocated to higher speed services. It follows that if the Commission uses the slowest speed price as its benchmark price, this will not allow for full recovery of all common costs; and
- the allocation of costs between otherwise identical services with different speeds in the benchmark jurisdictions is not 'cost-based' in the TSLRIC sense of this terms.

166. We set out the reasoning behind these two points in more detail in sections 6.1 and 6.2 respectively.

167. In our view, instead of benchmarking the price for the slowest speed, the Commission should use the average price that will recover the total costs allocated to bitstream services in the models. The Danish model generates the average price directly (the re-allocation between speeds happens externally to the model), and the inputs into the Swedish model can be adjusted to generate an average price. This is described more fully in section 6.3.

6.1 Using the slowest speed price will not allow for full cost recovery

168. Both Sweden and Denmark implement a so-called 'allocation gradient' to re-allocate costs associated with bitstream to services with different speeds. In both cases, only the core network bitstream costs are re-allocated to different speeds. Access network bitstream costs all are attributed equally across the different speeds.

169. In Sweden, the re-allocation of core network costs between speeds is undertaken within the cost model itself. In Denmark, the cost model only produces one (average) price, and the allocation gradient is implemented separately to the model to derive prices for different speeds.

170. The allocation gradient in both jurisdictions is based on a logarithmic formula:

$$Allocation\ gradient = \ln\left(\frac{connection\ speed}{minimum\ speed}\right)$$

171. In Sweden, the minimum speed is 64 Kbps (equivalent to a normal POTS line). With the Swedish inputs the logarithmic formula results in an allocation factor of 1.36 for the slowest speed (250 Kbps), and 6.84 for the fastest speed (60 Mbps). In

Denmark, the denominator is set at 240 Kbps.[29] In this case the allocation factor is 0.065 for the slowest speed (256 Kbps) and 5.340 for the fastest speed (50,048 Kbps). The prices resulting from the allocation gradient in Sweden and Denmark respectively are illustrated in the following table. Note that the prices in the Swedish model are given on a per month basis, and on an annual basis in the Danish model.[30]

Table 6-1 Allocation gradients in Swedish and Danish cost models

Sweden			**Denmark**		
Speed	**Allocation gradient**	**Price per month**	**Speed**	**Allocation gradient**	**Price per year**
250 Kbps	1.36	137 Kr	256 Kbps	0.065	524 Kr
500 Kbps	2.06	141 Kr	512 Kbps	0.758	591 Kr
2 Mbps	3.44	151 Kr	1024 Kbps	1.451	658 Kr
8 Mbps	4.83	160 Kr	2048 Kbps	2.144	724 Kr
24 Mbps	5.93	168 Kr	3072 Kbps	2.549	763 Kr
30 Mbps	6.15	169 Kr	4086 Kbps	2.837	791 Kr
60 Mbps	6.84	174 Kr	5120 Kbps	3.060	813 Kr
			6144 Kbps	3.243	830 Kr
			8064 Kbps	3.515	856 Kr
			10,240 Kbps	3.753	880 Kr
			15,360 Kbps	4.159	919 Kr
			20,480 Kbps	4.447	946 Kr
			40,960 Kbps	5.140	1,013 Kr
			50,048 Kbps	5.340	1,033 Kr
Average (no allocation gradient)		**157 Kr**			**872 Kr**

Source: PTS and Erhvervsstyrelsen (2013)

172. In effect, by adopting an allocation gradient, the regulators ensure that low and high usage intensive products do not end up having the same price. In particular, the allocation gradient results in usage intensive services bearing a higher proportion of the common costs.

173. This is usefully explained by the Swedish regulator, PTS, in the following excerpt from a consultation document in 2007 relating to the BU-model. The initial

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[29] No explanation is provided for the choice of minimum speed.

[30] See Swedish cost model and accompanying documentation from Swedish regulator, PTS on http://www.pts.se/sv/Bransch/Telefoni/SMP---Prisreglering/Kalkylarbete-fasta-natet/Gallande-prisreglering/

See also Danish cost model and accompanying spreadsheet on implementing the allocation gradient on http://www.erhvervsstyrelsen.dk/prisafgoerelse comment is from the operator Telenor, and PTS' response is contained in the box that follows:[31]

> ***3 Telenor***
>
> *[...]*
>
> *3.11 Bitstream costing*
>
> *The allocation of costs must consider how the market functions. Allocating passive costs like trenching to products using high throughput is not relevant. The cost driver for large throughput is active equipment, not passive costs.*
>
> *[Confidential]*

> *PTS does not agree that allocating costs like trenching to product based on usage is not relevant. On the contrary, not doing so would ultimately mean, for example, that very usage intensive data services (such as 155 Mbps leased lines) would incur the same monthly cost as a very lightly used low speed retail adsl product.*
>
> *However, as mentioned previously [...] we have now adapted the model such that the costs of broadband/Bitstream services can be apportioned according to an allocation gradient, initially set to approximate the retail gradient of TeliaSonera's broadband products.*

174. A usage intensive service bearing a higher proportion of the passive costs (or common costs) is, in itself, not controversial. However, when the Commission selects the slowest speed price as the benchmark price it in effect 'misses out' on some of the common costs which have been allocated in a higher proportion to higher speed services. The slowest speed price from the Swedish and Danish cost models therefore do *not* provide an indication of the minimum level of fixed costs necessary to provide the service, in the manner that the Commission contends[32]. This is discussed in more detail in the next section.

6.1.1 Why selecting the slowest speed price does not provide an indication of the fixed costs necessary to provide the service

175. A simple example can be used to illustrate why selecting the price corresponding to the slowest seed service:

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[31] PTS (2007) *PTS consultation response on draft BU-model,* p. 24

[32] Commerce Commission (2012) *Unbundled Bitstream Access Service Price Review,* p.22

- does not provides an indication of the fixed costs necessary to supply the bitstream service; and
- does not allow for the full recovery of costs that are common across different service speeds.

176. Assume that 'Country B' has a network that has exactly the same dimensions and characteristics as Chorus' in New Zealand. Assume also that each county has 50 UBA subscribers. However, there are different services offered in each location:

- in New Zealand, there is only a basic UBA service; whereas
- in Country B, there is a basic service for $10/month and an enhanced service for $20/month.

177. The prices in Country B are set so as to cover the total costs of providing the relevant service (i.e., they do not entail any economic rent). Those prices also include an allocation of the costs that are common between the two services (i.e., common to high and low/basic speed service). Suppose finally that the higher speed service is allocated a significantly greater proportion of those common costs.

178. If New Zealand uses benchmarking to set the price for its basic UBA service, and selects the price of the basic service observed in Country B (i.e.,$10/month), this risks underestimating the cost of providing the service. Even though New Zealand is only offering a basic service, it will still be incurring some of the common costs that are being allocated to high speed services in Country B. A $10/month price will prevent those costs from being recovered.

179. In precisely the same way, if the Commission selects the prices for the slowest services as its benchmarks, then Chorus would not be able to recover all of the common costs that it incurs providing the regulated service in New Zealand. Clearly, that would be inappropriate.

180. An additional complication is that, unlike incumbent operators in Sweden and Denmark, Chorus, does not have voice on its network. That is, in building a bottom-up cost model in New Zealand, all costs would need to be recovered from bitstream services, whereas in Sweden and Denmark some of the common costs are routed to other services such as voice.

6.2 The cost allocation between otherwise identical services with different speeds is not cost based

181. Cost-based prices reflect the stand-alone costs incurred providing the service, as well as an allocation of common costs. Although there is no standard economic approach it is common practice in bottom-up cost models of fixed telecommunications networks to allocate common costs based on the LRIC contribution to the busy hour.

182. The prices produced by implementing the allocation gradient are unlikely to be cost-based. The simple reason for this is that the Swedish regulator, PTS, initially set the allocation gradient to reflect the retail pricing structure of the incumbent TeliaSonera:[33]

> *[…] we [PTS] have now adapted the model such that the costs of broadband/Bitstream services can be apportioned according to an allocation gradient, initially set to approximate the retail gradient of TeliaSonera's broadband products.*

183. We would not expect the retail pricing of a profit maximising incumbent operator to be solely cost-based, and the allocation gradient has been calculated using the same formula ever since.[34]. This is because one would reasonably expect that price discrimination would be an important reason for there being differences between retail prices for services provided at different speeds.

184. As noted by Laffont & Tirole (2000): (i) the structure of unregulated firms' prices will reflect Ramsey-Boiteux principles (a form of price discrimination) and (ii) the price structure will the same in the absence and presence of regulation (although the level of prices will be "a notch down" for a regulated monopolist). This effectively means that TeliaSonera's retail prices will reflect a degree of (non-cost based) price discrimination. Laffont & Tirole (2000) observe that:[35]

> *Academic economists and policymakers both often argue that regulators do not have the information to set Ramsey prices. One leg of the argument, namely, the widespread shortage of relevant information, is correct. Regulatory agencies have much smaller staff and less contact with markets than telecommunications operators.*
>
> *But taken as a whole, this argument should look unconvincing to any observer of unregulated businesses. The latter indeed engage in sophisticated marketing strategies. They offer discounts to high-elasticity-of-demand customers, adjust their prices to competitive pressure, and carefully coordinate the pricing of substitutes or complements. The structure of unregulated firms' prices (though not the level if the firms have substantial market power) thus reflects Ramsey-Boiteux precepts. This observation suggests that the most promising alley for implementing Ramsey prices in a*

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[33] PTS (2007) *PTS consultation response on draft BU-model,* p. 24.

[34] The preceding quote is taken from a 2007 document of PTS consultation responses on the draft BU-model (also quoted above). However, the logarithmic formula has remained the same since this document was published indicating that the basis for the allocation gradient has not changed.

[35] Laffont & Tirole (2000), Competition in Telecommunications, the MIT Press, London, England, pgs 63, 132-133

> *regulatory context is to decentralize pricing decisions to the operator. (p. 132 – 133)*
>
> *[…]*
>
> *[…] the price structure is the same in the presence or absence of regulation: The ratio of the relative markups over marginal costs of two services is equal to the ratio of the inverse elasticities of demand. Put more crudely, the Ramsey-Boiteux prices are the same as those of an unregulated monopolist, just a notch down. (p. 63)*

6.3 The Commission should use a weighted average price

185. In summary, it would be more appropriate for the Commission use the average price for services in the benchmark countries, rather than the prices for services with the slowest speeds. Provided that the average price reflects an allocation of common costs that would typically be seen in a bottom-up model of a fixed line network (rather than a retail gradient), it will be cost-based – consistent with the Commission's objective. It would also allow all of the costs associated with providing the bitstream service to be recovered.

186. The Danish cost model generates the average price directly in its model – that price is 872 Kr per year (the price for the slowest speed is 524 Kr per year. The Swedish cost model does not generate an average price directly. However, one can be determined by setting the allocation factor for all bitstream and broadband services (at all speeds) equal to the same number (so long as this number is greater than 0, ensuring full cost recovery). The average price is 157 Kr per month (the price for the slowest speed is 137 Kr per month).

187. Finally we note that, in the event that the Commission opts to use the slowest speed prices as its benchmarks - a decision which will mean that Chorus cannot fully recover its costs – then, it follows that Chorus should be permitted to set a higher price for services with higher speeds.

188. The following two tables show the benchmark prices for Sweden and Denmark (unadjusted, econometric adjusted and ratio adjusted) if Chorus was allowed a higher price for higher speed services (reflecting the allocation gradients in those jurisdictions).

189. In the case of Denmark, the costs for the core network and a portion of the access network are allocated using a logarithmic allocation gradient. The portion of the access network which represents the cost of the shared access loop is not allocated using the allocation gradient. In the case of Denmark, about 49% of the incremental bitstream costs are allocated using the allocation gradient.

Table 6-2 Swedish benchmark price allocated by speed

Speed (Kbps)	Subscribers	Allocation gradient	Unadjusted	Econometric adjustment	Ratio adjustment
250	27,321	1.36	$7.40	$8.44	$9.69
500	35,439	2.06	$8.27	$9.44	$10.83
2,000	332,068	3.44	$10.01	$11.43	$13.11
8,000	383,615	4.83	$11.76	$13.41	$15.39
24,000	193,390	5.93	$13.14	$14.99	$17.20
30,000	12,971	6.15	$13.42	$15.31	$17.56
60,000	879	6.84	$14.29	$16.30	$18.70
Weighted average			$11.22	$12.80	$14.68

Source: Swedish cost model, CEG analysis

Table 6-3 Danish benchmark price allocated by speed

Speed (kbps)	Subscribers	Gradient	Unadjusted	Econometric adjustment	Ratio adjustment
256	5,031	0.06	$2.81	$4.32	$4.81
512	11,448	0.76	$4.04	$6.21	$6.92
1,024	5,920	1.45	$5.27	$8.11	$9.03
2,048	26,259	2.14	$6.50	$10.00	$11.15
3,072	6,986	2.55	$7.22	$11.11	$12.38
4,096	66,984	2.84	$7.73	$11.90	$13.26
5,120	58,985	3.06	$8.13	$12.51	$13.94
6,144	49,058	3.24	$8.45	$13.01	$14.49
8,064	44,331	3.51	$8.93	$13.75	$15.32
10,240	210,304	3.75	$9.36	$14.40	$16.05
15,360	74,174	4.16	$10.08	$15.51	$17.28
20,480	231,769	4.45	$10.59	$16.30	$18.16
40,960	0	5.14	$11.82	$18.19	$20.27
50,048	965	5.34	$12.18	$18.74	$20.88
Weighted average			$9.22	$14.19	$15.81

Source: Danish cost model, CEG analysis

Appendix A Chorus line density data

A.1 Data sources relied upon by CEG

190. Chorus has supplied a many-to-many mapping between Statistics New Zealand meshblock areas and exchange service areas. This mapping was developed by identifying over 300,000 cable terminals in Chorus' network, their geographic location and the number of customers served through each terminal. An approximate split of the customers in each exchange service area into meshblocks is generated by associating each terminal with a meshblock and allocating the customers at that terminal to that meshblock.

191. Chorus has also supplied a list of DSLAM site codes and their associated exchange codes and handover points. The location of each of these sites is identified as well as the DSL demand associated with each site.

192. This second dataset contained a slightly different list of exchange service areas from the first dataset. We identified that the mapping file contained 56 exchange codes that were not contained in the DSLAM site information dataset, and the DSL site information dataset contained 52 exchange codes that were not contained in the mapping file. We understand that the reasons for these differences are that:

    - the mapping file contains all exchanges and cabinets, whereas the DSL dataset shows only locations where there is DSL demand; but
    - the mapping file focuses only on 'level 1' locations, whereas the DSL dataset includes DSL equipment installed at sites such as airports or retirement homes which may not be identified as 'layer 1'.

193. In order to ensure sufficient coverage in the mapping file to inform locations in the DSL dataset, we requested and obtained from Chorus additional meshblock to exchange service area mappings for locations not covered in the mapping file. We were supplied a one-to-one mapping for 46 additional locations, meaning that only 6 of 771 exchanges in the DSL dataset cannot be mapped to meshblock areas.[36]

194. Finally, we have obtained from Statistics New Zealand a complete list of 41,369 meshblocks in New Zealand together with the population and area (in square kilometres) associated with each of these.

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[36] We note that the one-to-one mapping provided for the 46 additional locations is not as sophisticated as the many-to-many approach developed for other exchange service areas. However, given the number of locations involved, this is unlikely to be important to the analysis.

A.2 Our approach to determining the importance of line density as a cost driver

195. To test our hypotheses, we have calculated by exchange service areas:

- customer density, being the number of DSL customers per square kilometre;
- average customers per DSLAM locations, differentiated between exchange building locations and cabinet locations; and
- average distance from the DSLAM location to the handover point, differentiated between exchange building locations and cabinet locations.

196. The calculation of each of these variables from the data provided by Chorus and Statistics New Zealand is described below.

A.2.1 Customer density

197. Within Chorus' meshblock mapping dataset, the proportion of each meshblock associated with a particular exchange service area is calculated as:

- the number of lines in that meshblock and service area; divided by
- the total number of lines in that meshblock.

198. We use this proportion as an approximation with which to allocate the population of each meshblock across exchange service areas. We calculate the total population and area of each exchange service area by summing up the population and area allocated to that exchange service area from each meshblock.

199. The customer density of each exchange service area is calculated as the sum of DSL demand associated with that exchange divided by the area of the exchange service area as calculated above.

A.2.2 Average customers per DSLAM location

200. Within the DSL database provided by Chorus, locations are differentiated between exchange buildings and cabinets located within that exchange service area with a tag.

201. Using this tag, we compute the total number of exchange building DSLAM locations and cabinet DSLAM locations within each exchange service area. The total number of DSL services provided through exchange buildings and cabinets for each exchange are calculated using the same tag on DSL demand.

202. The average number of customers per DSLAM location in each exchange serving area is calculated as:

- for exchange buildings, the number of services provided through exchange buildings divided by the number of DSLAM exchange building locations in each area (there can be at most one such location); and
- for cabinets, the number of services provided through cabinets divided by the number of DSLAM cabinet locations in each area.

A.2.3 Average distance to the handover point

203. The distance from each DSLAM location to the handover point is calculated as:
    - the distance from the location to the local exchange (which is zero if that location is the exchange); plus
    - the distance from the local exchange to the associated first data switch.

204. Each of these distances are calculated using straight lines plus an adjustment to scale line of sight distances up by 38% to reflect average cable distances.

205. The average distance to the handover point is calculated as:
    - for exchange buildings, the average distance from exchange buildings that are DSLAM locations to the handover point within each exchange service area, weighted by demand at those locations (there can be at most only one such location); and
    - for cabinets, the average distance from cabinets that are DSL locations to the handover point within each exchange service area, weighted by demand at those locations.

Appendix B Danish cost model

206. The Danish cost model consists of seven modules, being:

- the access module;
- the core module;
- the co-location module;
- the CATV + fibre access module;
- the expenditures module;
- the economic depreciation module; and
- the consolidation module.

207. The calculations described in this appendix have been applied to the core module, with validation to some results from the consolidation module.

208. Although there are many different types of assets captured in the Danish cost model, it is not necessary to consider all of these in computing the average bitstream unit cost at each edge router location. Despite there being 165 different "cost categories" in the core network model, comprising 81 network equipment categories (a more general classification), the core network routing table shows that only 10 network equipment classes contain costs that are allocated to bitstream services.[37]

209. These 10 network equipment categories and their 31 corresponding cost categories are documented at Table B-1 below.

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[37] This is evident from the core module and row 274 of worksheet "A2_I_Route_Table".

Table B-1 Network equipment and cost categories allocated to bitstream

Network equipment category	Cost category
DSLAM/MSAN: MDF: All	MDF: Type 1 MDF: Type 2 MDF: Type 3 MDF: Type 4 MDF: Type 5
DSLAM/MSAN: Line card: ADSL	DSLAMs/MSANs: ADSL card
DSLAM/MSAN: Processor: Card-related - xDSL	DSLAMs/MSANs: Chassis Type 1: xDSL card related DSLAMs/MSANs: Chassis Type 2: xDSL card related
DSLAM/MSAN: Processor: Traffic-related - xDSL	DSLAMs/MSANs: Chassis Type 1: xDSL traffic related DSLAMs/MSANs: Chassis Type 2: xDSL traffic related
Layer 2 aggregation: Line card: DSLAM - xDSL - Gbps	Layer 2 Aggregation Switches : GBIC Adaptor : xDSL
Layer 2 aggregation: Line card: DSLAM - xDSL - Mbps	Layer 2 Aggregation Switches : GBIC Module Type 1 : xDSL
Layer 2 aggregation: Line card: L2 ring - Gbps	Layer 2 Aggregation Switches : 10GE Adaptor : Rings
Layer 2 aggregation: Line card: L2 ring - Mbps	Layer 2 Aggregation Switches : 10GE Module : Rings
Layer 2 aggregation: Processor: All	Layer 2 aggregation switches: Chassis Type 1 Layer 2 aggregation switches: Chassis Type 1 Layer 2 aggregation switches: Processor Type 2 Layer 2 aggregation switches: Processor Type 2
TX path: L2 aggregation ring: All	Edge to DSLAM - Total: Trench - none Edge to DSLAM - Total: Trench - earth Edge to DSLAM - Total: Trench - large stones, eg, slabs Edge to DSLAM - Total: Trench - asphalt/tarmac Edge to DSLAM - Total: Trench - tunnelled, eg, under a road Edge to DSLAM - Total: Trench - small stones Edge to DSLAM - Total: Trench - soil - ploughed cable (if used) Edge to DSLAM - Total: Trench - others, eg, concrete? Edge to DSLAM - Total: Duct Edge to DSLAM - Total: Cable - buried Edge to DSLAM - Total: Cable - ducted Edge to DSLAM - Total: Links over bridges Edge to DSLAM - Total: Submarine cable

Source: Danish cost model

210. This means that in order to understand how the unit costs of bitstream varies across different edge router locations, it is only necessary to examine the provisioning of the assets listed at Table B-1 above.

211. In the "A5_I_Equipment" sheet, provisioning for many of these items for each edge router and its child nodes is already calculated. In the "B5_C_Equipment" sheet these calculations are used, together with mark-ups for spares, to calculate the total number required for each cost category. We take the asset numbers estimated for

each edge router location in the "A5_I_Equipment" worksheet and mark these up at each location by the total from "B5_C_Equipment" divided by the total from "A5_I_Equipment" to capture the effect of these mark-ups. The result of this is that each edge router is calculated as have a fractional part of an asset.

212. The level 2 trenching and cable network consists of aggregation rings connecting child nodes to edge routers. These are costed directly by edge router location at "B4_C_Trenching_Local".

213. The capital costs for equipment and materials, and installation, are allocated using a tilted annuity with the same assumptions as used by Analysys, taken from the ‘Consolidation’ sheet. These assumptions are WACC, asset life, price trend and scrap value. The WACC that is used is 5.4%. The other assumptions are set out in Table B-2 below.

Table B-2 Asset life, price trend and scrap value assumptions for annualisation of cost categories

Cost category	Asset life	Price trend	Scrap value
MDF: Type 1	5	-5%	0%
MDF: Type 2	5	-5%	0%
MDF: Type 3	5	-5%	0%
MDF: Type 4	5	-5%	0%
MDF: Type 5	5	-5%	0%
DSLAMs/MSANs: ADSL card	5	-5%	0%
DSLAMs/MSANs: Chassis Type 1: xDSL card related	5	-5%	0%
DSLAMs/MSANs: Chassis Type 2: xDSL card related	5	-5%	0%
DSLAMs/MSANs: Chassis Type 1: xDSL traffic related	5	0%	0%
DSLAMs/MSANs: Chassis Type 2: xDSL traffic related	5	0%	0%
Layer 2 Aggregation Switches : GBIC Adaptor : xDSL	5	0%	0%
Layer 2 Aggregation Switches : GBIC Module Type 1 : xDSL	5	0%	0%
Layer 2 Aggregation Switches : 10GE Adaptor : Rings	5	0%	0%
Layer 2 Aggregation Switches : 10GE Module : Rings	15	0%	0%
Layer 2 aggregation switches: Chassis Type 1	15	0%	0%
Layer 2 aggregation switches: Chassis Type 1	15	0%	0%
Layer 2 aggregation switches: Processor Type 2	15	0%	0%
Layer 2 aggregation switches: Processor Type 2	15	0%	0%
Edge to DSLAM - Total: Trench - none	40	3%	0%
Edge to DSLAM - Total: Trench - earth	40	3%	0%
Edge to DSLAM - Total: Trench - large stones, eg, slabs	40	3%	0%
Edge to DSLAM - Total: Trench - asphalt/tarmac	40	3%	0%
Edge to DSLAM - Total: Trench - tunnelled, eg, under a road	40	3%	0%
Edge to DSLAM - Total: Trench - small stones	40	3%	0%
Edge to DSLAM - Total: Trench - soil - ploughed cable (if used)	20	3%	0%
Edge to DSLAM - Total: Trench - others, eg, concrete?	40	3%	0%
Edge to DSLAM - Total: Duct	40	3%	0%
Edge to DSLAM - Total: Cable - buried	20	-5%	0%
Edge to DSLAM - Total: Cable - ducted	20	-5%	0%
Edge to DSLAM - Total: Links over bridges	15	-8%	0%
Edge to DSLAM - Total: Submarine cable	15	-8%	0%

Source: Danish cost model

Appendix C Swedish cost model

214. This Appendix describes more fully the way in which costs have been attributed to edge locations in the Swedish model, as discussed in section 4.2.

215. The Swedish cost model does not rely on locational information at the edge location to the same extent that the Danish cost model does. However, it does provide a sufficient amount of information by edge location for us to be able to estimate average unit costs at each edge location with some simplifying assumptions.

216. We have focused this analysis on core costs, which represents the additional costs to the local loop. As noted in the body of the report, the average additional cost per unit is 63.7 Kr per month.

217. The core network of the Swedish model contains a large number of cost categories. As was the case in the Danish cost model, only a sub-set of these cost categories are relevant to the bitstream service. A portion of the total cost for these cost categories are allocated to the bitstream service by way of routing factors. The relevant cost categories for bitsteam belong to one of following four network elements:

- Layer 2 Aggregation
- Layer 3 Edge
- RUC Edge
- Residential Access Full Fibre

218. Only the costs associated with the RUC Edge network elements are provisioned by edge location in the model. These are the costs associated with trenching, ducting and fibre. In the model, 64 of 139 edge locations and sampled and scaled up to estimate a total cost for the network (rather than using information from all the edge locations). The scaling is dependent on an edge location's urbanisation category (A-D). We have estimated total costs by sampled edge location.

219. The total costs for fibre access switches (which together with line cards make up the Residential Access Full Fibre network element) are provisioned in the model by way of design rules. That is, the number and types of fibre access switches at a node is a function of the number lines at that node. A type 1 fibre access switch has only one slot for line cards (a line card has 24 ports, so the maximum number of customer connections is 24 for a type 1 switch), whereas a type 2 switch has 20 slots for line cards (maximum number of customer connections of 480). This can be seen in the core model in the sheet I_Design_rules, cells J105 and J117.

220. In the model the calculation to determine the total number of type 1 and type 2 fibre access switches is done based on summarised information across the network, and not information on edge location basis. This is done in the core model in sheet

C_Equipment in rows 58 to 67. The total number of nodes (7,545) is split into 8 categories based on maximum number of lines per site. Sites with less than 100 lines are allocated a type 1 fibre access switch, and sites with more than 100 lines per site are allocated a type 2 access fibre switch. About 40% of sites have less than 100 lines. The average number of lines in each category (total lines / number of nodes) and the number of sites in each category is used to determine the number of fibre access switches.

221. We have assumed that all nodes associated with an edge location is the same size (i.e. has the average number of lines of that sampled edge location) and used the design rules to determine fibre access switches on a per sampled edge location basis. We have used the number of fibre switches at each sampled edge location and the design rules to determine the number of line cards at each sampled edge location (24 customers per line card, see I_Design_rules in the core model, J103 and J115).

222. The cost for Layer 2 aggregation comprise of aggregation switches, metro switches and the management system. We have allocated the cost for aggregation switches to sampled edge locations by way of the fibre access switches and the design rules: There are on average 7 fibre access switches per aggregation switch (see sheet I_Design_rules cell J128).

223. We have attributed the costs for metro switches, the management system and the edge routers and repeaters (Layer 3 Edge) equally between the sampled edge locations. This reflects the fact that the design rules set the total units for these elements with no regard to other factors (i.e. envisage a constant distribution across locational areas). This can be seen in the sheet I_Design_rules in the core model in rows 132 to 146.