

Generic DS0 Impairment

Technical Appendix

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I. INTRODUCTION

A. The Network Architecture Tools – The Creation of a Hypothetical CLEC Network

Two primary steps must be undertaken to quantify Competitive Local Exchange Carrier (“CLEC”) cost disadvantages relating to local loop access and backhaul. The first step is to simulate the design and construction¹ of an efficient CLEC-provided CLEC backhaul network that would be needed, in a given study area, to connect end-user loops, located at an Incumbent Local Exchange Carrier’s (“ILEC’s”) wire center, to a CLEC’s local switch. Once that backbone network is designed, it can be evaluated to quantify the facilities and costs required to provide the appropriate functionality. Because ILEC wire centers must be connected to CLEC local switches, whether directly through CLEC-provided facilities, or indirectly through leased facilities, the first task is to determine (1) how to efficiently connect, subject to practical engineering constraints, the largest ILEC wire centers using the CLEC’s own transport facilities; and, (2) how the remaining ILEC wire centers can be most efficiently connected to the CLEC’s backbone network through the use of leased transport facilities.

To that end the Facility Ring Processor constructs a hypothetical CLEC local transport network (*i.e.*, a set of interconnected local fiber rings) which interconnects key ILEC wire centers (CLEC Network Nodes) located within a common geographic area – typically a Local Access and Transport Area (“LATA”) – with one another. The identified locations are “interconnected” using an iterative algorithm that seeks to

¹ The terms “design” and “construct” here refer to the tools’ design algorithms and cost simulations which simulate a hypothetical CLEC network.

minimize the total route distance within a user-defined limit of the maximum number of locations that may be put on a single Synchronous Optical Network (“SONET”) ring.

For the purpose of designing rings, each location is paired with two other network locations (except for rings which contain only two nodes) to permit alternate path routing in the event of a facility failure, while minimizing total segment length. Because ILEC network locations are being addressed, and because Vertical (V) and Horizontal (H) coordinates are known for each of these locations (as represented in the Local Exchange Routing Guide (LERG) maintained by Telcordia Technologies, the distances between paired locations can be computed. Route distances for locations that are placed on a CLEC-owned transport network (i.e., node locations) are calculated using rectilinear distances. Rectilinear distances are used to allow for natural obstructions (rivers, parks, railroads, etc) that are not easily traversed in a real world build. Distance calculations between Satellite Offices and node offices are based on airline mileage. Airline mileage is used in this case because ILEC leased transport rates typically have a mileage component that is determined by the airline mileage distance between the two points connected – in this case, a Satellite Office to a CLEC node location. The rectilinear mileage formula that is employed in the tools is: $(|V_1 - V_2| + |H_1 - H_2|) \div \sqrt{(10)}$. The airline mileage is calculated as $\sqrt{((V_1 - V_2)^2 + (H_1 - H_2)^2) \div 10}$.

The ILEC wire centers that are designated as CLEC Network Nodes are based on two criteria generally. The primary selection of nodes in a LATA is based on a total line threshold (in terms of Voice Grade Equivalents) such that the largest wire centers are selected as nodes on the ring to cover 33% of the total lines in the LATA. Since these on-

net locations have higher demand for total telecommunications services than a generic CLEC would find most economically attractive due to typical high concentrations of enterprise (i.e., large business) customers.² In addition to the line threshold determination of on-net locations, there are two constraints to the node selection criteria: (1) all study areas must have at least 2 nodes on the ring and (2) all ILEC tandem switches are placed on the hypothetical CLEC ring.³

Based on this categorization of the ILEC wire centers, the Facility Ring Processor performs two functions: First, it creates a hypothetical facilities network placing all CLEC Network Node locations on one or more optical fiber rings. As part of this task, the tool identifies the mileage required by density zone so that the cost of the ring facility may be established. Second, it homes the Satellite Offices (smaller ILEC wire centers that are not classified as CLEC Network Nodes) to the nearest CLEC Network Node office and stores the associated distance to connect each Satellite Office to its CLEC Network Node. Further details relating to the quantification of fiber backbones and the backhaul network are discussed in Section III.

² The FCC recognized that under generally optimal conditions at least 12 DS-3s of demand are required to justify a facility build (*Review of the Section 251 Unbundling Obligations of Incumbent Local Exchange Carriers (CC Docket No. 01-338)*, *Implementation of the Local Competition Provisions of the Telecommunications Act of 1996 (CC Docket No.96-98)*, and *Deployment of Wireline Services Offering Advanced Telecommunications Capability (CC Docket No.98-147)*, August 21, 2003, ¶388). This is equivalent to more than 8,000 VGEs. If an individual CLEC were to capture 10% share of the total market (not just mass-market POTS, but mass-market, enterprise, voice and data), that would imply a minimum office size of 80,000 VGEs.

³ This is based on the fact that in most instances, an efficient CLEC will connect to the ILEC local tandem and terminate all DS0 usage (at the tandem) for any of the subtending offices and pay usage-based transport charges to terminate this traffic. ILEC local tandem switches are either included on a ring for a particular geographic area or else appear as satellite locations, if the tandem location exceeds the user-adjustable ring node threshold distance.

B. Cost Quantification

Establishing a means for efficiently connecting ILEC central offices is only the beginning of a process to quantify relevant backhaul costs. The next step is to identify equipment needs, space requirements, and the operational costs that a new entrant would face when seeking to offer mass-market local services. The DS0 Impairment Analysis tool was designed to compute these parameters. The tool develops costs in three main categories: (1) costs of preparing communications for transport, (2) costs of connecting the ILEC's office to the new entrant's switch location, and, (3) costs of physically transferring customers from the ILEC's network to the new entrant's network.⁴

II. THE DS0 IMPAIRMENT ANALYSIS TOOL

A. Overview

A CLEC's cost disadvantage relative to the ILEC, with respect to mass-market voice local services, is due in large part to the cost the CLEC must incur to extend loop UNEs to its own network (i.e., to backhaul loops to its switch). This impairment arises because of the additional cost required to overcome the closed network of BellSouth. To establish service over a voice grade loop, an ILEC need only connect the vertical side of its Main Distribution Frame ("MDF") to the horizontal side of the frame using an MDF tie pair that is nothing more than a few feet of 24-gauge copper wire, at a cost of only about 24 cents for a 10-foot length.⁵ In other words, a simple inexpensive cross-connect

⁴ The backhaul impairment analysis considers only the cost disadvantage implicit in extending loops from the ILEC wire center to the CLEC local switching center. Any other impairment – such as customer acquisition, to name just one area – are not addressed herein.

⁵ See, for example pricing information at <http://www.phonegeeks.com/croswir1pair.html>. In fact, in many instances, the retail customer's location is already pre-wired to the ILEC's switch port. Only a software instruction is required, rather than physical work, to initiate service.

between an end-user's loop and the ILEC's switch represents the extent and complexity of the ILEC's backhaul requirement. However, a facilities-based new entrant (*i.e.*, a CLEC providing its own switching) must pre-establish an extensive network of facilities and equipment to accomplish the same purpose achieved by the ILEC's MDF tie pair.⁶ Because of the design of the ILEC's local network, the CLEC must incur hundreds of thousands of dollars of sunk investments to cross connect the first customer to be served, while the ILEC has a sunk investment of only a few pennies.

The analytical framework of the DS0 Impairment Analysis tool is designed to quantify the minimum added equipment and network capability a CLEC would require to achieve the equivalent functionality of an MDF tie pair for the ILEC.⁷ The DS0 Impairment Analysis tool computes the relevant costs in each of the appropriate categories based on information specific to each BellSouth wire center in South Carolina.

The total number of lines the particular entrant might practically serve in an individual ILEC office must be known to compute a mass-market local service cost disadvantage. The DS0 Impairment Analysis tool calculates the lines addressed by the CLEC by multiplying the eligible local service VGEs of BellSouth for a specific office in South Carolina by the market share the new entrant is expected to achieve and maintain. The result is the number of lines in each BellSouth wire center that the CLEC will

⁶See Figure 1 in the direct testimony.

⁷ The costs for loops connecting the customer premises to the ILECs serving wire center are not included in the backhaul cost calculation. It is assumed that whether the new entrant or the ILEC provides service, the same loop is required. This is generally accurate except for the instances where the ILEC employs integrated digital loop carrier ("IDLC"). To the extent the customer must be moved from IDLC and there is a charge for the transfer, these costs are captured in the hot cut expenses included in the DS0 Impairment Analysis tool.

engineer its equipment and network to serve.⁸ The number of “CLEC addressable lines” in a wire center is calculated in the DS0 Impairment Analysis tool as the sum of the following:⁹

$$\text{Addressable Business Lines} = B \times \{1 - [D \times I \times (1 - T)]\} \times (1 - E)$$

$$\text{Addressable Residential Lines} = R \times \{1 - [D \times I \times (1 - T)]\}$$

Where: B = Total Business VGEs in service

R = Total Residential VGEs in service

E = % Enterprise Customers

D = % of VGEs Served by DLC

I = % of DLC Lines Served via IDLC

T = % of IDLC Lines Transferable to UDLC or Copper Pairs

and thus $[D \times I \times (1 - T)]$ = the % of all loop not addressable due to IDLC issues

- **% of VGEs Served by DLC** = User adjustable input that indicates the proportion of local loops, in a geographic area, that employ digital loop carrier in the feeder network. The default assumption relies on the LECs DLC line counts reported in its ARMIS filing.
- **% of DLC Lines Served via IDLC** = User adjustable input required to develop the proportion of DLC lines that are served using IDLC technology. Different percentages of IDLC penetration can be input based on the density of the wire center.

⁸ Because the cost disadvantage is a function of number of lines served in a particular office by an individual competitor, and because few of the costs vary by the particular office under consideration, precisely specifying the market share of a single competitor in a single office is not critical. Rather, it is important that the market penetration percentage produces a representative number of lines that would be addressed by a single CLEC in a single office.

⁹ CLECs will only be able to compete for a subset of the total voice grade equivalents (VGEs) in a given wire center. Residential lines served by IDLC would be excluded, in addition to any customer locations where it is otherwise deemed economic to serve the location with a DS1 loop (it is highly unlikely that a CLEC could or would price its single line/multi-line local services so as to capture such customers). As a result, these VGEs should be excluded from the addressable market. The DS0 Impairment Analysis tool refers to the lines that *do not* fall into one of these groups as “CLEC addressable lines.”

- **% of IDLC Lines Transferable to UDLC or Copper Pairs** = Proportion of DLC loops that employ IDLC technology for which the ILEC can transfer the loop to UDLC or spare copper.¹⁰

The calculation of % Enterprise Customers is based on a bottoms-up formulation involving separate inputs for South Carolina. First, the model utilizes an input matrix estimating the business line distribution by customer location size for the study area in question, by UNE zone:

Percent Lines Above Cross Over (for Enterprise Customers)

Lines	UNE Zone				
	1	2	3	4	5
1	80.00%	75.00%	70.00%		
2	78.00%	73.00%	68.00%		
3	76.00%	71.00%	66.00%		
4	74.00%	69.00%	64.00%		
5	72.00%	67.00%	62.00%		
6	70.00%	65.00%	60.00%		
7	68.00%	63.00%	58.00%		
8	66.00%	61.00%	56.00%		
10	64.00%	59.00%	54.00%		
12	62.00%	57.00%	52.00%		
16	60.00%	55.00%	50.00%		
20	58.00%	53.00%	48.00%		
24	56.00%	51.00%	46.00%		
999	54.00%	49.00%	44.00%		

¹⁰ When IDLC is used to provision an ILEC loop, individual circuits remain multiplexed within a DS-1 at the ILEC's DSX-1 from its DLC Central Office Terminal ("COT"). Although such circuits can be technically groomed onto a DS-1 dedicated to the CLEC, most ILECs are not offering that type of connectivity to CLECs. CLECs are therefore usually forced to have the ILEC transfer UNE-L loops to a spare copper pair if available, or to spare Universal DLC equipment if available. Given the mandated requirement of full subloop unbundling in the FCC's Third report and order, this figure should be 100%, however in practice this is often not the case.

The business line threshold percentages are used in conjunction with an input that specifies the crossover for when it becomes economical to provision customers via DS1 (in which case these customers will not be served via voice-grade loops and are excluded, as per the equation above). This input assumption can be made to vary for each UNE Zone in the model.

Given the projected number of mass-market voice grade loops that must be accommodated in an ILEC wire center,¹¹ the DS0 Impairment Analysis tool makes the following determinations:

- The quantity of equipment a CLEC will need to collocate to extend the UNE-L loops from a particular office to its own switch that, by necessity, is in a different location.¹² In general terms, this equipment includes:
 - DLC equipment in the ILEC's wire center serving retail customer loops.
 - Interfacing DLC terminal equipment at the CLEC switch location.
 - Cross connection equipment in both the ILEC office and the CLEC switch locations.
 - Power distribution equipment.
- The costs for space, power, facility cross-connection, construction and other collocation-related costs based on state-specific and ILEC-specific collocation charges.

¹¹ Because the FCC has determined that a particular location will be assigned to the mass or enterprise market based upon whether or not the location could economically be served by a DS1 loop, most enterprise customers (even though they could in principle have a large number of individual locations that have all the characteristics of a mass-market location) will normally be served via DS1 or higher capacity facilities.

¹² Even an efficient CLEC could not achieve the scale economies necessary to collocate switches. The CLEC would almost always have fewer lines per switch than the ILEC and lower utilization of inter-switch trunks. Furthermore, CLEC circuit switching equipment is either barred from ILEC collocation space, or the rules for permitting such collocation are so onerous as to make it infeasible.

- The cost of connecting CLEC circuits at the ILEC wire center (where the loop is delivered by the ILEC) to the CLEC switch location (where local service is delivered by the new entrant) – otherwise referred to as CLEC backhaul. These costs involve leased transport connecting small Satellite Offices to CLEC Network Nodes, plus costs for CLEC-provided transport facilities from a CLEC Network Node to the CLEC switch location.¹³ Leased transport facility costs are calculated based on three factors: (1) the distance between the Satellite Office and its associated Network Node,¹⁴ (2) the capacity of the facility required,¹⁵ and (3) the applicable charges for leased facilities or the unit cost of CLEC-provided facilities.¹⁶ Quantification of the CLEC-provided transport facility costs are discussed later in this Technical Appendix.¹⁷
- The costs that BellSouth applies when customers are transferred from the ILEC network to the CLEC network (*i.e.*, to execute the “hot-cut”), and, to the extent quantified, the costs that the CLEC incurs to perform companion work necessary to complete the customer transfer.

The tool also adjusts the calculated costs for two considerations: (1) the timing of the cash flows, and (2) and cost effects of customer demand “ramping-up” to the steady-state office penetration (*i.e.*, projected demand level in the office).

¹³ As discussed earlier, some ILEC wire centers are large enough to be CLEC Network Nodes, and the backhaul cost for those wire centers would not have a leased transport component.

¹⁴ See Section III.A for further explanation of how this distance is established.

¹⁵ The capacity of the facility is governed by the nature of the DLC utilized (which will generally be either a DS-1 or DS-3 interface), the number of lines addressed at the location, and the concentration afforded by the DLC.

¹⁶ The tool employs, as a default, interstate access rates because the service can be obtained between any ILEC offices. The same is not generally true for UNE-transport. As specified by the user, the tool employs the selected short (1 year) mid-range (2 to 3 year) or long term (4 to 5 year) price(s), applies any umbrella discounts, and determines the applicable recurring and non-recurring charges based on the rate regulation applicable at the end-points of the span, and on the capacity of the leased channel(s).

¹⁷ The costs reflected in the DS0 Impairment Analysis tool are designed to calculate the *minimum* cost disadvantage that a CLEC would experience, assuming its physical transport assets were utilized at an extremely high rate of fill for a typical CLEC (80% utilization is assumed as the steady-state once the full ramp-up of demand has occurred). This equates to the assumption that 39 of 48 DS-3 channels are utilized in the OC-48 fiber ring, an extremely conservative assumption. See Section II.C below.

B. First DS0 Cost Component – Costs of Preparing the Loop for Transport Out of BellSouthWire Centers

As noted above, the ILECs' loop plant terminates at its serving wire centers – the first point at which a CLEC can feasibly access voice grade UNE loops. Unlike the ILEC, whose switch is located where its loops terminate, for any customer served by the CLEC, the CLEC must incur *additional* costs to prepare the communications for transport to a different location, *i.e.*, the location at which the loop will ultimately terminate on the CLEC's local switch port.

The CLEC must install equipment that terminates, digitizes, concentrates, and multiplexes the customer communications in each BellSouthwire center where it hopes to provide competitive local service. This equipment must be placed in collocation space and use power and cross-connection infrastructures obtained from the ILEC.

1. Equipment Costs

A CLEC requires three principal types of equipment when it provides voice grade local services using UNE-L and backhauls them to its own circuit switch. These equipment types include:

- **Digital Loop Carrier (DLC) equipment** - the electronics necessary to digitize, concentrate, and multiplex the individual voice grade loops and manage the interoperation of the switch port;¹⁸ and;

¹⁸ Although this discussion is in terms of the cost of equipment in the LSO, some node equipment is also incorporated in the Transport (see Section III below). For example, the associated terminal equipment that works in tandem with the DLC in the LSO is included with the investment required in the collocation. Although this equipment is not physically placed within the LSO, it is an investment that is necessitated by the equipment deployed within the collocation. DLC costs are further disaggregated based upon four potential cost drivers, which are derived based on the number of projected CLEC lines to be served. These include: 1) common equipment, 2) frames, 3) in-frame sub modules (shelves), and 4) line cards.

- **Facility terminating equipment** - the cross-connection equipment within the CLEC's collocation facilities in each ILEC wire center on which the incoming voice grade loops terminate, the out-going interoffice facilities terminate, and where interconnecting collocated equipment occurs.
- **Power Distribution Equipment** – Battery Distribution Fuse Bay and related equipment

a) **Digital Loop Carrier (DLC)**

To calculate the DLC investment component at a particular wire center, the DS0 Impairment Analysis tool considers three DLC size options, based on the maximum number of lines per unit, *e.g.*, Type 1 = 2016 lines; Type 2 = 120 lines; and Type 3 = 24 lines. For each BellSouthBellSouthwire center, the DS0 Impairment Analysis tool determines the bottom-up gross investment associated with each of the three types of DLC equipment and then selects the DLC type that minimizes the gross investment for the number of lines, based on market share, to be served in an office.¹⁹

When quantifying the cost of a DLC installation, the DS0 Impairment Analysis tool establishes the number of lines the CLEC would potentially serve, determines the equipment that must be placed both at the ILEC collocation site and at the CLEC switching node, and employs bottom-up estimates of the material plus total hours and labor rates for engineering, installing, turning up and testing the DLC equipment. The

¹⁹ See, DS0 impairment analysis tool.xls at tabs titled "DLC type 1", "DLC type 2", and "DLC type 3". Note that employing three different DLC options is very conservative. A CLEC entrant would probably deploy a single type to simplify and optimize its maintenance procedures and maximize the size of its equipment purchases, thereby incurring lower than optimal fill rates.

following table shows an example of the components included in the DLC cost investment calculation.²⁰

Table 1 - Example of DLC Cost Calculations (DLC Type 1)

²⁰ The highlighted variables are user adjustable inputs.

Case No. 2003-00379
Direct Testimony of Steven E. Turner
Exhibit SET-2

	Per 2016		Line Increment		Allocation		Cost
	Material		LSO (RT)	POP (COT)			
Firmware & Common Plug Ins	\$ 12,600.00		1.00	0.20		\$ 15,120.00	
Electrical Transceiver	\$ 800.00		1.00	0.20		\$ 960.00	
Channel Bank Assembly & Commons	\$ 2,166.00		-	0.20		\$ 433.20	
DSX-1 and Cabling	\$ 800.00		-	0.20		\$ 160.00	
Test Access System & Equipment	\$ -		-	0.20		\$ -	
						\$ 16,673.20	
						\$ 1,078.73	
						\$ 17,751.93	
						2,016	

	Per 672		Line Increment		Allocation		Cost
	Material		LSO (RT)	POP (COT)			
Time Slot Interchangers	\$ 2,200.00		1.00	0.20		\$ 2,640.00	
						\$ 2,640.00	
						672	

	Per 224		Line Increment		Allocation		Cost
	Material		LSO (RT)	POP (COT)			
Channel Bank Assembly, Commons & Cables	\$ 2,166.00		1.00	-		\$ 2,166.00	
						\$ 272.52	
						\$ 2,438.52	
						224	

	Per 4		Line Increment		Allocation		Cost
	Material		LSO (RT)	POP (COT)			
DS0 Line Card	\$180.00		1.00	-		\$ 180.00	
DS1/U Interface Card	\$288.00		-	0.0417		\$ 12.00	
						\$ 192.00	
						4	

The preceding table shows the inputs for the tool based on an Alcatel Litespan[®] 2000 DLC installed in a central office environment. The DLC equipment deployed assumes Integrated Digital Loop Carrier (“IDLC”) with 5 remote terminals at ILEC collocation arrangements per one central office terminal at the CLEC switch location. Total installed costs consist of four main cost categories:

- Common equipment (one per 2,016 lines of capacity at each ILEC collocation end plus 1/5th of a unit at the CLEC switch end) for a total of \$17,752;
- Time Slot Interchange (one set per 672 lines of capacity at each ILEC collocation end plus 1/5th of a set at the CLEC switch end) for a total of \$2,640;
- Channel Bank Assemblies (channel card frames) (one per 224 lines of capacity at each ILEC collocation end and 1/5th of one Channel Bank Assembly per 2,016 lines of capacity at the CLEC switch location) for a total of \$2,438;

- The cost per POTS channel unit card (one per 4 lines of capacity at each ILEC collocation end plus 1/24th of a DS1/U IDLC switch interface card per POTS line card)²¹ of \$192.

Therefore the total installed cost necessary to serve the first four lines is equal to $\$17,752 + \$2,640 + \$2,438 + \$192 = \$23,022$.²² Figure 2 below illustrates how the gross investment changes as the number of lines served increases:

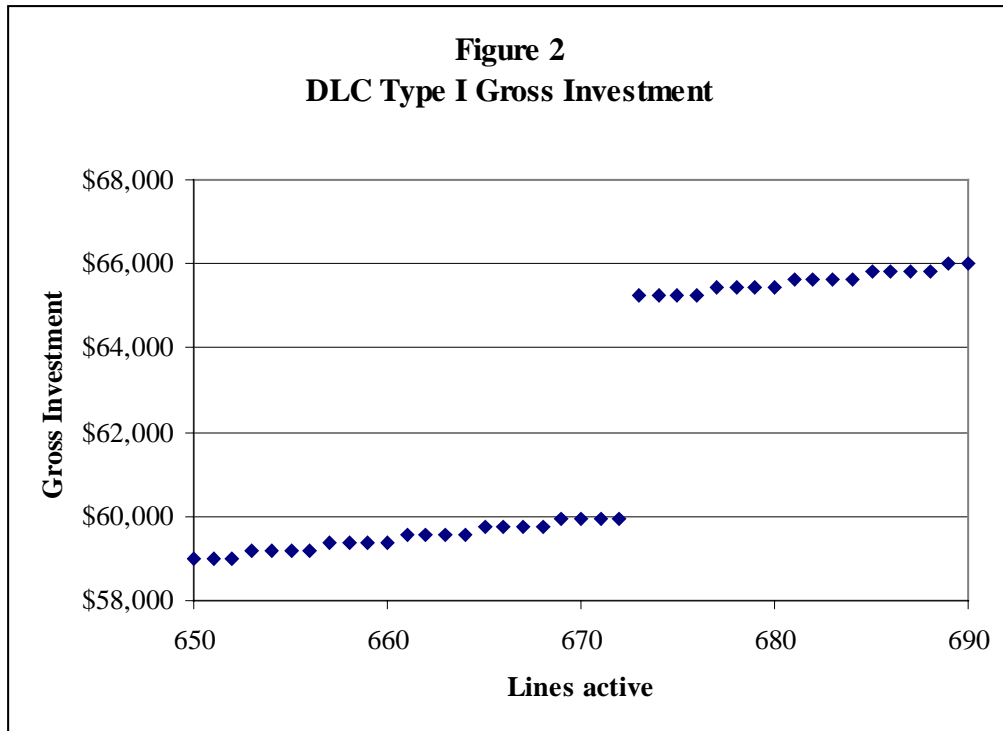


Figure 2 graphically depicts the “lumpy” nature of the gross investment. In particular, the incremental investment for the time slot interchangers is apparent at 672

²¹ This assumes a traffic concentration ratio of 4:1 and a DS1/U card with 24 DS-0 time slots per card. Therefore one DS1/U card can handle 96 POTS channels at a 4:1 concentration ratio. Since each POTS channel unit card handles 4 POTS lines, one DS1/U card is required for every 24 POTS line cards ($96 \div 4 = 24$).

²² Inputs for the Type 2 and Type 3 DLC equipments are based on the use of Advanced Fibre Communications (“AFC”) Model UMC-1000.

line capacity intervals, and the increment for the line card investment is evident every four lines.

As discussed above, the DS0 Impairment Analysis tool determines whether Type 1, Type 2 or Type 3 DLC equipment results in the least gross investment for each BellSouth wire center in South Carolina by calculating the total DLC investment for each of the three types of DLC equipment (based on the number of lines the CLEC is projected to serve at that wire center).²³ In general, the DLC investment is calculated as follows:²⁴

- **DLC Type 1 Investment** =
$$\begin{aligned} &L \div F \div 2016 \times C_1 \\ &+ L \div F \div 672 \times T \\ &+ L \div F \div 224 \times B \\ &+ L \div F \div 4 \times P_1 \end{aligned}$$
- **DLC Type 2 Investment** =
$$\begin{aligned} &L \div F \div 120 \times C_2 \\ &+ L \div F \div 6 \times P_2 \end{aligned}$$
- **DLC Type 3 Investment** =
$$\begin{aligned} &L \div F \div 24 \times C_3 \\ &+ L \div F \div 6 \times P_2 \end{aligned}$$

Where: L = Line Capacity Required
F = Engineered Fill
C₁ = Common Equipment Investment for Type 1 DLC
C₂ = Common Equipment Investment for Type 2 DLC
C₃ = Common Equipment Investment for Type 3 DLC
T = Time Slot Interchanger Investment for Type 1 DLC
B = Channel Bank Equipment Investment for Type 1 DLC.

²³ See, DS0 impairment analysis tool.xls at tabs "DLC type 1", "DLC type 2" and "DLC type 3" as well as the "Impairment by office" tab at columns titled *DLC Type 1 Investment (both Common & Line Related)*, *DLC Type 2 Investment (both Common & Line Related)*, and *DLC Type 3 Investment (both Common & Line Related)* for the DLC investment calculations.

²⁴ Note that in each case, when the number of projected lines to be served is divided by the engineered fill, the result is rounded up (to an integer) before being multiplied by the installed unit cost. This is necessary to provide the correct cost by equipment group. For example, if there are four lines per line card and five lines are to be served, two line cards are required.

P_1 = POTS Line Card Investment for Type 1 DLC
 P_2 = POTS Line Card Investment for Types 2 & 3 DLC

In addition to selecting the option that minimizes total investment per line, the tool determines the number of frames required (which is used to determine collocation space requirements), the transport interface associated with the selected DLC, the designed line concentration ratio (which is used to determine the type and quantity of transport facilities), the maximum power consumption (used to size power feeders), and average power consumption (used to determine total power consumption). In addition, a certain proportion of copper fed loops will require the use of extended range cards in the CLEC collocation arrangement. Therefore, the tool allows the user to specify both the power usage for range extended loops²⁵ as well as the expected number of range extended loops for each wire center based on density.²⁶

b) Facility Terminating Equipment (Cross Connection Panels)

The DS0 Impairment Analysis tool calculates termination equipment costs based on equipment characteristics supplied by the user, including the wholesale price of the equipment (including any discounts from list prices), the maximum fill rate, the

²⁵ Long loops, such as those terminating at more than 18,000 feet from the central office, pose electrical challenges. When the subscriber goes off-hook, a cable pair behaves like a single loop inductance coil with a -48 Volts DC potential and an electrical current flow of between 20 - 50 mA DC (Electrical current values vary with cable length and gauge). A minimum current of approximately 20 milliamps DC is required to convey terminal signaling information to the network. There is also a minimum power level required to provide adequate volume for the voice signal. An extended range line card increases the line voltage and amplifies the signal to account for these difficulties.

²⁶ Because many range extended loops have already been converted to DLC, the DS0 Impairment tool allows the user to specify the percentage of loops greater than 18,000 feet in length, and the proportion of loops greater than 18,000 feet in length requiring range extension, separately.

termination capacity, the unit height (to determine frame deployment), labor costs and labor hours associated with engineering and installing the equipment, the useable vertical height and footprint for the frame, and power capacity/requirements.²⁷ As a first step, the number of transport backhaul facilities required by the CLEC at each BellSouth wire center is established. This calculation is based on the projected line count served by the CLEC in a particular wire center, the concentration ratio of the DLC, and the type of transport interface employed by the selected DLC size (either DS-1 or DS-3). This general calculation is as follows:

- **Number of Required Transport Backhaul Facilities**²⁸ = Rounded up integer $\{(\text{Projected lines}) \div [(\text{Facility capacity})^{29} * (\text{Concentration ratio})]\}$

The number of transport backhaul facilities required for each wire center, generated by the above equation, is then used both to determine the required number of cross connection panels and to price-out the backhaul. Based on the type of transport (DS-1 or DS-3), the cross-connect panel requirements are determined (*i.e.*, DSX-1 for DS-1s and DSX-3 for DS-3s) using the following general computation:

- **Number of Required DS-1/DS-3 Cross-Connection Panels**³⁰ = Rounded up integer $\{[(\text{Terminations required per active transport backhaul facility}) * (\text{Number of transport backhaul facilities required})] \div [(\text{Termination capacity of panel} * \text{Maximum fill})]\}$

²⁷ Forward-looking economic costs for an efficient carrier are employed. These inputs are in general consistent with those underlying state approved TELRIC studies. Where they are not available, the experience of independent consultants and/or trade press/websites is relied upon.

²⁸ See column titled Number of Transport Facilities in DS0 impairment analysis tool.xls at the “Impairment by Office” tab.

²⁹ For a DS-1 interface, the facility capacity is 24 DS0s; for a DS-3 facility, it is 24*28=672 DS0s.

³⁰ See DS0 impairment analysis tool.xls at the “Impairment by Office” tab, columns titled *DS-1 panels* and *DS-3 panels*.

A similar calculation is performed for the DS0 termination panels except that the number of active voice grade lines is used instead of the number of active transport backhaul facilities:

- **Number of Required DS0 Cross-Connection panels**³¹ = Rounded up integer $\{[(\text{Terminations required per active voice grade line}) * (\text{Projected Lines})] \div [(\text{Termination capacity of panel}) * (\text{Maximum fill})]\}$

The DS0 Impairment Analysis tool assumes that all the termination panels are placed in the same rack but that rack is separate from the DLC equipment.³² Accordingly, the number of termination racks (or frames) is determined by the following formula:

- **Number of Termination Frames**³³ = Rounded up integer $\{[(\text{DS0 termination panels required} * \text{DS0 panel height}) + (\text{DS-1 termination panels} * \text{DS-1 panel height}) + (\text{DS-3 panels required} * \text{DS-3 panel height})] \div (\text{Standard frame capacity in inches of height})\}$

The DS0 Impairment Analysis tool computes total termination costs by multiplying the total number of termination frames calculated above by the total installed cost of a standard rack (iron work only).³⁴ The installed cost of a standard rack is

³¹ See DS0 impairment analysis tool.xls at the “Impairment by Office” tab, column titled *DS0 panels*.

³² This comports with generally accepted engineering practice that designates powered frames separate from termination frames.

³³ See, DS0 impairment analysis tool.xls at the “Impairment by Office” tab, column titled “Termination Frames”.

³⁴ See, DS0 impairment analysis tool.xls at the “Impairment by Office” tab, row titled “Total Termination Investment”.

developed with a bottoms-up calculation that combines the total material cost, labor hours, and labor rates as appropriate for the work required.³⁵

The tool accumulates all the frames deployed for DLC and termination equipment and multiplies the accumulated frame count by the floor space footprint requirements:

Table 2
User Adjustable Input Assumptions for Frame Calculations

Satellite Office			Network Node Office	
Number of frames for initial 100 square feet	Number of frames for 100-200 square feet	Number of frames for 200-300 square feet		
6.0	10.0	10.0		
16.7	10.0	10.0	11.5	300.0
Square feet per frame, 100 square feet	Square feet per frame, 100-200 square feet	Square feet per frame, 200-300 square feet	Square feet per frame	Minimum Square Footage Requirement

The square footage requirements are computed differently for the CLEC's Network Nodes and the Satellite Offices.³⁶ In Satellite Offices, although the above defaults are available, the tool allows the user to specify the number of frames per 100 square feet separately for the initial 100, second 100, and third 100 square feet of collocation space. The operative assumption is that as the total collocation space increases, that space is also used more efficiently, and thus the default values reflect a

³⁵ See, DS0 impairment analysis tool.xls at the "Basic Inputs" tab, row titled "Standard Rack".

³⁶ Nevertheless as the size of a Satellite collocation approaches the size of a typical node collocation (i.e., 300 square feet), the average square footage per frame numbers converge. More specifically, a 300 square foot Satellite collocation accommodates 26 frames for an average footprint of $(300/26) = 11.54$ square feet per frame.

proportionately larger number of frames in the second and third blocks of space (e.g., a 200 square-foot collocation space can accommodate 16 frames). At CLEC Network Node offices, the square footage per frame is also user adjustable, but fixed over the entire range of collocation space. Because a Network Node collocation is generally established to address a number of services and a wide variety of equipment from the outset (i.e., mass-market, enterprise customers etc.), large initial space arrangements will typically be made, and more efficient placement of equipment will be possible.

The resulting square footage is the minimum amount of collocation space required to serve the specified lines in service, which is used in a subsequent step of the impairment calculation related to collocation costs. Note that the actual space required may be substantially less than the minimum offered by the ILEC, particularly in Satellite collocations. This situation results in added CLEC expense for space not really required.

c) Power Equipment

ILEC collocation charges generally include the functionality of an ILEC-supplied Battery Distribution Fuse Bay (BDFB), however, if the CLEC misjudges its fusing requirements, it may incur substantial future cost of power augments and rearrangements. Accordingly, CLECs may opt to deploy an in-cage BDFB panel to allow have a large capacity feed to the cage and insert fusing and filtering within its cage to minimize the need to reconfigure power arrangements. The user has the option to include this equipment or set its costs to zero. If the BDFB costs are included, the DS0 Impairment Analysis tool determines the optimally sized BDFB, based on the power consumption of

the equipment and, if the collocation is a Network Node, apportions the cost between the voice grade service infrastructure and the transport infrastructure. The apportionment factor is the ratio of the maximum power drain of the DLC being provided divided by 200 amps – the maximum capacity judged reasonable for a Network Node collocation.³⁷

The total installed cost of the BDFB is developed from user-adjustable inputs that identify the total material cost plus the labor hours and costs required to install a BDFB. Based on the current drain for the equipment, a look-up is performed to select the panel that has the smallest capacity still large enough to serve the identified current drain. If the user decides to exclude the BDFB, the investment can be set to zero.

Table 3
BDFB Costs in the DS0 Impairment Analysis tool

	Option 1	Option 2	Option 3	Option 4	Option 5 (Node)³⁸
Net Price per panel	\$200	\$500	\$800	\$1,000	\$5,500
Capacity (DC Amps)	20	50	100	200	200
Maximum fill	100%	100%	100%	100%	100%
Labor type	3	3	3	3	3
Labor rate	\$50	\$50	\$50	\$50	\$50
Hours	14.0	16.5	19.0	21.5	24.0
Total Installed Cost	\$900	\$1,325	\$1,750	\$2,075	\$6,700

- **BDFB Prorating Factor** = [(BDFB capacity required for DLC equipment) ÷ (BDFB capacity required in a node collocation based on user-adjustable minimum)]

³⁷ Note that because the BDFB is generally only an 8-inch panel, no assignment of floor space or rack space is made for this item.

³⁸ There is a user adjustable input for minimum power requirements at each Network Node. The current default is set at 200 amps DC. This is based on the presumption that a typical efficient CLEC could have equipment at such an office for other services (e.g., trunking, data, etc.).

- **Gross Investment** = (cost of BDFB + installation labor per BDFB) * (BDFB prorating factor)

2. Costs of Collocation Space

Before a CLEC can deploy the equipment required to prepare a loop for transport, it must obtain collocation space from BellSouth in each ILEC wire center. The source data for the DS0 Impairment Analysis Tool includes data on prevailing collocation rates as approved by the Commission for BellSouth in South Carolina. An external process was used to identify the collocation charges relevant to caged physical collocation and to aggregate a number of individual charges to common drivers. For example, there may be separate charges for the collocation application, a space availability report, and engineering of the application. These would be summed together as a single charge with a driver of “per collocation cage” because they all generally apply only to the establishment of the new cage.³⁹ The DS0 Impairment Analysis tool calculates bottom-up estimates of new entrant collocation costs in each ILEC wire center used to provide service to the customers transferred from the network of BellSouth in South Carolina. These charges are based on the requirements of the new entrant as determined by the equipment required for the office, as dictated by the number of lines projected to be served in that particular office. The tool accumulates and evaluates current collocation charges organized in the following categories (which tend to have common cost drivers):

³⁹ The process treats recurring and non-recurring charges separately. Furthermore, some charges may be converted to an alternative basis so as to simplify computations. For example, if a charge is \$0.10 per foot per feed for a 50A power feed, it may be restated to a \$10.00 per feed charge if the average feed length is determined to be around 100 feet. This adjustment simplifies the modeling without significantly sacrificing accuracy.

- Power Costs
- Space Occupancy and Construction Charges
- Administrative Charge
- Connectivity Charges
- Transport Connectivity Charges

Depending on the particular ILEC and state, AC power costs are computed as the sum of the charge per feed and the charge per AC amp. The tool employs user adjustable inputs with defaults of two feeds and 20 amps per feed. AC power is typically required for purposes such as lighting and to run ancillary equipment in the collocation. Because DC current powers the telecommunications equipment and the DC current is not generally obtained by rectifying AC power at the collocation cage, AC power requirements are not likely to be substantial or highly variable from cage to cage. The formula for AC power costs is as follows:

- **AC Power Cost** = [(Number of AC power feeds required) * (ILEC charge per AC power feed) + (AC power drain) * (ILEC charge AC amp)]⁴⁰

DC power costs are based on the actual power consumption and the size of the feed required for peak demand period. In some cases, the charges may vary by zone and, in such cases, the variations are taken into account by the tool (i.e., the appropriate zone charge table is used based on the specific ILEC office under consideration). The tool also

⁴⁰ See, DS0 impairment analysis tool.xls at the "Impairment by Office" tab, columns titled "AC Power Recurring" and "AC Power Non-recurring."

accommodates charges based on load amps or fused amps.⁴¹ DC power charges are computed similarly according to the following formula:

- **DC Power Cost** = [(Number of DC power feeds required) * (Appropriate ILEC charge per DC power feed⁴²) + (DC power drain) * (Appropriate ILEC charge per DC amp) * (DC load amp:fuse amp conversion factor)]⁴³

Note that the power requirements at Satellite Offices are solely due to DLC equipment. At Network Node offices, the relevant power drains are increased to include the power requirements of an OC-48 multiplexer.⁴⁴ The power drain of the multiplexer is considered because, in many instances, the cost of the power feed and/or power decreases on a \$ per DC amp basis when more power is purchased. The backhaul infrastructure is assigned a share of the overall power cost at the Network Node, based on its relative share of the total power drain.

The relevant collocation space occupancy and construction charges can vary by minimum and additional square footage breakpoints, as well as by geographic zone. The DS0 Impairment Analysis tool first determines the minimum square footage required to

⁴¹ In some instances the ILEC applies power charges based on actual usage; in other instances, it may apply the charge based on a percentage of the maximum potential drain of the equipment. In the latter case the user may specify a factor that increments the calculated average drain to a different figure more in line with the manner in which the ILEC applies its charges. *See*, DS0 impairment analysis tool.xls at the “I” tab, cell D27 “DC peak load:average load conversion factor”.

⁴² ILEC tariffs for DC power feeds tend to be in fixed increments (e.g., 40 amps, 60 amps, 100 amps, etc.) with capacity determined by peak period potential usage. Accordingly, the DS0 tool determines the peak period drain and then selects the feed that is large enough to carry that level of demand. In some instances, the charges for power drain are “banded.” In those cases the tool determines the average current drain for the equipment, determines the appropriate charge band (e.g., greater than 60 amps) and applies the appropriate charge per amp to the average current drain. *See*, DS0 impairment analysis tool.xls at tab “S”, columns BE:BF and BI:BR.

⁴³ *See*, DS0 impairment analysis tool.xls at the “Impairment by Office” tab, columns titled “DC Power (Sat) Recurring” and “DC Power (Sat) Non-recurring.”

⁴⁴ *See*, DS0 impairment analysis tool.xls at the “Impairment by Office” tab, columns titled “DC Power (Node) Recurring” and “DC Power (Node) Non-recurring.”

house the equipment that would be deployed in a particular ILEC office (largely based on the estimated number of lines projected for service). This determination is accomplished in a two-step process. First, the number of frames is accumulated (*see* prior discussions regarding how frame counts are derived). Then, based on whether the location is a Satellite or Network Node, the frame count is multiplied by the appropriate number of square feet required per frame. In the case of Network Node offices, the default value is 11.5 square feet per frame. In the case of Satellite Offices, the frame footprint varies depending on the total number of frames deployed.⁴⁵ The tool then selects the smallest block of caged physical collocation the ILEC offers that is sufficiently large to house the frames.⁴⁶ For example, if 3 frames are required with a footprint of 11.45 feet per frame, 34.5 square feet of space is required. If the smallest block of collocation is 50 square feet, the tool selects that block. On the other hand, if the minimum size is 100 square feet, that block is selected. To the extent the requirements exceed the minimum collocation block size, the tool selects the least expensive option of a single standard block of collocation space or a smaller standard block combined with additional standard increments.⁴⁷ Once the relevant units of collocation space demand are established, the

⁴⁵ *See*, DS0 impairment analysis tool.xls at the “Impairment by Office” tab, columns titled “Collocation Occupancy Charge Recurring” and “Collocation Occupancy Charge Non-Recurring.”

⁴⁶ In the case of a Network Node office, the standard cage size is 300 square feet. Accordingly, the charges selected by the tool for the 300 square feet of collocation are accumulated, divided by 300 and then multiplied by the voice grade space requirements.

⁴⁷ Different ILECs offer different initial and additional square footage breakpoints for the computation of relevant collocation construction costs. In addition, these charges may also vary by UNE density zone. Because of the varied nature of ILEC construction and space related charges, the DS0 Impairment tool computes construction charges for every possible collocation size from 1 square foot through 300 square feet using all the possible minimum and additional combinations, and then selects the minimum charge based on that square footage. The tool then selects the appropriate charge based on the actual square footage requirements for the particular wire center being analyzed. *See*, DS0 impairment analysis tool.xls at tab “S”, columns CM:DY.

tool selects the appropriate charges based on the blocks required (by geographic zone, if appropriate) and multiplies the two to establish the space related costs at each wire center:

- **Space Occupancy Cost** = [(Collocation block required based on square footage requirements of equipment) * (Appropriate ILEC charge per unit of space)]⁴⁸

The appropriate ILEC administrative charges (both recurring and non-recurring) are added to the specific collocation costs.⁴⁹ Administrative charges are those ILEC collocation charges that are independent of the scope or volume of service undertaken by the new entrant. In other words, those charges are the fixed overheads of collocation. Examples of such fees are the collocation application charge, space availability report charges, construction planning fees, charges for light fixtures or keys for locks, et cetera. Because these items are not demand-driven, they are simply summed, separately, by recurring and non-recurring charge types. In Network Node offices, these administrative charges are apportioned to voice grade and transport functions separately, based on the frame (i.e., space) requirements of the relevant equipment.

DS0 connectivity (i.e., termination) charges are those imposed to provide the physical connectivity between the ILEC's MDF, where the voice grade loop UNEs of the ILEC terminate, and the collocation space of the new entrant, where its equipment is housed. To varying degrees the charges are applied based on the number of active lines

⁴⁸ See, DS0 impairment analysis tool.xls at the "Impairment by Office" tab, columns titled "Collocation Occupancy Charge (Sat) Recurring" and "Collocation Occupancy Charge (Sat) Recurring."

⁴⁹ See, DS0 impairment analysis tool.xls at the "Impairment by Office" tab, columns titled "Collocation Administrative Charge Recurring" and "Collocation Administrative Charge Non-Recurring."

the CLEC will serve.⁵⁰ In some instances, the ILEC charges do not include the installation of the physical cable between the collocation and the first cross-connection frame within ILEC space. In these cases, the new entrant must still incur these costs – generally paid to an ILEC-approved contractor. The tool provides for the input of these costs, which are generally expressed as a “per cable, one time charge” and, to the extent relevant, they are added to any ILEC charges applied on the same basis.⁵¹ The relevant formula, expressed in general terms, follows:

- **DS0 Connectivity Charges** = {[Projected CLEC Lines * ILEC charge per 2-wire termination) + Rounded up integer (Projected CLEC Lines ÷ 25) * (ILEC charge per 25 2-wire pairs) + Rounded up integer (Projected CLEC Lines ÷ 100) * (ILEC charge per 100 2-wire pairs) + Rounded up integer (Projected CLEC Lines ÷ 250) * (ILEC charge per 250 2-wire pairs)⁵²] + [(Projected CLEC Lines ÷ Maximum 2-wire cable size) * (ILEC standard cable charge + ILEC fixed 2-wire cable charge)]⁵³

Naturally, if a particular ILEC does not apply a charge, such as one per 25 pairs, the tool will find a zero charge and the term will effectively “drop out” of the preceding equation. It is important to note, at this point, that the cost of physically transferring a customer – known as a hot-cut – is *not* part of the DS0 Connectivity Charges. The hot-cut charges and other associated costs are discussed in section D.1 below.

⁵⁰ Costs include charges per 2-wire termination, per standard block of pairs (such as 25, 100, 200 or 300), and/or per cable installed.

⁵¹ Despite the fact that the costs are neither ILEC applied nor pursuant to a tariff or interconnection agreement, they are, nonetheless, legitimate economic costs that add to the potential impairment of the new entrant. Furthermore, many times ILECs place an intermediate frame called an IDF that also requires cabling and cross-connects, for which the CLEC pays.

⁵² Generally each ILEC tariff will include only one charge, either per 25, 100, or 250 terminations.

⁵³ See, DS0 impairment analysis tool.xls at the “Impairment by Office”, columns titled “DS0 Connectivity Charge Recurring” and “DS0 Connectivity Charge Non-Recurring.”

There is a second set of connectivity charges that relate to transport. In effect, the preceding connectivity charges were for the “customer connections” to the collocation. The connectivity charges that are the topic of the next discussion are for the “outputs” of the collocation – the connectivity that links the collocation to its CLEC switching node. Such connectivity is either leased, in which case it will be a DS-1 or DS-3 facility as determined by the demand at the collocation, or it will be a self-constructed facility of the new entrant. Despite the fact that the new entrant may have access to its own facility, it must generally still pay connectivity charges to the ILEC for the segment connecting the manhole outside the ILEC central office (where the new entrant’s fiber exits) and the fiber termination panel in the new entrant’s collocation. Transport connectivity charges are developed based on the situation that exists in each ILEC central office. If the office is a Satellite Office, the charges will be DS-1 or DS-3 transport connectivity (but not both). If it is a Network Node office, the connectivity will be fiber-based charges.

For Satellite Offices, connectivity charges are computed based on each office’s unique situation. First, the tool determines the bandwidth of the connectivity required. This is a function of the DLC equipment selected. Next, it determines the quantity of transport facilities required.⁵⁴ The relevant formulas are:

- **DS-1 Transport (DLC Types 2 and 3)** = [(Number of transport facilities required) * (ILEC fixed charge per DS-1) + Rounded up integer (Number of transport facilities required ÷ 6) * (ILEC charge per 6 DS-1s) + Rounded up integer (Number of transport facilities required ÷ 28) * (ILEC charge per 28

⁵⁴ The number of facilities required is the rounded-up result of dividing the lines served by the practical facility fill. The preceding result is then divided by the number of DS0s that can simultaneously operate on the facility (i.e., 24 for a DS-1 and 672 for a DS-3) with that result divided by the concentration ratio associated with the selected DLC equipment.

DS-1s) + (Number of transport facilities required ÷ Maximum DS-1 cable size) * (ILEC standard cable charge + DS-1 cable charge)]⁵⁵

- **DS-3 Transport (DLC Type 1)** = [(Number of transport facilities required) * (ILEC charge per DS-3) + Rounded up integer (Number of transport facilities required ÷ 6) * (ILEC charge per 6 DS-3s) + (Number of transport facilities required ÷ Maximum DS-3 cable size) * (ILEC standard cable charge + ILEC DS-3 cable charge)]⁵⁶

As was the case with DS0 connectivity, connectivity costs may vary based on the number of facilities, blocks of facilities, and/or number of cables.

The DS0 Impairment Analysis tool offers the option of computing collocation charges at Satellite Offices in two ways: based on the actual amount of space needed, or by imposing minimum purchase blocks for collocation space – thereby forcing the payment of so-called “breakage.” In general terms the collocation cost as described above is as follows:

- **Monthly collocation cost (breakage):** (Recurring administrative) + (Recurring DS0 connectivity)⁵⁷ + (Recurring space occupancy) + (Recurring space construction) + (Recurring transport connectivity) + (Recurring AC power) + (Recurring AC power feed) + (Recurring DC power) + (Recurring DC power feed) + [(Non-recurring administrative) + (Non-recurring DS0 connectivity) + (Non-recurring space occupancy) + (Non-recurring space construction) + (Non-recurring transport connectivity) + (Non-recurring AC power) + (Non-recurring AC power feed) + (Non-recurring DC power) + (Non-recurring DC power feed)] * (annuity from present amount factor)

⁵⁵ See, DS0 impairment analysis tool.xls at the “Impairment by Office” tab, columns titled “Transport (DS-1/DS-3) Connectivity Recurring” and “Transport (DS-1/DS-3) Connectivity Recurring.”

⁵⁶ See, DS0 impairment analysis tool.xls at the “Impairment by Office” tab, columns titled “Transport (DS-1/DS-3) Connectivity Recurring” and “Transport (DS-1/DS-3) Connectivity Recurring.”

⁵⁷ Because DS0 connectivity charges and DC power related charges are purchased only as demand arises, these two collocation cost elements receive an investment adjustment factor prior to the ramp-up adjustment which is later applied to all collocation charges. See Section B.3 below for a discussion of this investment adjustment factor.

- **Monthly collocation cost (no breakage):**⁵⁸ {(Recurring administrative) + (Recurring DS0 connectivity) + [(Recurring space occupancy) + (Recurring space construction)] * (space required/space acquired) + (Recurring transport connectivity) + [(Recurring AC power) + (Recurring AC power feed) + (Recurring DC power) + (Recurring DC power feed)] * (power required/power acquired)} + {(Non-recurring administrative) + (Non-recurring DS0 connectivity) + [(Non-recurring space occupancy) + (Non-recurring space construction)] * (space required/space acquired) + (Non-recurring transport connectivity) + [(Non-recurring AC power) + (Non-recurring AC power feed) + (Non-recurring DC power) + (Non-recurring DC power feed)] * (power required/power acquired)} * (annuity from present amount factor)

3. Ramp-Up

A new entrant does not acquire all of its customers instantaneously. The gross investment recovery calculations, within the unit costs in the DS0 Impairment Analysis tool, are adjusted to reflect the effect of a “ramp-up” of demand.⁵⁹ For example, the DLC common equipment (*i.e.*, the firmware and common plug-ins, the time slot interchangers, and the channel bank assemblies, common cards and cables) is sized to meet projected demand. In other words, the tool selects Type 1, 2 or 3 DLC equipment based on the *final* CLEC market share assumed in the study, even though this demand will obviously not materialize on day one.⁶⁰ Use of a ramp-up assumption reflects the greater per line impairment cost associated with common equipment investments being recovered over a smaller number of customer lines than would be the case if the projected demand existed for the entire economic life of the DLC common equipment.

⁵⁸ Because of the manner in which Node office space requirements are calculated and costed, there is no breakage. Thus, the monthly collocation cost with and without breakage are identical.

⁵⁹ The tool does not, however, account for the carrying costs of investments made before service is initiated in a particular area. Those costs alone can constitute a significant barrier to entry.

The ramp-up adjustment is best understood as an adjustment to the standard Annual Cost Factor (“ACF”), used to derive the annual (or in this case, monthly) costs associated with the forward-looking investments which must be incurred to provide service. The ramp-up calculations rely on several user-adjustable inputs to reflect the implications of different starting and ending office market share assumptions, and the time period required to achieve intermediate and final levels of demand.

For example, assume a 10-year asset life, a 15% cost of money, and a total investment of \$1.00. The correct mid-period ACF (assuming straight-line depreciation) in this case is 0.18580. The following table proves that this ACF calculation is correct by demonstrating that it produces just enough revenue to cover the initial \$1.00 investment:

Year	Annual Payment	Mid-Year Present Value Factor	Present Value of Annual Payment
1	0.18580	0.93250	0.17326
2	0.18580	0.81087	0.15066
3	0.18580	0.70511	0.13101
4	0.18580	0.61314	0.11392
5	0.18580	0.53316	0.09906
6	0.18580	0.46362	0.08614
7	0.18580	0.40315	0.07491
8	0.18580	0.35056	0.06514
9	0.18580	0.30484	0.05664
10	0.18580	0.26508	0.04925
			1.00000

⁶⁰ Likewise, collocation is sized for projected use so as to minimize the likelihood of costly space and/or power augments and to better assure availability of contiguous floor space. Contiguous floor space is important to permit appropriate and economical cross connection of CLEC equipment items.

Assuming a 1,000-line projected demand, the ACF per line is $0.18580/1000 = 0.00018580$. Further assume that the fixed investment required to serve these 1,000 lines is \$20,000 plus a per-line cost of \$2, and that this demand occurs instantaneously. Because the full demand is present immediately, the present value of the investment is \$22,000. Once we have calculated the correct ACF, we compute the cost per line as $0.00018580 \times \$22,000 = \4.0876 per line.

Next, we note that this same cost per line can also be calculated by dividing the initial investment by the present value of the lines, using the cost of capital as the discount rate. Conceptually, we are simply calculating an "annuity" per line by discounting lines instead of the number of periods. Because the total cost recovery occurring in each year is equal to the cost per line multiplied by the number of lines in service in that year, and we want the cost per line to be identical in all years, this approach makes mathematical sense. In the example above, the initial investment required is \$22,000. The present value of the lines is computed using the same Present Value factor as in the table above:

Year	Number of Lines in Service	Mid-Year Present Value Factor	Present Value of Lines in Service
1	1,000	0.93250	933
2	1,000	0.81087	811
3	1,000	0.70511	705
4	1,000	0.61314	613
5	1,000	0.53316	533
6	1,000	0.46362	464
7	1,000	0.40315	403
8	1,000	0.35056	351
9	1,000	0.30484	305
10	1,000	0.26508	265
			5,382.0

The \$4.0876 computed above can now be computed as $\$22,000/5,382 = \4.0876 per line.

Now, suppose we will achieve the 1,000 line market share over a linear ramp-up period of five years instead of immediately. We still must invest the \$20,000 fixed investment immediately, but that investment is spread out over a number of lines for which the present value will be *lower*, due to the time required to achieve target market share. This translates directly into higher average costs per line. The variable investment per line, however, will not be incurred immediately, but rather will track with market share penetration. Thus, the variable investment will have a present value that is lower than if all of the investments occurred immediately. While costs for both the fixed and variable investments will be developed by spreading the present value of the investment over the present value of the lines, the investment timing differences dictate slightly different treatments for each.

For the fixed investment, because all of the costs are incurred immediately, the present value of the investment is equal to the fixed investment amount. We can show that the ACF necessary to recover the investment is merely the ACF assuming instantaneous market share, multiplied by the ratio of the present value of lines assuming instantaneous market share, and the present value of lines assuming ramp-up. Thus, if we assume mid-period cash flows and a 5-year ramp-up:

Year	Number of Lines in Service	Mid-Year Present Value Factor	Present Value of Lines in Service
1	200	0.93250	186.5
2	400	0.81087	324.3
3	600	0.70511	423.1
4	800	0.61314	490.5
5	1,000	0.53316	533.2
6	1,000	0.46362	463.6
7	1,000	0.40315	403.2
8	1,000	0.35056	350.6
9	1,000	0.30484	304.8
10	1,000	0.26508	265.1
			3,744.8

Now we compute the ratio of the two line counts $5,382.0/3,744.8 = 1.437187$ multiplied by the original ACF of $0.00018580 = 0.0002670$. Multiplying this adjusted ACF by the \$20,000 initial investment yields \$5.34 per line. To demonstrate that this recovers our full investment of \$20,000 while yielding a return of 15%, we perform the following calculation:

Year	Lines in Service	Cost per Line	Total Cost Recovered	Mid-Year Present Value Factor	Present Value of Cost Recovered
1	200	\$5.34	\$1,068.12	0.93250	\$996
2	400	\$5.34	\$2,136.23	0.81087	\$1,732
3	600	\$5.34	\$3,204.35	0.70511	\$2,259
4	800	\$5.34	\$4,272.47	0.61314	\$2,620
5	1,000	\$5.34	\$5,340.59	0.53316	\$2,847
6	1,000	\$5.34	\$5,340.59	0.46362	\$2,476
7	1,000	\$5.34	\$5,340.59	0.40315	\$2,153
8	1,000	\$5.34	\$5,340.59	0.35056	\$1,872
9	1,000	\$5.34	\$5,340.59	0.30484	\$1,628
10	1,000	\$5.34	\$5,340.59	0.26508	\$1,416
					\$20,000

The calculation differs slightly for the variable investment. Because that investment will occur over time as the number of lines increase toward the target demand levels, the present value of the variable investment is lower than the nominal cost of \$2.00 per line. Thus, in order to avoid a cost over-recovery, the present value of the variable investment stream must first be computed as set forth in the following table:

Year	Gross Number of Lines Added	Nominal Cost per Line	Total Cost	Mid-Year Present Value Factor	Present Value of Cost
1	200	\$2.00	\$400.00	0.93250	\$373.00
2	200	\$2.00	\$400.00	0.81087	\$324.35
3	200	\$2.00	\$400.00	0.70511	\$282.04
4	200	\$2.00	\$400.00	0.61314	\$245.26
5	200	\$2.00	\$400.00	0.53316	\$213.26
6	0	0	0	0.46362	\$0
7	0	0	0	0.40315	\$0
8	0	0	0	0.35056	\$0
9	0	0	0	0.30484	\$0
10	0	0	0	0.26508	\$0
					\$1,438

The present value of the variable investment can now be spread over the present value of the lines in a manner similar to the fixed investment. Dividing the \$1,438 investment figure by the present value of the lines under this ramp-up scenario computed above of 3,744 yields a cost for variable investments of \$0.3839720 per line. This figure is added to the \$5.34 per line figure computed above to yield the correct per line investment figure of \$5.72. The following table demonstrates that this cost per line is sufficient just to cover the cash flows that are required to be spent over the 10-year period:

Year	Common Equipment Investment	Variable Investments	Lines in Service	Cost Recovery per Line	Total Cost Recovery	Net Cash Flow	Mid-Year Present Value Factor	Present Value of Net Cash Flow
0	(\$20,000)		0			(\$20,000)	1.00000	(\$20,000.00)
1		(\$400.00)	200	\$5.72456	\$1,144.91	\$744.91	0.93250	\$694.63
2		(\$400.00)	400	\$5.72456	\$2,289.82	\$1,889.82	0.81087	\$1,532.40
3		(\$400.00)	600	\$5.72456	\$3,434.74	\$3,034.74	0.70511	\$2,139.83
4		(\$400.00)	800	\$5.72456	\$4,579.65	\$4,179.65	0.61314	\$2,562.71
5		(\$400.00)	1,000	\$5.72456	\$5,724.56	\$5,324.56	0.53316	\$2,838.84
6			1,000	\$5.72456	\$5,724.56	\$5,724.56	0.46362	\$2,654.02
7			1,000	\$5.72456	\$5,724.56	\$5,724.56	0.40315	\$2,307.86
8			1,000	\$5.72456	\$5,724.56	\$5,724.56	0.35056	\$2,006.80
9			1,000	\$5.72456	\$5,724.56	\$5,724.56	0.30484	\$1,745.07
10			1,000	\$5.72456	\$5,724.56	\$5,724.56	0.26508	\$1,517.47
								0

The ramp-up adjustment to the ACF is computed within the DS0 Impairment Analysis tool as follows:

1. Calculate the present value of lines served over the economic life of the particular equipment (e.g., DLC common equipment) assuming projected service levels occur instantaneously.
2. Next, calculate the present value of lines served assuming projected market share is achieved over the user-specified ramp-up period.
3. Calculate the adjustment factor by dividing the Step 1 result by the Step 2 result. In the preceding example, the numerator is 5,382 and the denominator is 3,744 for a resulting factor of 1.437187.
4. Adjust the ACF for that equipment, based on projected demand, by multiplying the ACF by the ratio calculated in Step 3.
5. Calculate the monthly cost per line for the particular equipment by multiplying total investment from Step 4 by the appropriate ACF, and then dividing by 12.

Like the DLC example provided above, the ramp-up adjustment is applied to all categories of investment that require up-front investments sized to total demand, as well as to any investments which are not demand sensitive. Thus, DLC infrastructure

investments, termination investments, most collocation investments, and backhaul costs are also adjusted to incorporate the effect of ramp-up. For example, power feed related charges are incurred immediately based on the maximum expected lines in service, and collocation space construction is based on the projected number of frames, rather than incrementally as each frame is added.⁶¹ Costs which are not incurred on day one, but only as demand materializes, are treated as variable investments in the above example. For example, the line-card related investment portion of total DLC investment is not incurred until new customers subscribe. In addition, collocation amperage-related charges (including HVAC) as well as DS0 termination charges are incurred only as actual demand materializes. Using the procedure demonstrated in the variable investment example above, the ramp-up treatment for these items accounts for this timing difference.

C. Transport Connectivity Component – Costs of Connecting the Collocation to the New Entrants Network (Backhaul Infrastructure)

A backhaul infrastructure is necessary to provide the physical connectivity between each BellSouth wire center, at which the CLEC's DLC equipment is collocated, and the Network Node at which the CLEC switch serving the customers for each BellSouth wire center is located. In effect, the loop UNE must be extended to the local switched network of the CLEC. If a wire center is designated as a Satellite Office, the total backhaul cost must include the cost to get from the Satellite Office to its nearest Network Node and, once at the closest Network Node office, the cost of getting from the

⁶¹ Indeed it would not only be cost prohibitive (in light of space augment charges) but also technically and administratively impossible or impractical (due to lead times and risk of contiguous space being unavailable) to employ a "pay as you grow" approach.

Network Node office to the local switch of the new entrant. In this case, the backhaul cost (from a Satellite Office) includes the recurring and non-recurring rates charged by BellSouth for connectivity – using DS-1 or DS-3 transport as appropriate, under price cap or pricing flexibility⁶² – multiplied by the distance between the Satellite Office and its nearest Network Node.^{63,64} The preceding results must then be increased by the CLEC-provided backhaul infrastructure costs.

The CLEC-provided backhaul infrastructure costs are developed in the Transport Cost Analysis tool, which is discussed below in Section III. For each wire center, the DS0 Impairment Analysis tool utilizes the average cost per DS-3 per Network Node developed in the Transport Cost Analysis tool (assuming 80% utilization, i.e., 39 of 48 DS-3s are active) to calculate the wire center backhaul cost.⁶⁵ The following equations summarize the backhaul costs in the DS0 Impairment Analysis tool.

⁶² The choices are between “price capped” and “price flexibility” regulation. “Price Cap” effectively means that Phase II Pricing Flexibility has not been granted for a given ILEC wire center. Conversely, “Price Flexibility” means that some form of Phase II Pricing Flexibility has been granted for a given ILEC wire center. “CT” means that PF has been granted for channel terminations only. “Both” means that PF has been granted for both transport and end-user channel terms. “None” means that no PF has been granted at all.

⁶³ The costs for DS-1 and DS-3 connectivity are input from a connectivity charge database, which reflects monthly recurring and non-recurring charges for DS-1 and DS-3 ILEC special access applied pursuant to various term commitments (month-to-month, two-year and five-year). Special access charges are those submitted in the July 2003 interstate tariff revisions.

⁶⁴ These calculations appear in the “WC homing input” tab of the DS0 Impairment Analysis tool at columns AM and AN.

⁶⁵ Note that the assumption of 80% utilization (after a CLEC has achieved its ultimate market share) here is extremely conservative for a typical CLEC. In practice, the only way a typical CLEC could achieve this level of utilization is through the utilization of the ring for non-DS0 services (i.e., data, trunking, etc.) or by minimizing the number of facilities that it builds to (i.e., node locations). Indeed, a larger number of facilities placed on-net will erode the actual fill that the ring can achieve. Furthermore, backhaul costs are calculated assuming 39 of the 48 DS3 channels in the OC-48 fiber ring are utilized even though the maximum demand at any wire center in the analysis is 4 (for a Wire Center in Manhattan, NY LATA 132) and the median demand across all study areas is only 1 DS3. Thus the assumption of 80% utilization is extraordinarily conservative.

Network Node Offices

- **DS-1 Backhaul** = [(Cost per CLEC-provided DS-3 per month per DS-3) ÷ 28] * [1+ (Other Taxes Percent)]
- **DS-3 Backhaul** = (Cost per CLEC-provided DS-3 per month per DS-3) * [1+ (Other Taxes Percent)]

Satellite Offices⁶⁶

- **DS-1 Backhaul** = {(Total Air miles) * (DS-1 Cost per mile per month) + (DS-1 Fixed Cost per month) + [(Cost per CLEC-provided DS-3 per month per DS-3) ÷ 28]} * (1+ Other Taxes Percent)
- **DS-3 Backhaul** = {(Total Air miles) * (DS-3 Cost per mile per month) + (DS-3 Fixed Cost per month) + [(Cost per CLEC-provided DS-3 per month per DS-3)]} * [1+ (Other Taxes Percent)]

D. Costs of Transferring Customers from the ILEC to the CLEC Network

1. Customer Transfer Costs

A major component of CLEC impairment is the cost associated with transitioning customers from the ILEC to a termination connecting to the new entrant's collocation. Such a customer transfer is referred to in the industry as a "hot cut." Hot cut costs include both the hot cut charges imposed by the ILEC as well as the costs associated with work that the CLEC must perform to accomplish the transfer with, hopefully, minimal customer impact.

⁶⁶ Non-recurring charges are amortized over the expected life of the collocation (a user-adjustable input) and then added to the recurring charges.

Furthermore, in some instances, the ILEC may find it necessary to dispatch its personnel to transfer an existing ILEC retail customer loop from IDLC to either UDLC or to available copper facilities that are capable of supporting voice service.⁶⁷ Where this occurs, and the ILEC applies an additional dispatch charge, the costs are included as part of the hot cut cost.

2. Preliminary Hot Cut Calculations

The DS0 Impairment tool calculates hot cut costs separately for business and residential customers. For residential customers, the DS0 tool uses two input tables to determine hot cut charges. First, the following input table is used to specify hot cut charges for BellSouth, both in situations where BellSouth is required to dispatch a technician and when such a dispatch is not required, for both connects and disconnects.⁶⁸ The residential hot cut charges reflect the total average per line ILEC cost associated with all of the hot cut charges applied when transferring the residential customer over to the CLEC assuming that all lines for a multi-line premises are transferred lines

⁶⁷ When IDLC is used to provision an ILEC loop, individual circuits remain multiplexed within a DS-1 at the ILEC's DSX-1 from its DLC Central Office Terminal ("COT"). Although such circuits can be technically groomed onto a DS-1 dedicated to the CLEC, most ILECs are not offering that type of connectivity to CLECs. CLECs are therefore usually forced to have the ILEC transfer UNE-L loops to a spare copper pair if available, to spare Universal DLC equipment if available (or to abandon the potential customer). Both options are technically inferior, and normally incur additional CLEC costs. Transfer of a customer from IDLC involves dispatching an ILEC technician to the Serving Area Interface ("SAI") who removes the existing cross connection wire from the copper distribution - derived feeder terminations, and runs a new cross connection wire from the copper distribution termination to either a spare copper feeder termination or to a derived feeder termination from UDLC remote terminal equipment. In addition, the central office end of the circuit must now be cross connected from either the copper feeder MDF termination, or from the UDLC central office terminal equipment appearance at the MDF, to the CLEC termination point in the central office.

⁶⁸ The current UNE rates for the rate elements that comprise hot cut functions have been used.

simultaneously and to the same CLEC. The percentage of such multi-line transfers is equal to the presence of multi-line households in the study market area.

Residential Hot Cut Charges			
Company	Connect	Dispatch	Residential
LEC-State	Type	Action	Hot Cut
ILEC	connect	no dispatch	\$ 50
ILEC	connect	dispatch	\$ 0
ILEC	disconnect	no dispatch	\$ 20
ILEC	disconnect	dispatch	\$ 0

The user further inputs whether or not a dispatch is required for BellSouth. The percentage of times a dispatch is expected is computed as the product of (1) The % of all loops which are fiber times (2) The % of DLC loops which are IDLC times (3) the overall percentage of % IDLC Loops Transferable to UDLC or Copper.

These two pieces of information are then used to compute the effective residential hot cut charges, for both connects and disconnects. In addition to these charges, there is a user adjustable input that allows the user to enter costs born by the CLEC's internal operations associated with transferring the customer to its network.

For business hot cuts, the DS0 Impairment Analysis tool contains an input matrix for the average costs (connects and disconnects with and without a dispatch) over a wide range of potential limits for the business mass-market location sizes. This is necessary

because some charges apply once per location while others apply only to the initial line converted at the location or only to each addition line converted at a location. The matrix reflects the weighted average cost per line based upon the distribution of locations and lines at or below the line cut off specified on the left-hand side of the matrix. The per line business hot cut costs reflect the average per line ILEC charges associated with all of the hot cut functions required to transfer business customers over to the CLEC assuming a distribution of line reflecting the different size customer locations within that ILEC study area.

Business Hot Cut Charges at or Below Line				
Lines	Connect, no dispatch	Connect, dispatch	Disconnect, no dispatch	Disconnect, dispatch
1	\$75		\$50	
2	\$71		\$46	
3	\$67		\$42	
4	\$64		\$39	
5	\$61		\$36	
6	\$58		\$33	
7	\$55		\$30	
8	\$52		\$27	
10	\$49		\$24	
12	\$46		\$21	
16	\$43		\$18	
20	\$40		\$15	

The tool then uses a second input matrix to select the appropriate connect and disconnect costs associated with the crossover point where DS-1s are economic to serve business customers and selects the hot cut charge that is reflective of all of the lines at or below that threshold. This calculation also uses the matrix above for residential services to determine whether or not a dispatch is required for BellSouth, and the percentage of times a dispatch is expected.

UNE Zone	Cross Over
1	10
2	9
3	8
4	0
5	0

Using the crossover point above, the tool selects the appropriate connect and disconnect charges and calculates an effective hot cut cost per line. As with residential, any CLEC hot cut charges are input by the user as well.

3. Hot cut per line Calculations

Churn (a user-adjustable input) affects per-line costs for hot cuts. There is little dispute that customer churn occurs in a competitive market, leading to shorter than ILEC-typical customer retention lives. Churn is a function of competitive forces (e.g., win-back campaigns), customer experience (e.g., quality of the service establishment process) and external factors (such as relocations and business closures). Churn is critical because the disconnections resulting from churn must be overcome *before* net market share

growth can occur. The DS0 Impairment Analysis tool computes the hot cut expense stream by converting the total cost to a levelized cost per line based on churn, the pre-tax cost of capital, and an expected study period assumption. The calculation is performed separately for mass-market residential and small business segments to provide for different churn rates. The DS0 Impairment tool assumes a monthly gross churn rate of 4.6% for both business and residential customers based on assumptions regarding the CLEC industry contained in an April 2003 Banc of America Equity Research report.⁶⁹

The first step in computing per-line hot cut costs is to multiply the hot cut charge computed above by the expected number of customers. This is accomplished by calculating the total of the gross new customer additions over the life of the collocation. This represents the gross investment involved in hot cuts. Continuing with the example from section II.B.3 above, the following table demonstrates the calculation of the total number of gross customer additions, based on a churn rate of 10% annually:⁷⁰

⁶⁹ “AT&T Corporation - A Case for Consumer Services”, Banc of America Equity Research, April 30, 2003, page 10-11.

⁷⁰ The use of 10% annual churn is used for illustrative purposes only and is not consistent with the proposed inputs to the DS-0 tool. As discussed above, the actual churn rates in the DS0 Impairment Analysis tool are based on assumptions regarding the CLEC industry contained in an April 2003 Banc of America Equity Research report (see previous footnote).

Year	Net Number of Lines Added	Gross Number of Lines Added
1	200	220
2	200	240
3	200	260
4	200	280
5	200	300
6	0	100
7	0	100
8	0	100
9	0	100
10	0	100
	1,000	1,800

In this example, a total of 1,800 customers are added over the 10 year period, 800 of which are solely due to churn.

Because the hot cut payments are not due up front but only as new customers are added, the gross cost figure must be adjusted before it is amortized. The DS0 Impairment Analysis tool computes an adjustment to the ACF that reduces the gross investment to the level justified by the demand being currently served. This adjustment is computed by taking the ratio of the total lines (including churn) to the present value of the total lines. Continuing with the above example, the calculation of the correct adjustment factor is shown in the following table:

Year	Gross Number of Lines Added	Mid Year Present Value Factor	Present Value of Lines in Service
1	220	0.9325	205.2
2	240	0.81087	194.6
3	260	0.70511	183.3
4	280	0.61314	171.7
5	300	0.53316	159.9
6	100	0.46362	46.4
7	100	0.40315	40.3
8	100	0.35056	35.1
9	100	0.30484	30.5
10	100	0.26508	26.5
	1,800		1,093.4

The correct adjustment factor is the ratio $1,093.4/1,800=0.6075$. This is multiplied by the gross investment before the ramp-up adjustment is applied.

Finally, the ramp-up adjustment factor is applied to the hot cut investment, which is then multiplied by the standard ACF applying to collocation, and is then divided by 12 to produce a levelized monthly cost stream.⁷¹ The DS0 Impairment Analysis tool Summary Table presents the per-line hot cut charge for BellSouth in South Carolina.

E. Total CLEC DS0 Impairment

At this point the tool has calculated the monthly cost incurred by the CLEC, at the wire center level, for the DS0 infrastructure equipment, collocation, backhaul costs, and transfer of the customers from the ILEC to the CLEC network. Based on the projected number of lines to be served by the CLEC in each office, the results are expressed as a

⁷¹ Because a new entrant, unlike the ILEC, must almost always *by definition* take share away from the incumbent in order to gain new customers, hot cut costs are in some sense an investment in developing a stable customer base. As such it is appropriate from the perspective of an efficient CLEC entering the market to treat Hot Cuts as an investment expense.

cost disadvantage for the CLEC, per line served in each wire center. These are the added costs that the new entrant must incur (compared to the ILEC) to connect a retail mass-market customer to its local switch and thereby provide POTS service.⁷² The net impairment by wire center for the CLEC is summarized in the “DS0 summary” tab.

III. TRANSPORT COST ANALYSIS

As noted above, one element in the backhaul cost component of DS0 impairment is the cost of CLEC-provided transport between Network Node locations, including outside plant and associated electronics for that transport. These particular cost components are captured as an output of the Transport Cost Analysis tool. Using a geographic identification of potential Network Node locations, the Transport Cost Analysis tool employs a set of algorithms to size the hypothetical CLEC transport network and to develop the construction costs of that network based on publicly available unit cost data. The Facility Ring Processor is responsible for quantifying the specific components of the hypothetical CLEC transport network described above, which are used as inputs to the Transport Cost Analysis tool.

⁷² The costs are not the total cost of service for the new entrant, as the loop UNE cost is not reflected, nor are any switched local network costs or customer servicing costs, such as marketing, sales, billing, repair, etc. Likewise, these costs do not reflect any operational impairment, particularly with respect to customer acquisition, retention, or servicing that the new entrant may experience with respect to the ILEC.

A. Facility Ring Processor

1. Overview

The Facility Ring Processor (“FRP”) develops a reasonable network architecture that supports the carriage of traffic from the point of UNE-L availability (i.e., the point of UNE-L termination in the ILEC wire center) to a CLEC switch. To this end, the Facility Ring Processor performs two key tasks. First, based on an input file that identifies Network Nodes, Satellite Offices, and Tandem Office locations,⁷³ the Facility Ring Processor creates a hypothetical ring architecture to connect strategic points within the service area of BellSouth in South Carolina. Second, the Facility Ring Processor determines which Satellite Offices should home on which Network Node locations, and which Network Node and Satellite Office locations should home on which Tandem Office locations.⁷⁴ In sum, the Facility Ring Processor develops a network architecture that can be used to compute a reasonable estimate of the cost of backhauling UNE-L lines to a CLEC switch. After defining this basic network architecture profile for a given study area, it is then possible to generate fundamental network statistics such as average

⁷³ Although the user may directly specify the points that must be included on the facility network (by specifying V & H coordinate pairs) the general approach is to identify a subset of the largest ILEC offices within a specific geographic area, such as a LATA. If this latter approach is employed, the V & H coordinates are readily available from the LERG database. In addition, ILEC wire center sizes can be reasonably established from input files to cost models such as those initially considered in the Local Competition dockets. The information is recalibrated by trending the VGE counts based on FCC ARMIS data for the ILEC-state and by validating the office list (e.g., 8-character CLLI) with that which appears in recent iterations of the LERG database. Regardless of the source employed, the basic input necessary to run the Facility Ring Processor is a list of physical locations, i.e., ILEC wire centers— identified at minimum by V&H coordinates that have a designation as either on-net (i.e., node location) or off-net (Satellite Office).

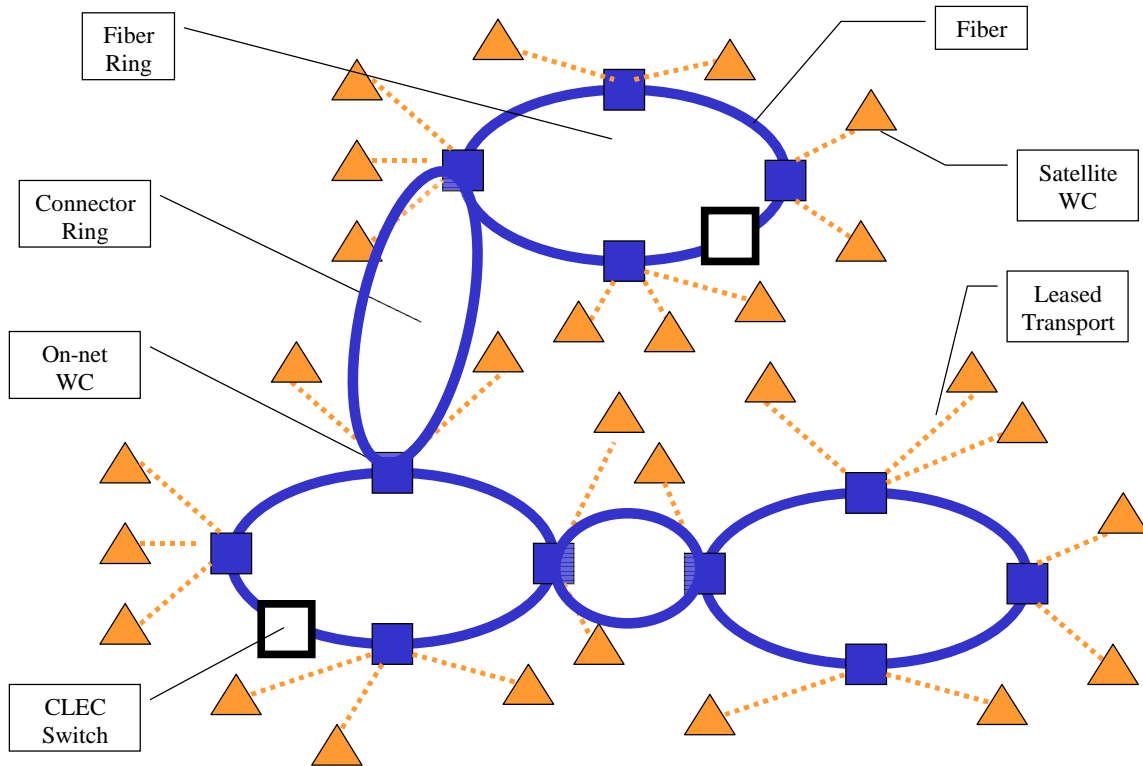
⁷⁴ The FRP also determines the homing of local offices to local tandems. This step is independent of whether or not one or more local tandems are selected as Network Nodes. This second "homing" step is used to determine the average tandem-to-end office distances for separate analysis of reciprocal compensation, such as may be involved in a business case analysis.

distance between Network Node locations and distances between Satellite Offices and the Network Node locations to which they home. These basic statistics are critical inputs to subsequent calculations to establish the cost of (a) CLEC-provisioned transport between Network Node locations and (b) purchased transport (e.g., special access or dedicated UNE transport from the ILEC) between Network Node locations and their subtending Satellite Offices.⁷⁵

The following figure displays the basic architecture employed in the Facility Ring Processor:

⁷⁵ For example, New Jersey LATA 220 (Atlantic Coastal) has a total of 25 Verizon wire centers, of which 9 have >15,000 VGE lines associated with them. Assuming the user opted to place all wire centers servicing >15,000 VGEs on-net, the user would input the 9 wire centers in the Facility Ring Processor as “Network Node locations” and the 16 remaining wire centers (i.e., those with <15,000 VGE lines) in the Facility Ring Processor as “Satellite Offices.” The Facility Ring Processor would then (1) determine how the 9 Network Node locations should interconnect with one another and (2) determine to which of the 9 Network Node locations the 16 Satellite Offices should sub-tend. Once the Facility Ring Processor establishes this basic “network profile”, it also calculates basic statistics such as average distance between Network Node locations and distances between Satellite Offices and the Network Node locations. These basic network profile statistics are in turn used in subsequent tools to (1) estimate the costs of CLEC-provisioned transport with respect to Network Node locations and (2) estimate the costs of leased transport facilities (e.g., special access or dedicated transport UNEs leased from the ILEC) that are needed between Satellite Office locations and Network Node locations.

Figure 3 – Underlying Architecture of the Facility Ring Processor



2. Source Data

The network architecture created by the Facility Ring Processor requires the designation of Network Nodes and Satellite Offices that are to home to Network Node locations. The FRP data set also requires the location of Tandem Offices. From this list of locations, the Facility Ring Processor constructs a transport network consisting of one or more SONET rings, dedicated point-to-point transport to Satellite Offices, and ring connectors.

The default input database identifies Tandem Office locations and ILEC wire centers that can serve as Network Node or Satellite Office locations. The database contains current ILEC locations that house local switches (i.e., ILEC wire centers). By

default the largest wire centers that cover at least 33% of the total lines as network nodes. These CLEC Network Node locations represent the locations judged to have the most significant potential total telecommunications demand. In rural areas where little entry has occurred, a minimum number of 2 of the largest wire centers are selected.

In addition, the node selection must ensure that tandem switches may be placed on the ring. This is based on the fact that in most instances, a typical CLEC will connect to the ILEC local tandem and terminate all DS0 usage (at the tandem) for any of the subtending offices and pay usage-based transport charges to terminate this traffic. Thus, ILEC local tandem switches are always included either as ring nodes or as satellite locations for a particular geographic area, regardless of demand.

The relevant information concerning these node locations was derived from wire center demand data in conjunction with LERG data. Among various other data elements that are used outside of the Facility Ring Processor, the wire center data provide the user with wire center VGE demand by major ILEC and by CLLI.⁷⁶ The LERG is in turn used to confirm and update the wire center data (i.e., switch existence) and to provide the vertical (V) and horizontal (H) coordinates of each wire center location,⁷⁷ the LATA and the deploying operating company.

⁷⁶ COMMON LANGUAGE® Location Identifier. COMMON LANGUAGE is a registered trademark of Telcordia Technologies, Inc. CLLI codes are unique alphanumeric codes that identify a network location (first eight characters) and equipment or an interconnection point within that location (e.g., a switch). For example, “CDKNNJCK” indicates a unique network location (e.g., building) in Cedar Knolls, NJ while two digital circuit switches in that building might be designated as “CDKNNJCKDS1” and “CDKNNJCKDS2.”

⁷⁷ V and H coordinates are commonly used to specify the geographic location of network locations. They are the mathematical transformation of longitude and latitude to a plane surface (i.e., they are adjusted for the curvature in the earth) so that distance between two locations may be easily calculated from the difference in the V and H coordinates.

Because multiple switches may exist within the same building, and because the records are manually input by different individuals, there is a chance that the V and H coordinates may not precisely match for switches that actually reside within the same physical building.⁷⁸ When multiple switches (i.e., unique 11 character CLLIs) exist within the same physical location (e.g., unique first eight characters of the CLLI) but have different V&H coordinates, the V and H coordinate values are averaged across all occurrences of the same eight-digit CLLI.⁷⁹

Each ILEC wire center location record contains an eight character CLLI, a state abbreviation, and a LATA number, MSA and ILEC designation – to facilitate data extraction for granular analysis – and the V and H coordinates among other data elements.⁸⁰ The user must separate the list of offices for a given study area into the categories of on-net and off-net, or Satellite Office and Network Node offices. In addition to the default node selection criteria, the user has the ability to identify and select any subset of offices for the given study area,) as Network Node offices.⁸¹ Once the

⁷⁸ The unit of distance in the V&H coordinate system is $\sqrt{0.1}$ or 0.316 miles or 1670 feet.

⁷⁹ Naturally, if all records had the same V and H coordinates, the results of the averaging would be the same. In most instances, where a discrepancy existed, it was in the last digit of the 4-digit coordinate and was generally only different by ± 1 . Such a discrepancy amounts to a deviation 0.316 miles. As a result, when averaged, the net impact would be of minimal impact on cost.

⁸⁰ Although not used in the Facility Ring Processor for the purpose of creating the basic network architecture profile needed to cost out a network in a given study area, certain additional data elements are also associated with each ILEC wire center in the “ILEC WC Detail File” and are used in other tools downstream. For example, the DS0 Impairment Analysis tool uses the following additional data: Total Lines, Business Lines, Residential Lines, Special Lines, Public Lines, Single-Line Business, Households, UNE Zone, % DLC, Density, Density Zone, Special Access Zone, Price Flexibility Status, and Copper Length Distributions.

⁸¹ The identity and location of the ILEC wire centers was derived from the LERG database. In particular, as certain wire center statistics such as line counts are required in the impairment analysis, the data file which houses such line data serves as the basis. The LERG was used to verify that the ILEC wire centers are active or within the ownership of the ILEC, and also provides the most current location (e.g., address, state, LATA, etc.) associated with each ILEC wire center. The base source for the VGE line count data is 1996

Network Node offices are identified, the Facility Ring Processor classifies, as Satellite Offices, all ILEC wire center locations (within the study area) that are *not* designated as Network Node office locations. A “1” in the Core Flag field of the “Offices” tab within the Facility Ring Processor denotes a location as a Network Node candidate, and it will appear as an on-ring Network Node if it does not violate the user-adjustable ring distance limit.⁸²

B. Required User Inputs

In addition to the identification of Network Node and Satellite Offices in the Facility Ring Processor as described above, the Facility Ring Processor employs a set of user-adjustable inputs. These include:

- **Maximum Nodes per Ring:** This determines how many Network Nodes can be placed on an individual physical ring.
- **Regenerator Spacing:** This input is used to determine how many regenerators will be required on each ring and lateral connection. Regenerators are electro-optical devices inserted into the optical cable path to overcome transmission loss due to long fiber lengths. This input specifies the optical segment distance at which a regenerator will be inserted.
- **CLLI Rejection Threshold:** This input is used to determine whether offices classified as Network Nodes will be moved off-ring and become Satellite Offices. Network Nodes with on-ring distances exceeding the CLLI Rejection

line counts for each wire center normalized to reflect 2002 line counts that the ILEC reports to the FCC in its ARMIS database. Specifically, we used the growth in lines from 1996 to 2002 reported in ARMIS along with the distribution of line counts in each wire center and each line type (e.g., residential, business, etc.) in 1996 to reflect the wire center specific line counts.

⁸² The maximum segment limits were established to prevent outlying large offices from being forced onto a ring when in reality they would be too distant to include. This safeguard prevents inflation of the conductor miles and associated costs. In these cases, the Facility Ring Processor will reclassify Network Nodes and Tandem Offices as Satellite Offices. See discussion in “Module Structure” section *infra*.

Threshold are moved off-ring, and become Satellite Offices (See footnote 84 below).

C. Module Structure

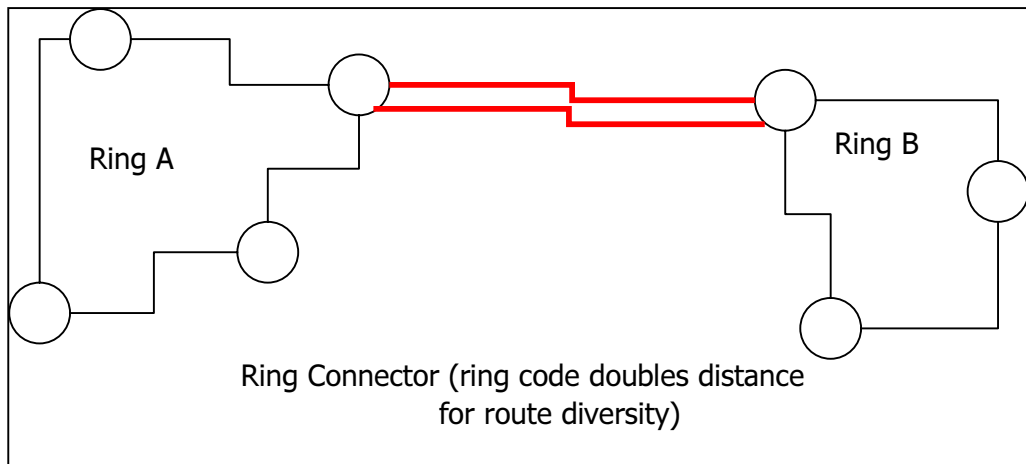
As noted above, the Facility Ring Processor constructs a hypothetical transport network that connects Network Node locations (with CLEC-provided fiber) and Satellite Office locations (with leased facilities). This network would be sufficient to permit UNE-L loops terminated at any BellSouth wire center to connect to a CLEC switch, and would permit the CLEC to provide voice grade services to all mass-market customers throughout South Carolina. Although the transport network constructed by the Facility Ring Processor is “hypothetical”, it is grounded in the real characteristics of existing networks and on the actual locations of ILEC wire centers.

The first step performed by the Facility Ring Processor is to incorporate Network Node locations, in the selected study area, onto one or more rings. The Facility Ring Processor builds rings by connecting (within constraints such as maximum distance) each Network Node to two neighboring Network Nodes, with the constraint that no more than the user-specified maximum number of Network Nodes may be on a single ring. An additional constraint is included to prohibit wire centers from being placed on the ring if they exceed a distance threshold (“CLLI rejection threshold”). When the Facility Ring Processor calculates the need to create more than one ring per study area, individual rings are connected to adjacent rings using alternate path “ring connectors.”⁸³ These are

⁸³ “Ring Connector” segments are redundant in that the mileage calculated for a given ring connector is doubled in order to account for a second diverse routing path for this segment.

effectively “two-node” rings that connect the closest Network Nodes on adjacent rings, and thus permit any Network Node to be connected to any other Network Node. The user may input a segment/ring connector maximum distance. Figure 4 illustrates the ring interconnection modeling performed by the Facility Ring Processor.

Figure 4 – Ring Interconnection



An algorithm written in Visual Basic for Applications (“VBA”) code groups Network Nodes into rings and builds connections between rings. The ring determination process begins by identifying a central Network Node location (referred to as the “*seed location*”) that is situated roughly in the middle of the entire set of locations. This *seed location* is determined by selecting the Network Node location that is the closest to the average V and H coordinates for the entire group of Network Nodes for the selected study area.

Once the *seed location* is identified, the algorithm begins forming rings by connecting all Network Nodes and Tandem Offices to the *seed location*. Therefore, in the initial case, there are typically numerous two-node rings, each consisting of the seed

location, and a Network or Tandem node. Following the first iteration of the algorithm, two of the two-node rings will merge, resulting in a three-node ring that is comprised of two Network or Tandem nodes and the seed location.⁸⁴ Merging rings in this way presumes that the total distance of the entire “ring system” can be reduced by allowing the two-node rings to merge. Additionally, rings with four nodes or more are allowed to close on themselves. That is, rings with four or more nodes may divorce themselves from the seed location and become standalone rings. Rings will continue to merge and close in this way until all nodes have been merged into larger rings or until it is no longer possible to reduce the total ring system distance by merging or closing any rings.

To determine the order in which rings are merged, the algorithm determines the “savings” associated with merging every possible ring combination, and then merges the rings that yield the greatest distance savings. The savings that are produced by merging any two rings is the difference between the sum of all the distances between all connected nodes prior to merging any two rings and the sum of all the distances between connected nodes after merging those rings. For each node in the study area, the algorithm merges the pair of rings that yields the greatest distance savings.

During the course of computing savings, it sometimes happens that savings can be maximized by allowing a ring to “close” on itself. That is, a ring may divorce itself from the seed location and become a standalone ring. The algorithm allows any ring with at

⁸⁴ For example, seed node A is initially connected with nodes B and C via redundant paths, which covers a total distance of $[(A \text{ to } B) + (A \text{ to } C)] * 2$. The FRP examines the distance associated with merging rings AB and AC with each other to form ring ABC, and determines whether the new distance $[(A \text{ to } B) + (B \text{ to } C) + (C \text{ to } A)]$ is less than the distance associated with the non-merged rings $[(A \text{ to } B) + (A \text{ to } C)] * 2$. If merged distance is less than the non-merged distance, the FRP will allow ring AB to merge with ring AC, and a

least four nodes to close on itself, and the savings are computed as previously described. In some sense, closing a ring can be thought of as a ring merging with itself.

The process of computing savings, merging rings, and closing rings will continue until no additional savings are possible, or other constraints, such as maximum allowable ring size, are realized. The end result of the merging and closing process is a set of interconnected nodes (i.e., rings) that have been arranged in a fashion that strives to reduce total distance.

After all Network Nodes and Tandem Offices have been incorporated into rings by the FRP, the distances associated with each node are examined.⁸⁵ If both of the distances associated with a given node exceed the user-specified “CLLI rejection threshold,” that node will be reclassified as a Satellite Office (and later processed as such), and the ring construction algorithm will be rerun.⁸⁶ This process continues until all Network Nodes and Tandem Offices can be placed on a ring without violating the CLLI distance rejection threshold.

larger ring, ABC, is formed. In subsequent evaluations, other rings may merge with ring ABC, as long as the newly formed ring does not exceed the user-defined maximum allowable number of nodes per ring.

⁸⁵ Because every node on a ring connects to two other nodes on the same ring, there are two distances associated with each network node. See Facility Ring Processor.xls at the “Ring IO” worksheet, fields ‘Core Office’, ‘Core Office Connects to CLLI (CLLI #1)’, and ‘Core Office Connects to CLLI (CLLI #2)’. Also see Facility Ring Processor.xls at the “Summary” worksheet, cell “E11,” “CLLI Rejection Threshold, mi.”

⁸⁶ In some cases, the Facility Ring Processor will reclassify Network Nodes and Tandem Offices as Satellite Offices. As the FRP builds rings, it examines the distances associated with each on-ring node. If the distances associated with the on-ring node exceed the user-defined “CLLI rejection threshold,” that on-ring node is reclassified as a Satellite Office. Application of the CLLI Rejection Threshold is useful because it can identify situations where either the V & H coordinates associated with an on-ring node may have been miscoded or a node location is so geographically remote that its inclusion on a ring is not prudent. Tandem Offices that are reclassified as Satellite Offices retain their tandem switching functionality.

Following the formation of rings, the FRP runs a process that identifies a set of “ring connectors” that are used to interconnect the formed rings with each other. The application of these ring connectors ensures that each ring can “reach” every other ring and that, as a result, every node in the study area has a physical path to every other node in the study area. The FRP identifies ring connectors by finding the shortest rectilinear path between any two nodes on any two rings; a logical representation of the role of the ring connector is depicted by the red lines in Figure 4.

After interconnecting Network Nodes in the relevant study area, the Facility Ring Processor associates each Satellite Office with its nearest Network Node. The operative assumption in the transport analysis process is that Satellite Offices will be connected to Network Nodes using ILEC-supplied (*i.e.*, UNE and/or Special Access) interoffice transport. Because BellSouth charges for these types of connectivity are based on airline distance, the Transport Cost Analysis tool must determine the closest Network Node to each particular Satellite Office, measured on the basis of airline distance. The DS0 Impairment Analysis tool uses the Satellite to Network Node distances to determine pricing of ILEC supplied connectivity (*i.e.*, interoffice transport) in the calculation of backhaul costs.

Identifying the homing arrangements from Satellite Nodes is a straight-forward process that is based on minimizing the total airline distance between the Satellite Node and its serving Network Node. The FRP assigns Satellite Nodes to Network Nodes by computing the airline distance between every Satellite Node and every on-ring Network Node in the study area; after these distances are calculated, the FRP simply associates the Satellite Node with the nearest on-ring Network Node. The Satellite Node to Network

Node distance is stored for each Satellite office and is used subsequently to determine pricing of incumbent supplied connectivity (*i.e.*, interoffice transport) in the calculation of backhaul costs in the DS0 Impairment Analysis tool.⁸⁷ Also, the FRP calculates the average Satellite Node to Network Node distance across all Satellite offices within the study area.

Identifying the homing arrangements for Tandem Office locations is similar to that used when assigning Satellite Nodes to their associated Network Nodes. Again, the goal is to minimize the airline distance between each Node (both Satellite Nodes and Network Nodes) and its assigned Tandem Office.⁸⁸ To make the Tandem Office to node assignments, the FRP first looks for on-ring Tandem Offices. To the extent that the FRP finds on-ring Tandem offices, it will compute the airline distance between all nodes in the study area and each on-ring Tandem.⁸⁹ Node-to-Tandem Office associations are then made on the basis of minimum airline distance. If the FRP does not identify any on-ring Tandem Offices, it will compute the distance between all nodes in the study area and each off-ring Tandem Office and then make its node-to-Tandem assignments on the basis of minimum airline distance.

⁸⁷ The fundamental assumption in the Facility Ring Processor tool is that Satellite offices will connect to nodes using incumbent-supplied interoffice transport (*i.e.*, special access). Because [ILEC] charges for these types of connectivity are based upon airline distance, the FRP tool determines the closest Network Node to each particular Satellite office on the basis of airline distance.

⁸⁸ Tandem homing arrangements are computed for Satellite Nodes and Network Nodes (*i.e.*, all nodes in the study area).

⁸⁹ Although study areas may include both off-ring and on-ring tandems, off-ring tandems will be ignored in cases where at least one on-ring tandem is found.

The Facility Ring Processor calculates the rectilinear mileage⁹⁰ between Network Node-to-Network Node office pairings, based on the V and H coordinates of the pair. The tool separately accumulates the rectilinear distances for all Network Node-to-Network Node connections required in a particular study area⁹¹ and divides these results by the Network Node count to calculate the average rectilinear miles per Network Node within the South Carolina study area. Similar calculations are made for the ring connector (ring-to-ring) distances. These outputs are used downstream in the Transport Cost Analysis tool to calculate costs such as fiber facilities and structure costs.

By default the Facility Ring Processor selects rectilinear distances between Network Nodes and for Ring Connectors as outputs for the cost computations in the Transport Cost Analysis tool. The logic for using the rectilinear distance between Network Node locations is simple: There are very few instances where cable can be run on a line-of-sight or “as the crow flies” basis. More commonly (particularly in suburban and urban markets), rather than cutting diagonally across a city block (the hypotenuse of a triangle) the cable runs down the street to the next intersection and then turns to follow the cross street in the appropriate direction (i.e., the sides of the right triangle are followed rather than the hypotenuse).

In addition, the FRP computes the Satellite Office to Network Node distance, the node (i.e., all non-tandem nodes in the study area) to Tandem Office distance, and the

⁹⁰ The rectilinear calculation is the combined lengths of the sides of the right triangle connecting the two points (rather than the hypotenuse of the triangle calculated for the air line distance). The formula is as follows: $[ABS(V_2 - V_1) + ABS(H_2 - H_1)] \div \sqrt{(10)}$, where “ABS” indicates that absolute value of the difference is employed.

⁹¹ Rings do not connect to Network Nodes outside the specified study area.

average node to Tandem Office distance. Based on these distance calculations, the FRP tool determines where regenerators are required (using the user-specified regenerator spacing input) for rings and ring connectors. Finally, the FRP tool calculates a density zone distribution for conductor mileage connecting the Network Nodes. The rectilinear distance identified for each Network Node is categorized and accumulated separately based on the density zone for that node. The resulting miles, by density zone interval, divided by the total miles, yields a proxy for the distribution of the outside plant across the strata established for construction costs.⁹²

To summarize, the Facility Ring Processor incorporates the following functionality and produces the following outputs:

- Forms rings up to a user-specified maximum node count
- Moves Network Nodes with distances greater than a user-defined value off net; these Network Nodes become Satellite Nodes
- Calculates node-to-node distances (both airline and rectilinear) for each node pair
- Calculates average internodal distance for all rings
- Identifies “ring connector” nodes to interconnect adjacent rings
- Calculates ring connector distances
- Assigns Satellite locations to the nearest ring node
- Computes Satellite-to-node distances (airline and rectilinear)

⁹² The DSO Impairment tool can utilize independent construction cost inputs for as many as nine different user-adjustable density zone breakpoints, enabling the analyst to develop costs for transport facility construction that are location-specific for the [insert State or other study area]. Where some, but not all offices input as a “node” office have a density, the offices lacking density information are assigned the average density of the office for which input was provided.

- Determines how many regenerators are required (according to user-specified regenerator spacing input) for rings, ring connectors and satellite offices
- Assigns Network and Satellite nodes to the nearest tandem switching location
- Computes the Network Node to tandem and Satellite Node to tandem distances.
- Produces a distribution by density zone of the total ring distance by extracting the ring distance associated with each ring node according to each node's associated density zone as listed in the Facility Ring Processor's 'Ring IO' worksheet

The net result of the Facility Ring Processor's ring-building process is a data set containing, in concise terms, the Network Node to Satellite Office associations, the node to Tandem Office homing arrangements, and the ring or set of rings formed in the study area.

D. Transport Cost Analysis tool

1. Overview

For CLECs seeking to serve mass-market customers (*e.g.*, residential and small-business customers) in BellSouth's territory in South Carolina, a primary issue is the connecting of individual voice grade UNE-L loops to the CLEC's switch efficiently and cost-effectively.

The Transport Cost Analysis tool estimates the costs that a CLEC would likely incur to provide its own transport between Network Node locations.⁹³ These transport costs are driven by three key components: (1) the transmission facility (and the physical structure needed to link two points or nodes on the ring), (2) the transmission terminal equipment, and (3) the collocation space at each ILEC central office required to house the terminal equipment.⁹⁴

The Transport Cost Analysis tool calculates the transport cost per DS-3 as a function of the number of DS-3s active on the entire network (*i.e.*, it calculates the transport cost per DS-3 based on the number of DS-3s that would be anticipated on the entire network assuming the 80 percent fill factor indicated earlier), based on the transport network for South Carolina “built” by the Facility Ring Processor as described above.

2. Facility Construction

Facility construction cost includes the cost of the material and construction or leasing of the outside plant structure required to support the transport facilities that need to be built.⁹⁵

As described earlier, the basic transport architecture adopted by the DS0 Impairment Analysis tool is a ring architecture. Because each location (or Network Node) on a ring is connected to all other Network Nodes on the ring, and because rings

⁹³ As noted previously, Network Node locations are connected via a CLECs self-provisioned transport facility, which requires that the CLEC fund all of the costs associated with constructing such facilities.

⁹⁴ This space is in addition to collocation space required to house the DLC equipment discussed earlier.

are designed to connect all Network Nodes within a particular study area (rather than minimizing the mileage between any two particular locations), the costs of the ring facilities that CLEC's must construct to provide local service in BellSouth's territory in South Carolina is treated as a "joint" cost by the DS0 Impairment Analysis tool.

To determine facility construction costs, the Transport Cost Analysis tool calculates the structure cost the combination of nodes included in the CLEC-provided network. The Facility Ring Processor described above provides two key inputs that form the starting point for this calculation, *i.e.*, (1) the average transport miles per Network Node (based on the Network Nodes identified by the user in South Carolina) that can then be used to accumulate the miles of structure across all nodes, and (2) the density zone distribution of the structure miles deployed on the rings. The average structure cost per Network Node is calculated by (1) summing the product of the structure cost per foot times the average transport feet per Network Node divided by the average number of OC-48's per node, (2) the fiber cost per foot times the average transport feet per Network Node, plus (3) the product of the cost per leased foot times the average transport feet per Network Node.⁹⁶ Ultimately, this average facility construction cost per node is summed across all of the nodes in the network to develop the cumulative facility construction cost for the network.

- **Gross Investment (Structure)** = [(Structure miles per node segment) * (Structure cost per foot) * 5,280 ft/mi.] + [(Fiber Strands) * (Cost per strand foot) + (Fixed cost per foot)] * 5,280 ft/mi. * (Structure miles per node

⁹⁵ The facility construction costs developed include cost sharing opportunities to the extent they are available.

⁹⁶ The structure cost per foot is weighted by percent occurrence, e.g., % leased, etc.

segment) + [(Leased cost per foot) * (Structure miles per node segment) * 5,280 ft/mi.] * (Total Nodes on All Rings)⁹⁷

The structure cost per foot is the weighted-average costs for aerial, buried and underground construction, which are derived by multiplying the unit costs for each type of construction (aerial, buried or underground) by an estimate of the frequency of occurrence of each type of construction (*i.e.*, the structure distribution), adjusted to reflect structure sharing assumptions (*i.e.*, the fraction of the total cost of construction that each individual user must defray). The leased structure cost per foot is calculated as the percent leased by density zone weighted by the density zone distribution of the structure miles.

- **Cost per Strand Foot** = [(Aerial structure cost) * (Aerial weighted structure distribution) * (Aerial weighted structure sharing)] + [(Aerial cable cost) * (Aerial weighted structure distribution)] + [(Buried structure cost) * (Buried weighted structure distribution) * (Buried weighted structure sharing)] + [(Buried cable cost) * (Buried weighted structure distribution)] + [(Underground structure cost) * (Underground weighted structure distribution) * (Underground weighted structure sharing)] + [(Underground cable cost) * (Underground weighted structure distribution)]⁹⁸

Where:

- **Aerial Weighted Structure Distribution** = Sum for all density zones of (Density zone distribution of the structure miles * Aerial fiber feeder structure proportions)
- **Aerial Weighted Structure Sharing** = Sum for all density zones of (Density zone distribution of the structure miles * Aerial fiber feeder structure sharing)

⁹⁷ See, Transport Impairment Analysis tool at the “Facility Cost Calculator” tab, cells E74 through E81 for detailed calculations.

⁹⁸ See, Transport Impairment Analysis tool at the “Fiber Structure” tab for calculation of structure cost per foot and structure cost per foot leased.

- **Aerial Structure Cost** = [(Cost per pole) ÷ (Pole Spacing)] * [1 – (Percent aerial structure leased)]
- **Aerial Cable Cost** = (Aerial cable per ft.) + (Aerial cable engineering & installation per ft.)
- **Buried Structure Cost** = (Buried Excavation-Restoration per ft.)
- **Buried Cable Cost** = (Buried cable per ft.) + (Buried cable engineering & installation per ft.)
- **Underground Structure Cost** = [(Conduit per ft.) + [(Pull box investment) ÷ (2000 ft. between pullboxes)] + (Underground Excavation & Restoration per ft.)] * [1 – (Percent underground structure leased)]
- **Underground Cable Cost** = (Underground cable per ft.) + (Underground cable engineering & installation per ft.)

3. Annual Cost Factors

User adjustable inputs – such as the unit cost of cable, installation costs, and economic life – are required to calculate the average monthly facility cost per Network Node. In addition, the module derives the weighted salvage value, and weighted useful life by multiplying the factor specific to the construction type by the associated frequency of occurrence.⁹⁹

- **Fiber ACF** = (Aerial ACF) + (Buried ACF) + (Underground ACF)

Where:

- **Aerial ACF** = {[(Ratio of pole cost to total aerial cost) * (Pole ACF)] + [(Ratio of non-pole aerial cost to total aerial cost) * (Aerial fiber ACF)]} * (Aerial weighting)
- **Buried ACF** = (Buried fiber ACF) * (Buried weighting)

⁹⁹ These inputs are generally established in state TELRIC cases and can either be used directly or used to calibrate more disaggregated inputs employed for the impairment analysis.

- **Underground ACF** = {[(Ratio of conduit cost to total underground cost) * (Conduit ACF)] + [(Ratio of non-conduit underground cost to total underground cost) * (Underground fiber ACF)]} * (Underground weighting)¹⁰⁰

4. Transmission Electronics

To connect individual UNE-L loops to the CLEC-provided interoffice transport, optical multiplexers, optical patch panels, and power distribution (*e.g.*, power filtering and fuses) equipment must be installed in the CLEC collocation space in each ILEC central office at which UNE-L loops terminate.

The module assumes that OC-48 transport will be used on all Network Node rings. As a result, the DS-3 signal generated by the DLC equipment collocated at each ILEC wire center must be multiplexed up to OC-48 at the Network Node before being transported to the CLEC switch location. DS-3 or (in some Satellite Offices) DS-1 leased transport is used to move signals from each Satellite Office to its nearest Network Node. OC-48 multiplexing equipment located at each Network Node multiplexes and demultiplexes the transport signals so that circuits may be dropped at the Network Node and others may be added. The cost of multiplexers consists of a fixed cost for the base unit (which provides the common electronics for interfacing with the facility at the OC-48 level), and a variable cost for sub-modules that provide the capacity to add and drop DS-3 level circuits at the Network Node.

- **Gross Investment (OC-48)** = [(Cost per OC-48 base module) + (Installation labor cost per OC-48 base module)] * (Number of OC-48 base modules) +

¹⁰⁰ See, Transport Impairment Analysis tool.xls at the "Fiber Structure" tab, cells B90:B93 for calculation of the fiber ACF.

$$[(\text{Cost per added module per DS3}) * (\text{Average Number of Access/Egress DS3s})] + (\text{Number of frames required for OC-48})^{101} * (\text{Cost per Frame})^{102}$$

The Average Number of Access/Egress DS3s is calculated as:

- **Average Number of Access/Egress DS3s** = (Maximum OC48 Terminal Capacity) * (Fill Percentage) * (Percentage of Capacity Used for Access/Egress)¹⁰³

User-adjustable inputs in the “Equipment Inputs” tab of the Transport Cost Analysis tool permit the user to specify the cost, capacity, and current drain (for assigning power distribution costs) separately for the base unit and the sub-modules. The Transport Cost Analysis tool also allows the user to specify the cost to engineer and install the equipment. User-adjustable inputs related to the economic life, net salvage and annual maintenance factors for optical multiplexing equipment also are required. These input requirements, and their default values, are shown in the following table.

¹⁰¹ The OC-48 is assumed to require 0.5 frames. The cost per frame is calculated as: (Equipment cost per frame) * [(Number of base modules) * (Number of frames required per OC-48 base module) / Rounded up integer [(Number of base modules) * (Number of frames required per OC-48 base module)]].

¹⁰² See, Transport Impairment Analysis tool.xls at the “Facility Cost Calculator” tab, Cells E18 through E26 for detailed calculations.

¹⁰³ See, Transport Impairment Analysis tool.xls at the “Facility Cost Calculator” tab, Cells L5 through L46 for detailed calculations.

Table 4
OC-48 Costs in Transport Cost Analysis tool

Item	Cost
Fixed	\$28,632
Cost per added module	\$12,600
Capacity per module (DS-3)	12
Engineered DS-3 fill	80%
Frames required per base module	0.5
Current drain amps (per base module)	10
Current drain amps (per sub-module)	2.5
Labor type	1
Labor rate – Labor type 1 ¹⁰⁴	\$50
Hours – Labor type 1	21
Labor type	2
Labor rate – Labor type 2	\$50
Hours – Labor type 2	18
Frame Cost	\$350

5. Fiber Distribution Panel Investment

The fiber distribution panel terminates the fiber transport cable, and permits cross-connection of optical level transmission equipment. The “Equipment Inputs” tab of the Transport Cost Analysis tool requires user-adjustable inputs for the capacity and the practical fill of the panel, the number of panels that can fit in a collocation frame (to aid in sizing the collocation), and the expected life, net salvage and annual maintenance factors for the optical patch panel. These input requirements, and their default values, are shown in the following table:

¹⁰⁴ In the model, the user adjustable labor rate (set here at \$50) has a state specific wage index applied to it.

Table 5
Fiber Distribution Panel Costs in the Transport Cost Analysis tool

Item	Cost
Panel	\$200
Capacity (fiber strands)	24
Equipment Fill	100%
Cost to terminate a strand	\$60
Panels per frame	5
Labor type	1
Labor rate – Labor type 1	\$50
Hours - Labor 1	0.5
Labor type	2
Labor rate – Labor type 1	\$50
Hours - Labor 2	5

The investment in the fiber distribution panel is calculated by first determining the number of fiber terminations required. This is one transmit pair plus one receive pair for the outside plant cable terminations (four fibers total). Because a ring architecture is employed, one incoming pair and one outgoing pair of terminations are required for each base OC-48 module (i.e., the multiplexer must be connected to both the “east bound” and the “west bound” fiber pairs associated with its SONET ring). In addition, multiplexers are connected to panel terminations, not directly to the outside plant terminations. Therefore, for each OC-48 there should be two east-bound outside plant terminations, two east-bound multiplexer terminations, two west-bound multiplexer terminations, and two west-bound outside plant terminations, for a total of 8 terminations per OC-48. There should also be 4 patch cords per OC-48 to link the outside plant and multiplexer terminations to each other. The number of terminations required determines the number

of panels required. The calculations for the fiber distribution panel investment are detailed below:¹⁰⁵

- **Gross Investment** = [(Number of panels required * Cost per panel) + (Installation labor per connection * Number of connections required) + (Labor cost per panel * Number of panels required)]

Where:

- **Connections Required** = 4 * OC-48 base modules required
- **Panels Required** = Number of connections required ÷ (panel capacity * equipment fill)

6. Battery Distribution Fuse Bay Investment

User inputs are also required to develop the costs of the battery distribution fuse bay (BDFB). A single BDFB frame is commonly deployed for an entire CLEC collocation area, so the BDFB serves the voice grade equipment in addition to the optical multiplexer employed for transport. For consistency between the Transport Cost Analysis tool and the DS0 Impairment Analysis tool, both employ a default 200-amp BDFB. The cost assignment to transport is calculated as the OC-48 current drain (20 amps by default) divided by the 200 amp default capacity of the Network Node BDFB. The total installed cost of the BDFB is developed from user-adjustable inputs that identify the total material cost and the labor increments and costs required to install a BDFB. The following table summarizes the user-adjustable inputs used in these calculations, along with their default values.

¹⁰⁵ See, Transport Impairment Analysis tool.xls at the "Facility Cost Calculator" tab for detailed calculations.

Table 6
Power Costs in Transport Cost tool

Battery Distribution Fuse Bay - Node	
Capacity (amps)	200
Net price per panel	\$5,500
Maximum fill	100%
Labor type	3
Labor Rate – Labor type 1	\$50
Hours - Labor 1	24.0

The tool prorates the total cost of the BDFB to the collocated OC-48 multiplexers based on the proportion of their current drain to the total capacity of the BDFB. Because this is a Network Node location, it is assumed that a minimum of 200 amps of capacity will be placed.¹⁰⁶

- **Gross Investment** = [(Cost of BDFB) + (Installation labor cost per BDFB)] * (BDFB prorating factor)

The BDFB Prorating Factor is calculated as:

- **BDFB Prorating Factor** = [(Current drain OC-48 base module) * (Quantity of base modules) + (Current drain of OC-48 sub-modules) * (Quantity of OC-48 sub-modules)] ÷ (BDFB current capacity based on minimum Node Office amperage value)

To fully develop the levelized monthly cost of the BDFB investment item, economic life, net salvage, and annual maintenance factors for the BDFB are applied.¹⁰⁷

¹⁰⁶ This matches the assumption in the DS0 Impairment Analysis tool.

¹⁰⁷ Because some collocation space charges include power supply, the “General Inputs” tab includes the option to over-ride (*i.e.*, set to zero) the costs associated with the BDFB.

7. Collocation Space

The OC-48 multiplexers, optical patch panels, and BDFB equipment identified in the Transport Cost Analysis tool occupy collocation space along with the DLC equipment identified in the DS0 Impairment Analysis tool. A consistent methodology for quantifying collocation costs is employed for both tools.¹⁰⁸

Where a voice grade service infrastructure of the new entrant exists in a facility-based collocation (i.e., a Network Node office), the CLEC must also pay fiber transport connectivity costs to the ILEC. The relevant formula for the cost of collocation connectivity for self-provided fiber transport is:

- **Self-Provided Fiber Transport Cost** = [(Number of fibers) * (ILEC charge per fiber) + (Number of fiber pairs ÷ 2) * (ILEC charge per fiber pair) + (Number of fibers ÷ 4) * (ILEC charge per four fibers) + (Number of fibers ÷ 12) * (ILEC charge per 12 fibers) + (ILEC standard cable charge + ILEC fiber cable charge)] * (Number of fiber cables delivered to the collocation)¹⁰⁹

8. Cumulative OC-48 Terminal Investment

The preceding discussion has related to the development of the average investment per OC-48 Terminal based on the Average Access/Egress DS3s per Terminal. Ultimately, the cumulative investment for the SONET network is required for developing an average cost per DS3 served by the CLEC-constructed network. To perform this

¹⁰⁸ The calculations are based on the same collocation charges. The primary difference is that the node collocation is sized to 300 square feet and is assumed to require a 200 Amp BDFB and power feed. The equipment required for the backhaul of voice grade loops is assigned a pro-rata share of the costs. For example, the floor space related collocation costs are divided by 300 and then assigned based on the number of frames required (which could be fractional) times 11.5 sq ft per frame. Similarly, power related charges are assigned based on the current drain of an OC-48 divided by 200 amps.

calculation, the Transport Cost Analysis tool identifies Total OC-48 Terminals required for nodes and connector rings. This calculation effectively requires three steps.

First, each node that is placed on the network by the Facility Ring Processor receives at least one SONET OC-48 Terminal. This value is simply derived from the number of nodes on all rings that is provided by the Facility Ring Processor as an input into the Transport Cost Analysis tool.

Second, as more OC-48 Terminals are added to the same SONET ring, the quantity of DS3s that are terminated at each SONET node (the access or egress of DS3s) is diminished in that more of the capacity of the OC-48 SONET ring and therefore each terminal is used to transit capacity to other SONET nodes. The Transport Cost Analysis tool takes this effect into account and allows the user to add subdivided SONET rings. In other words, if the percentage of capacity at each OC-48 SONET node drops below a minimum threshold (“Minimum Access/Egress Capacity Used before Subdivision”) then the Transport Cost Analysis tool will automatically add subdivided rings so that there will be fewer OC-48 SONET nodes per logical OC-48 ring and the Average Access/Egress DS3s per Terminal will be higher overall. The “Minimum Access/Egress Capacity Used before Subdivision” is set to a default value of 50 percent. The subdivision process can effectively be turned off by setting this value to zero percent. The specific calculations related to this process can be found at the

¹⁰⁹ See, Transport Impairment Analysis Tool.xls at the “Collocation” tab, columns titled “Self-Provided Fiber Transport Recurring” and “Self-Provided Fiber Transport Non-Recurring.”

“Physical Ring Subdivision” section of the Facility Cost Calculator tab or the Transport Cost Analysis tool.

Third, the connector ring terminal investment must be included as well. Again, this is a very straightforward cost in that the Facility Ring Processor provides as an input to the Transport Cost Analysis tool the number of connector rings. Each connector ring requires two OC-48 SONET terminals in that these are two-point SONET rings.

Once the total terminals are determined from the above three calculations, the average investment per terminal is multiplied by this value to identify the cumulative OC-48 SONET Terminal investment. This, as with the fiber and structure cost described earlier, represents the total investment for the network. However, this investment must then be spread across the number of DS3s that can be served by this network. This value is calculated using the 80 percent fill factor for the overall network and is calculated as the product of the number of nodes on the network times the Average Access/Egress DS3s per Terminal discussed earlier. In this way, the total number of DS3s on the network can be calculated to spread the total node network investment across. This permits the calculation of an average investment per DS3 on the CLEC-provided network.

9. Maintenance and Taxes

Maintenance and taxes are included in the “Facility Cost Calculator” tab of the Transport Cost Analysis tool. Maintenance expenses are calculated by multiplying the

gross investment by an associated annual maintenance factor, which is then divided by 12 to yield a monthly result. The taxes (other than income) are region specific inputs that are incorporated as a percentage basis.

10. Summary of Approach

The Transport Cost Analysis tool calculates the average cost per DS-3 as a function of the total number of DS-3s active on the CLEC-provided network. This is accomplished by calculating the equipment, frame quantities and collocation space required for the full range of demand for the complete network based on the 80 percent fill assumption for this network regardless of whether this traffic comes from backhaul or serving enterprise customer demand. The critical output for the backhaul impairment analysis is the cost of a CLEC-provided DS-3. The module produces this cost by dividing the levelized costs of collocation, equipment and outside plant by the efficiently utilized capacity of the investments.