Estimating the Cost of Nationwide Optical Fiber Network Development in Japan

- A Step toward a Cost-Benefit Analysis of the Fiber-to-the-Home Initiative -

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I. Introduction

I.1. Purpose

Fiber-to-the-Home (FTTH) has emerged as the fastest growing broadband access technology in Japan today. The rapid growth, however, causes concern over the divide between the areas with access to FTTH network and those without, and it is now one of Japan's leading telecommunications policy issues.

Positive policy action may be necessary for developing and expanding FTTH and eliminating the divide, but any of such initiatives should be premised on a quantitative understanding of the impact. One approach is to do a societal cost-benefit analysis of nationwide FTTH network development, which we consider as the final goal of our study.

This paper, however, focuses on estimating the cost of FTTH and analyzing the background of the current inequality of FTTH as a step toward full analysis. To clarify the priority of the issues being addressed, the inequality of FTTH is compared with those of other broadband services. We then estimate the cost of FTTH development. Finally, we examine the result to identify the geographical factors contributing the regional differences, the costly elements possibly preventing the development of FTTH and the investment level which is required for nationwide coverage.

I.2. Background

FTTH is a technology that enables broadband Internet access through the installation of optical fiber cable between the carrier's central office and the subscribers' premises. Figure 1 compares the various fixed-wire and wireless broadband access methods.

Figure 1: Broadband Access Methods

Type		Characteristics
DSL		○ Uses an existing single twisted-pair telephone line ○ Transmission speed is asymmetrical
	ADSL (Asynchronous Digital Subscriber Line)	○ Down link max speed of 50 Mbps, up link max speed of 3 Mbps ○ Transmission speeds are affected by distance and circumstances ○ Service area is limited to within 6 or 7 km of a carrier's central office
	VDSL (Very high bit rate Digital Subscriber Line)	○ Higher speeds than ADSL (down link about 100 Mbps), transmission distances are shorter (several hundreds meters)
Cable Internet		○ Uses the same coaxial cable used for cable television ○ Asymmetrical transmission with a down link max speed of 30 Mbps and an up link max speed of 1 Mbps ○ Actual speeds are influenced by distance and circumstances

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FTTH		○ Optical fiber cable link from the central office to subscriber premises ○ Very low loss, enabling long-distance transmission ○ Optical cable is not affected by electromagnetic interference
	PON (Passive Optical Network)	○ Symmetrical transmission with both up link and down link speeds of 100 Mbps to 1 Gbps ○ A single cable can support 32 branches, creating a cost advantage
	SS（Single Star）	○ A single cable connects the central office and subscriber premises without branching, creating a quality management advantage ○ Speeds of about 100 Mbps on both the up link and down link
Wireless Broadband		○ Transmission speeds vary from 1 Mbps to 156 Mbps ○ Actual speeds are affected by obstacles, weather, other wireless systems and etc.

FTTH excels in several categories. It can transmit up to 1 Gbps in both directions, there is very little line loss, and it is unaffected by electromagnetic interference, which makes it ideal for high-quality, long-distance transmission. The use of wavelength division multiplexing (WDM) can even boost transmission speeds by combining a number of disparate wavelengths and transmitting different signals simultaneously. Since FTTH is superior to ADSL with its metallic cable and to CATV with its coaxial cable, Japan is looking to FTTH to form the core of the network infrastructure for next-generation information and communication. The number of subscribers has ballooned in recent years to 2.03 million (September 2004), which represents a significant penetration rate compared internationally. Figure 2 shows that the FTTH subscribers are increasing by 137% per year, which is significantly higher than other broadband services.

Figure 2: Broadband Subscribers in Japan (Unit: 10,000)

Service Type	2002/9	2003/9	2004/9	Rate of increase 2003 to 2004
FTTH	19	86	203	137%
Cable internet	180	234	279	19%
DSL	422	923	1,280	39%
Total	621	1,243	1,762	42%

Based on the Ministry of Internal Affairs and Communications "FY 2004 Survey on Competition in the Telecommunications Industry"

Considering the wide range of applications being developed to take advantage of FTTH, it is expected that FTTH will help to resolve or mitigate a variety of socio-economic problems. The advantages of FTTH are enumerated in Figure 3.

Figure 3: The Advantages of FTTH

Shrinking the geographical divide	・ Enables a high degree of information/knowledge sharing with remote areas ・ Eliminates areas with poor TV reception ・ Create technologically advanced education, medicine, and other specialized/public services ・ Expand business opportunities

Promote participation	• Employment of and participation by the elderly • Employment of and participation by the people with disabilities • Make work and child rearing more compatible • Strengthen communications with remote areas
Increase efficiency	• Increased efficiency by substituting for travel • Creating a technologically advanced business environment for small and medium size companies • Create diverse employment opportunities through telecommuting • Reduce the burden on the environment

The issues facing FTTH are shown in Figure 4. They include removing the geographical divide that denies some the opportunity to use FTTH services; expanding the selection of services and content available through FTTH; and simplifying construction and reducing costs through technological developments.

Figure 4: Some of the Issues Facing FTTH

Shrinking the geographical divide	• Balanced development of infrastructure • Ensuring opportunities to participate in the digital society
Expanding services and content	• Development of business rules • Development and improved compatibility of payment and authentication infrastructure
Technological development	• Simplifying construction/reducing costs • Improving transmission capacity

The geographical divide in service availability in particular has become the biggest problem. A survey conducted by the Ministry of Internal Affairs and Communications (MIC) showed that as of March 2005, FTTH service was available in only 32% of Japan's municipalities, which is far below the 88% coverage of DSL[iii]. The MIC [1] has pointed out the relationship between municipality populations and the availability of broadband services, and they are addressing the necessity for policy support and specific action.

There may be differences, however, in the make up of the gap even within broadband services, and a quantitative understanding is necessary to prioritize the issues being addressed.

According to Otomo [2], we measured the degree of equality, or inequality, of the deployment of broadband services by using Lorenz curve and the Gini coefficient of concentration (G). Figure 5 shows the Lorenz curve[iv] and Figure 6 shows the value of (G)[v].

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iii This included partial as well as complete coverage.

iv All the municipalities are sorted by the number of household from smaller to larger, and categorized into 10 groups. Then the cumulative percentage of municipalities providing broadband services and the cumulative percentage of municipalities are plotted on the graph area.

v The Gini coefficient is the ratio of the area between Lorenz curve and the diagonal on a graph to the area under the diagonal, which is calculated by the formula bellow. The degree ranges from 0 to 1, 0 representing perfect equality and 1 total inequality. For our purposes, *n* is the number of household classes, and y^i is the number of regions providing service in class i, represented as a percentage, and x^i is that number as a percentage of all regions.

$$G = \left(\sum_{i=1}^{n-1} x_i y_{i+1}\right) - \left(\sum_{i=1}^{n-1} x_{i+1} y_i\right)$$

Figure 5: The Lorenz Curve for the Number of Areas Providing Each Service[vi]

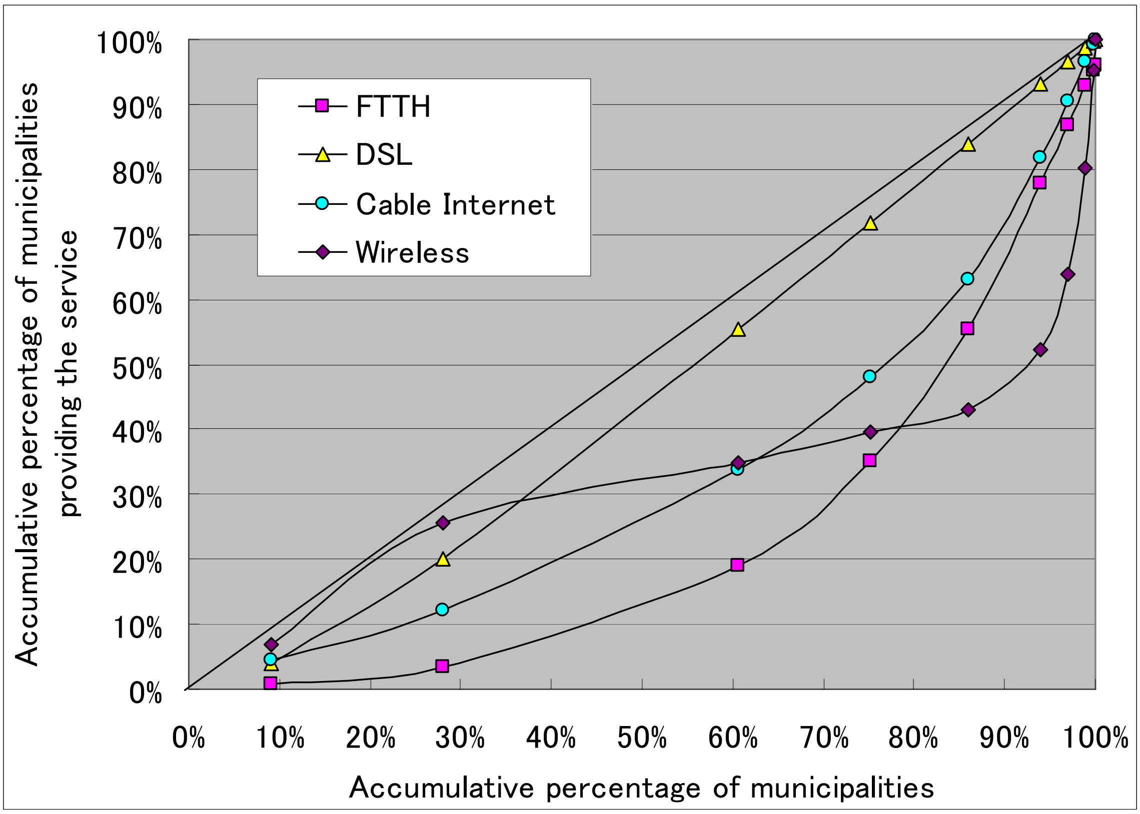

Figure 6: Value of (G)

	FTTH	DSL	Cable Internet	Wireless broadband
(G)	0.4906	0.0935	0.3504	0.3777

(G) = 0.4906 for FTTH has the greatest degree of inequality among the four services. In contrast, DSL has the lowest degree of inequality. The disproportionate distribution of cable Internet and wireless broadband is midway between that of FTTH and DSL, but the shape of their curves is much different from that of FTTH. Cable Internet has a more even distribution than FTTH because cable television has been developed in disadvantaged areas as a measure to reduce areas with poor reception. The distribution of wireless broadband is much greater in areas with fewer households since it is developed to supplement those areas where other broadband technology has not yet reached.

I.3. The Importance of This Research

As shown in the previous section, the distribution of FTTH is low, and the degree of regional inequality is much more pronounced than that of other broadband services. However, FTTH is expected to continue to be a primary access method because of its extremely small restrictions on transmission speeds. This makes the correction of regional differences in FTTH access the most important issue now. Although laws

vi Source; the Ministry of Internal Affairs and Communications and policy visions[vii] state that positive action should be taken to eradicate the gap, any of such initiatives should be premised on the analysis of the quantitative impact of FTTH development.

As mentioned, the goal of our study is to accomplish a cost-benefit analysis to examine the efficiency basis for such initiatives, and this paper focuses on estimating the cost as a step toward a full cost-benefit analysis.

For the purpose, we develop a cost model that can estimate the capital expenditure for FTTH on the municipality basis. This model provides the total cost required for nationwide development and the costs averaged by geographically grouped regions as well as the costs by elements composing FTTH.

In addition, we extract interpretations from the estimated result useful for understanding the background of the current divide. There are several possible reasons for the high degree of inequality with FTTH—from a simple time lag of demand to structural problems arising from the disproportion of the development cost—but an examination of the cost structure may provide a good handle to know what the reason is. We also examine geographical factors contributing the regional difference and costly elements, which may also be helpful to find efficient solutions to solve the divide.

On the topic of FTTH development, Oniki [3] discussed constructing the next-generation network, and he examined costs and benefits and offered a social system to achieve it. Cost-benefit analyses of FTTH development have also been tried by others, most notably Telecommunications Council [4], the Ministry of Posts and Telecommunications [5], and Kochi Prefecture [6]. Our research takes into consideration the technological advances of recent years and analyzes the geographical conditions, their relationship to costs, and other factors of the FTTH cost structure, to provide a new look at this subject.

II. Cost Model

II.1. Assumptions

Some broad assumptions were made when constructing the cost model.

First, this model does not assume competition between multiple carriers at the infrastructure level like in the real-world market, mostly in metropolitan areas. In contrast, this study assumes a single entity developing FTTH for the purpose of estimating cost.

Second, this model does not take into consideration some cost variations in materials between areas. For example, construction in metropolitan areas has higher labor costs and more safety regulations and standards than construction in outlying areas, which may make it more expensive.

Third, this model assumes the use of a passive optical network (PON), in which a single optical fiber cable is split and used by several people. Since the PON branches the optical cable and thus requires a lower investment in cable, it is more economically feasible when constructing a subscriber network.

Finally, this model only estimates the initial investment. In the benefit comparison that will be done later, we will include development period, depreciation, and maintenance costs, as well as other factors.

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vii Refer to Article 8 of the Basic Law for Forming an Advanced Info-Communications Network Society, "e-Japan Vital Planning 2004," "u-Japan Policy" etc.

II.2. Categorization of Geographical Conditions

While we can assume that there are few barriers to install cable in the lowlands, running fiber optic cable in the highlands requires detouring around ridges, and these and other difficulties can be expected to drive up the cost. In more developed areas, the higher population means more subscribers accessing proportionally less equipment, and more efficient use of the equipment can be assumed. To consider these influences, we categorized all the municipalities by geographical characteristics.

Explained in the later section, we assume that cable is installed along the roads, and we extracted four indexes[viii]—two (the Lowland index and the Highland Index) for terrain and two (the DID Index and the Urban Planning Index) for urban development levels—from the data on road side condition in *FY1999 Survey of Traffic Conditions on Streets and Highways* (The Road Traffic Census) [7]. We calculated these four indexes for all roads and then used the results to categorize each of the nation's 3,213 municipalities (as of April 2003, including the special districts of Tokyo) into five geographical categories as shown in Figure 7. Figure 8 shows the index values for each of the categories.

Figure 7: Five Categories Based on Geographical Characteristics

Category	Category Index Ranges	Assumed Geographical Characteristics
1. Urban Areas	DID Index of 0.5 or more	High percentage of densely populated areas
2. Lowland cities	Lowland Index of 0.8 or more Urban Planning Index of 0.5 or more	Lowlands that are relatively developed
3. Lowland suburbs	Lowland Index of 0.8 or more	Lowlands that are not densely populated
4. Highland cities	Highland Index of 0.2 or more (and Lowland Index of under 0.8) Urban Planning Index of 0.5 or more	Highlands that are relatively developed
5. Highland suburbs	Highland Index of 0.2 or more (and Lowland Index of under 0.8)	Highlands that are not densely populated

Figure 8: Index Values by Geographical Categories

Type	Number of Municipalities	Households (Thousands)	DID Index	Lowland Index	Urban Planning index
1. Urban Areas	166	18,060	**0.79**	0.97	0.99
2. Lowland cities	705	14,170	0.11	**0.96**	**0.91**
3. Lowland suburbs	366	1,492	0.01	**0.94**	0.15
4. Highland cities	508	10,373	0.08	0.60	**0.79**

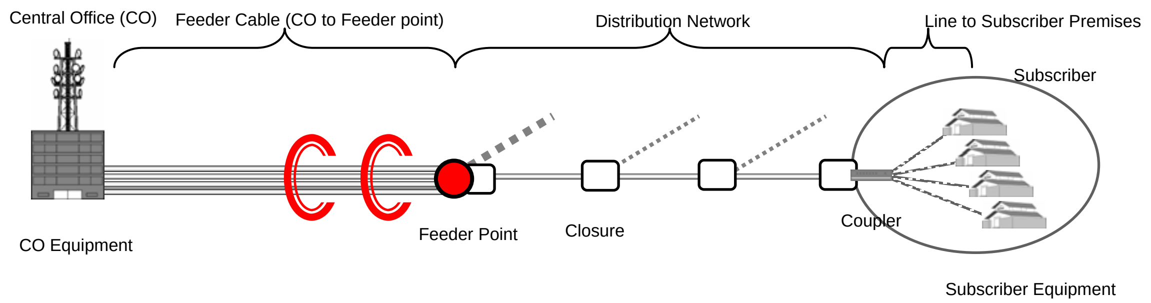
viii These indexes are calculated as follows: *DID Index* = DID Road Lengths/Total Road Length; *Urban Planning Index* = Urban Planning Road Lengths/Total Road Length; *Lowland index* = (DID Road Lengths + Other Urban Area Road Lengths + Lowland Road Lengths)/Total Road Length; and *Highland Index* = Highland Road Lengths/Total Road Length. DID roads are in areas with more than 5,000 inhabitants and abutted by dense populations per the national consensus (populations of more than 4,000 people per square kilometer). Other Urban Roads are roads in areas other than DID, that form a city area, and that are bounded by residences on both sides. Lowland Roads are in fields, lowlands, basins, and the like that are not abutted by residential housing, and where the grade of the roads is not steep. Highland Roads are in areas with rolling hills or foothills, where the grade of the roads is generally steep and the roads are not straight. Urban Planning Roads are in areas defined by Article 5 of the City Planning Law as cities with populations of more than 10,000, with more than 50% of the people engaged in non-agricultural work, and where the population at the center of the district is more than 3,000.

5. Highland suburbs	1,468	5,166	0.01	0.42	0.11
Total (Average)	3,213	49,261	0.08	0.65	0.44

II.3. Network Configuration

Figure 9 shows the FTTH network configuration assumed in this model.

Figure 9: FTTH Network Configuration



The network configuration between the central office and the subscriber's premises consists of a trunk line running from the central office to a feeder point, a distribution line running from the feeder point to the closure closest to the subscriber's premise, and a drop cable running from the closure to each subscriber's premises. An optical line terminal (OLT) is installed at the central office and an optical network unit (ONU) is installed at the subscriber's premises[ix].

As previously mentioned, we assume that optical fiber cable will be run along roads[x]. This method is not uncommon; Kochi Prefecture [6] did an estimate of FTTH development costs, and the Long-Run Incremental Costs Model Study Group [8] did an elaborate estimate for the telephone network. They both assumed cable would be run alongside roads. FTTH and CATV development projects conducted by local governments also install new cable aerially along the roads on a regular basis. We also assumed the distribution of feeder points and the number of premises covered by each subscriber point from the information of the existing telephone network, which determined the investment level for the optical cable in the distribution section, closures and couplers[xi].

III. Estimating Costs

We then estimated the initial FTTH investment cost per household based on the above information.

ix We assume that the system is installed on the existing facilities, e.g. buildings, poles and etc. to achieve maximum cost effectiveness in the FTTH development. While the multi-pair metallic cable used for telephone network was heavy, the cable between the central office and the feeder point was run underground in cabling ducts that cost much more to install, there is little need to run the optical cable underground since it is small and lightweight and is not affected by electro-magnetic interference.

x The specific calculation took the total road length within an area and divided it by the number of NTT central offices in those areas, and the average route length between each central office and its feeder points was assumed to be the cable length.

xi The actual feeder points on average cover an area with a radius of 500 meters, with an average of 300 households and a maximum of 600 households. To calculate the length of the wiring from the feeder point to the subscribers' premises, we assumed that the subscribers were evenly distributed around the feeder point on the arc of a circle that has the feeder point as its center, and the radius of that circle was that of a small circle, 1/2 the size of the service area of the feeder point. We assumed that closures were evenly spaced between the subscribers' premises, and that the route and core wire branched at each closure, and that the line is run to the subscriber's premises from the closure closest to the subscriber. We also assumed the coupler used on the network to branch the optical fiber cable is installed nearest to the subscriber for efficiency's sake.

There were four broad FTTH cost categories: central office equipment, feeder cable, distribution cable, and installation and subscriber equipment, shown in Figure 10. We calculated the per-household cost for these items in each area and totaled them.

Figure 10: FTTH Cost Items

Type	Description
Central Office Equipment	OLT PON Interface
Feeder cable (from central office to feeder point)	Running optical fiber cable Optical fiber cable core wire
Distribution (from the feeder point to the subscriber's joint closure)	Running optical fiber cable Optical fiber cable core wire Joint closure Coupler
Installation and subscriber equipment	Installation fee ONU

The conditions for each variable are shown in Figure 11. Since there is no published price for FTTH equipment and installation, we used the information collected from surveys on the preceding projects, contractors and other studies[xii].

Figure 11: Assumptions for Calculating Cost

Description	Unit price	Notes
Optical fiber cable installation	¥1 million/km	Based on FTTH and CATV development projects[xiii]. Estimates by Kochi Prefecture [6] were roughly ¥900,000
Optical fiber cable core wire	¥50,000/km[xiv]	Based on FTTH and CATV development projects. Actual unit cost will vary with degree of concentration, but this is average.
OLT	¥1 million/unit	Based on results of survey of FTTH development projects. Costs are split by 384 subscribers, the maximum number allowed per existing OLT specs
PON Interfaces	¥200,000/unit	Based on FTTH development projects. Device is added to OLT in response to service demand. Cost is split between 32 subscribers, the maximum number allowed.
Joint closure	¥20,000/50m	Based on FTTH development projects.
Coupler	¥320,000/unit	Based on survey results. Max 32 branches.
Installation	¥20,000/location	Includes wiring outside and inside the premises. Based on FTTH and CATV development projects.
ONU	¥10,000/unit	As use becomes more widespread, prices are expected to drop rapidly, so today's ADSL modem prices were used.

xii The technology for the equipment and cable used in FTTH networks is advancing so rapidly that using past surveys is almost meaningless. So, for items with a wide range of prices (optical fiber cable, installation fees), we took the average price of the prices in the lower third of the price range as our cost. The price of subscriber equipment was premised on rapidly falling prices, like those seen for DSL modems and similar equipment.

xiii Aerial distribution is quicker and less expensive than buried.

xiv The cost of optical fiber core depends on the concentration of cores in an optical fiber cable, but the cost is notably smaller than the cost of running optical fiber cable, so we used an average price for core wire to make the model simpler.

These basic costs may change with the volume of material procured during the actual development of the network, but the real FTTH and CATV development projects which we researched generally use an accumulative fixed-cost method, which is the same method we used in our estimates.

We categorized the estimated FTTH development costs from this model by geographical conditions, and the results are shown in Figure 12. We estimate the initial investment for FTTH development nationwide to be ¥7.79 trillion, or an average cost of ¥158 thousand per household. The estimated development cost per household in each area ranges from a low of ¥84 thousand in the urban areas to the highest of ¥583 thousand in the highland suburbs.

Figure 12: Average Development Cost per Household by Geographical Category

Type	Municipalities	Households (Thousands)	Cost per Household (thousand yen)	Total (billion yen)
1. Urban Areas	166	18,060	84	1,442.1
2. Lowland cities	705	14,170	216	2,084.1
3. Lowland suburbs	366	1,492	501	575.2
4. Highland cities	508	10,373	259	1,583.9
5. Highland suburbs	1,468	5,166	583	2,110.2
Total (Average)	3,213	49,261	-	7,795.4

To understand the cost structure, the estimated costs were broken down for each element of the cost model, the results of which are shown in Figure 13. The difference in optical fiber cable costs and central office equipment costs between categories is small, while the difference in cable installation costs between categories is very high.

Figure 13: Cost by Element (thousand yen)

Type	Cable Running Costs (To the Feeder point)	Optical Fiber Cable (To the Feeder point)	Central Office Equipment (OLT)
1. Urban Areas	16.39	15.20	8.88
2. Lowland cities	90.88	26.61	9.00
3. Lowland suburbs	297.99	29.81	9.23
4. Highland cities	119.59	29.66	9.10
5. Highland suburbs	364.62	38.48	9.53

Type	Cable Running Costs (Distribution network)	Optical Fiber Cable (Distribution network)	Distribution Network Equipment (closure, coupler,)
1. Urban Areas	1.49	0.32	11.39
2. Lowland cities	27.12	1.58	30.46
3. Lowland suburbs	72.04	3.72	58.44
4. Highland cities	33.62	1.89	34.73
5. Highland suburbs	75.83	3.90	60.87

IV. Examining the Results

IV.1. Difference by Geographical Conditions

In the FTTH development cost estimates shown in Figure 12, there is almost a seven-fold gap between the smallest value of ¥84,000 in the urban areas and the largest value of ¥583 thousand in the highland areas.

Comparing costs between terrain types, we see that the average development cost in the lowlands (categories 1, 2, and 3) is ¥282 thousand and the average in the highlands (categories 4 and 5) is ¥500,000, which forms a ratio of 1:1.76. In contrast, when comparing the degree of urbanization, we see that areas with an Urban Planning Ratio of more than 0.5 (categories 1, 2, 4) and an average development cost of 216 thousand, while suburban areas (categories 3 and 5) have an average cost of 567 thousand, for a ratio of 1:2.62. Figure 14 shows those ratios.

Figure 14: Linkage among the Cost and Indexes

Type	Lowlands	Highlands
Averaged Cost (thousand yen)	282	500
Ratio	1	1.76

Type	Urban	Suburban
Averaged Cost (thousand yen)	216	567
Ratio	1	2.62

IV.2. Cost by elements

As shown in Figure 15, the costs associated with optical fiber in each category are as follows: category 1, ¥18,000 (21% of development costs); category 2, ¥118,000 (55%); category 3, ¥370,000 (74%); category 4, ¥153,000 (59%); category 5, ¥440,000 (75%). The cost of running optical fiber cable as a percentage of total costs is higher in areas that are less urbanized.

Figure 15: Cost of Cable Installation by Category

Type	Total Cable Installation Costs per Household (thousand yen)	Percentage in the Total Cost per Household
1. Urban Areas	17.9	21%
2. Lowland cities	118.0	55%
3. Lowland suburbs	370.0	74%
4. Highland cities	153.2	59%
5. Highland suburbs	440.4	76%

IV.3. Investment Required for Nationwide Development

NTT [9] estimated that by the end of FY 2004 the percentage of feeder points converted to optical fiber was 83% for NTT East and 80% to 82% for NTT West. We calculated the initial investment by carriers to achieve 100% FTTH development, assuming that the percentage is directly applied to our cost model. These calculations assume that the subscriber will bear the cost of installation and ONU equipment and assumed that optical fiber conversion rate of the distribution network is the same as the percentage of FTTH service coverage in municipalities nationwide, which was reported as 32.0% at the end of FY 2004.

Based on the above, we estimated that of the 3,213 areas, 641 will not have optical fiber feeder points, and the cost required to convert the distribution network from the feeder point is ¥2.59 trillion.

IV.4. Interpretations

We estimate the initial investment for FTTH development nationwide to be ¥7.79 trillion. In 1994, the Telecommunications Council [4] estimated 75.0 million subscribers at a cost of ¥15.5 trillion, and in 2000, the Ministry of Posts and Telecommunications [5] estimated 52.7 million household and business subscribers at a cost of ¥9.3 trillion[xv]. The results of our estimates properly reflect the lower costs due to technological advances in recent years. The estimated average cost of ¥158 thousand per household also seems reasonable compared with the estimated average capital expenditure in the U.S. of $ 1590 per line in 2005[xvi]

As for the linkage between the cost and the geographical conditions, we can speculate that the per household development cost for FTTH will tend to be higher in terrain that is more highland, and costs will also tend to be higher in areas that are less urbanized. When comparing the terrain indexes with urbanization indexes, we can speculate that costs are more closely linked to urbanization.

The estimated development cost varies greatly with geographical conditions. This difference is probably an important factor contributing to the unequal distribution of FTTH services that we are seeing now, since the Lorenz curve in Figure 5 suggests that the areas with higher development cost have lower availability of FTTH, taking into account the fact that highland or suburban areas have fewer households. It is likely that policy support will be necessary to eliminate the geographical divide, and if so, it should have a framework that gives priority to support for areas with higher development cost.

We also found the possibility that reducing the cost of running optical fiber cable will greatly reduce the development cost per household, and that the less urbanized an area, the greater the benefit would be. One possible suggestion is the use of publicly owned but unused optical fiber, which is known as dark fiber. Based on a case study, Fujii [10] suggests that joint public/private use of the transit network in sparsely populated areas would lower the break-even point, which might help drive the development of the broadband communication environment. In our estimates as well, the use of dark fiber between the central office and the feeder points would lower the break-even point.

Finally, making a simple comparison of the estimated investment required for nationwide development, ¥2.59 trillion, to the nationwide development cost of ¥6.31 trillion, exclusive of installation and ONU cost, we see that about 60% of the investment required for FTTH development nationwide has already been made.

As discussed, the cost model is based on some broad assumptions that differ from reality, and the published information available to determine the unit price of each element composing FTTH is quite limited. Adjusting the estimates to better conform to reality remains an issue to resolve in the next step of our study.

V. Conclusion

As a step of a cost-benefit analysis, this study estimated the FTTH development cost for each

xv The figure is exclusive of installation costs and subscriber equipment.

xvi Source: TELEPHONY ONLINE, Mar. 1, 2005 municipality, the results of which were organized by geographical conditions, and this was used to estimate the difference in costs between areas, to describe the cost structure, and to estimate the required investment to develop FTTH nationwide.

From this, we found that development costs vary greatly with geographical conditions, and that the costs increase to the degree that the area is not urbanized or that it is a highland. The difference in costs is considered one of the factors behind the current unequal distribution of FTTH development. We also saw that the cable running costs forms a high percentage of the total cost, which indicates that the initial investment required could be reduced by using existing cable, such as dark fiber.

Finally, in addition to the cost-benefit analysis, there are a variety of issues that still need to be examined, including how to provide FTTH service to unprofitable areas. As we move toward a ubiquitous network society, we will also need to address new issues such as how to redefine universal service. We would like to continue our research and contribute to this discussion by clarifying the impact of FTTH on society.

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