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Developing the Method for Estimating the Costs of Providing Broadband Universal Service: Korean Case

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Developing the Method for Estimating the Costs of Providing Broadband Universal Service: Korean Case

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Abstracts

While the importance of both broadband itself and its speed increases in a whole society, the high cost of providing broadband as universal service at high-speed still raises a question of whether to introduce the USO. Therefore, the introduction of broadband universal service at 100Mbps since 2020 in Korea could be a meaningful case to study the necessity of broadband USO. This study attempts to propose an estimation model of the costs of providing broadband universal service in Korea and to introduce how the results by utilizing method can contribute to understanding the Korean case. In particular, since the proposed model was developed based on the bottom-up (BU) approach, which establishes an efficient network using the latest technologies, this paper suggested the accurate and reliable cost of providing broadband universal service with nationwide coverage in Korea by the estimation model. The main findings are twofold. First, the total cost of providing broadband USO at 100Mbps through FTTH technology was at ₩1.34 trillion. Since it was relatively small compared with the results in similar previous studies, the introduction of broadband universal service was reasonably acceptable in Korea. Second, there was no significant difference in the average cost per building for broadband USO between 50Mbps and 100Mbps; thus, the Korean government's decision, which sets the broadband speed for broadband USO at 100Mbps, was sufficiently reasonable at least from a cost perspective. Those results imply that at least developed countries with relatively high broadband penetration could consider providing broadband universal services at least 50Mbps by fiber-based technologies. They also suggest that the technology-neutral approach could contribute to the cost-effective deployment of broadband for USO.

Keywords: cost estimation; universal service; broadband; Korea

1. Introduction

As the importance of broadband increases in a whole society, the number of countries designating or planning to choose broadband as a universal service has also increased. Among them, in late 2018, the Korean government announced that a broadband universal service obligation (USO) of 100Mbps would apply since 2020. Although Korea is the leading country in broadband penetration in the world over the last decades (Picot & Wernick, 2007), there were still a significant amount of buildings where could not access high-speed broadband in rural areas of Korea as of May 2018¹. One surprising point of its decisions is the broadband download speed of 100Mbps for the broadband USO because perhaps it is the highest among the speed of USO worldwide². Even though broadband speed has a positive impact on the whole economy (Schneir & Xiong, 2016; Stocker & Whalley, 2018), the cost of deploying a broadband network has grown sharply as the speed required by USO increases (Stoker & Whalley, 2019)³. Some might argue that ultimately USO levels are subject to political and not technocratic decision making (Oughton, 2016). However, it is still necessary for governments to make reasonable and appropriate policy decisions about USO through a comprehensive process, including both qualitative and quantitative analyses. Especially, estimating the cost of establishing networks for broadband USO with nationwide coverage could be helpful for decision making in government, such as whether to introduce broadband USO or what speed level of the broadband USO. Although it is exceedingly difficult to accurately calculate the cost of providing broadband USO (Jeong & Kim, 2017), proposing an accurate and consistent method of estimating the total costs could also contribute to the operation of universal service policy.

The purpose of this paper is to propose an estimation model of the costs of providing broadband

¹ In December 2018, it was also released that there were about 800,000 buildings in Korea by the government that domestic ISPs cannot provide a fixed broadband service because of low profitability despite customer's requests.

² The highest speed obligation for the broadband USO is currently 10Mbps in the countries that introduced broadband USO, including the United States, Spain, and the United Kingdom. Meanwhile, among the countries planning to introduce the broadband USO, Canada has known to review to designate the broadband USO at 50Mbps.

³ For example, Stocker & Whalley (2019) mentioned based on Ofcom's technical note that it would cost £1.1 billion to provide broadband connections at 10Mbps in the United Kingdom and £1.9 billion if the obliged speed increases to 20Mbps.

universal service in Korea and to introduce how the results by utilizing the method can contribute to the Korean government's decision making. Because the analysis of the USO policy should focus on calculating incremental investment costs subject to the current broadband service coverage, it is not appropriate to estimate reasonable costs using a universal service operator's past investment history or future investment plans. Therefore, the proposed model was developed based on the bottom-up (BU) approach, which enables us to calculate the optimal incremental network costs by establishing an efficient network using the latest technologies. The model first designed two different fiber-based broadband access networks, which are fiber-to-the-curb (FTTC) and fiber-to-the-home (FTTH) networks at 23 sampled areas representing the whole country in Korea. Under the designed access networks, it estimated the incremental cost of deploying those networks for the broadband USO according to different scenarios depending on access technology (e.g., FTTC, FTTH, or least-cost technology), broadband speed (e.g., 20Mbps, 50Mbps, 100Mbps), and other elements. Because this study is perhaps the first attempt to quantitatively analyze the cost of providing the broadband universal service in Korea by the proposed estimation method, it could be entirely meaningful for academia and policymaker.

The rest of the article is structured as follows. Section 2 presents a literature review of scholarly articles and studies about broadband USO. Section 3 describes the geo-types, network architectures, and cost model employed for the analysis. Section 4 presents the results obtained: the average investment per building for providing broadband universal service and the total cost for achieving the 100% coverage through the broadband USO by different scenarios. It also presents a discussion of the results and policy implications. Finally, Section 5 offers a conclusion.

2. Literature Review

2.1. Previous studies on broadband universal service

Universal service is generally regarded as a telecommunication service that every citizen can access and use at a reasonable price (Batura, 2017), and the telecommunications act in Korea has also defined universal service at the same concept. Up to now, a fixed telephone service through PSTN has been widely designated as a universal service, and then several countries have recently begun to include broadband service as the scope of universal service. In most

cases, the broadband universal service has been interpreted as a fixed service through wired copper/fiber connection lines. However, from the principle of technology neutrality, some also argued that the scope of broadband universal services could be expanded flexibly and comprehensively in consideration of sharp changes in technology, consumers' preferences, and consumer usage patterns (Alleman, Rappoport & Banerjee, 2010). For example, the Finnish government included the mobile broadband service as the scope of broadband universal service in 2010, and the measure could be helpful for the government to achieve its broadband penetration goals (Benseny, Töyli, Hämmäinen & Arcia-Moret, 2019).

Most of the previous literature has focused on analyzing whether broadband should be within universal services, and broadband USO could contribute to broadband development, mostly in developed countries. First, from the positive aspects of broadband universal service, Bogojevic (2012) suggested that the broadband USO policy could be one of the measures or strategies to encourage broadband deployment despite the high cost of providing the broadband USO. The author also mentioned that broadband had been evaluated generally within the scope of universal service in Europe, except for the intervention cost criteria.

Second, there are also some studies suggesting negative aspects of broadband universal service. Falch & Henten (2009) suggested that the broadband penetration rate is continuously increasing in Europe, even though there are still differences between European countries and between cities and rural areas, and the competition between domestic ISPs through various access technologies is getting fierce. Thus they argued that the necessity to impose the broadband USO is not quite sufficient. Alleman, Rappoport & Banerjee (2010) also pointed out that the designation of broadband as universal service should be carefully considered because the introduction of the USO concept can cause distortions in the economic efficiency of the broadband market. Furthermore, Batura (2017) insisted that the broadband USO policy cannot be effective when used in broadband development and that it is possible to achieve broadband coverage goals more effectively through other broadband policy instruments.

Lastly, there are some previous studies on broadband universal service, which are not related to the necessity of introducing broadband USO. For example, Boik (2017) analyzed the users' pattern of adoption and substitution of broadband services in North Carolina in the United States. He found that the broadband USO policy did not lead to the adoption of broadband universal service by users, and there was a substitute relationship between high-speed fixed

broadband service and low-speed one. Stoker & Whalley (2019) qualitatively analyzed responses to the Broadband USO consultation by Ofcom and focused on suggesting policy implications for the government's operation of the broadband USO policy in the United Kingdom.

In summary, as shown in Table 1, a few different previous studies have tried to analyze the necessity of broadband USO from various aspects, including the relationship between the broadband USO policy and broadband development, mostly in developed countries. However, the rationale for their arguments seems to be relatively limited because the quantitative analyses, including the total cost of providing broadband universal service, were not performed.

Table 1. Previous studies on broadband universal service

Previous study	Pros and cons of broadband universal service	Relationship between broadband universal service and broadband development
Falch & Henten (2009)	Opposition (Unnecessary)	Broadband development is achieved through market competition without imposing universal service obligations.
Alleman, Rappoport & Banerjee (2010)	Neutral	No specific comments
Ragoobar, Whalley & Harle (2011)	Assent (Necessary)	USO could boost NGA deployment in rural areas in the United Kingdom.
Bogojevic (2012)	Assent (Necessary)	The inclusion of broadband in the scope of universal service could be one of the measures and strategies to encourage broadband development.
Batura (2017)	Opposition (Unnecessary)	The universal service policy in Europe is unlikely to be effective when used for broadband development.
Boik (2017)	Neutral	Households do not unconditionally adopt broadband universal service, and low-speed broadband can be chosen instead of high-speed one from a cost perspective.
Stoker & Whalley (2019)	Neutral	No specific comments

2.2. Previous studies on estimating the cost of providing broadband services

Most recent research on estimating the cost of offering broadband services has focused on analyzing the establishment of broadband networks in rural areas where the penetration rate at

the broadband is quite low. First, Schneir & Xiong (2016) estimated the total costs of providing broadband services at 30Mbps or 100Mbps, which are the targets that should be met by 2020, according to the European Digital Agenda. Their results showed that the cost of deploying broadband for non-urban or rural areas is 80% higher on average compared to urban areas, and the cost of providing broadband services was the highest when using FTTH technology and the lowest when using VDSL one.

Second, Oughton (2016) calculated the total cost of providing broadband over fiber connection lines to satisfy the 'needs' required in the United Kingdom. The author showed the result that the cost of deploying the broadband network in the urban area, which accounts for 70% of the whole United Kingdom, would be between £14.1 billion and £17.0 billion. In contrast, the deployment cost of the non-urban or rural areas, accounting for the remaining 30%, would reach between £13.7 billion and £15.8 billion. He also suggested that technologies such as fiber-to-distribution-point (FTTDP) could be acceptable in the short term because of the high cost of providing broadband services when using FTTH technology.

Finally, Ioannou, Katsianis, & Varoutas (2020) estimated the net present value (NPV) of establishing the broadband networks using FTTDP, VDSL, and LTE based fixed wireless access (FWA) technologies to provide broadband services at 30 Mbps in rural areas in Europe. As a result of the analysis, they suggested that LTE based FWA could be a feasible and cost-effective solution for providing broadband services at 30Mbps in rural areas.

In summary, although the studies mentioned above could give meaningful implications for broadband universal service located in non-urban or rural areas, they still did not sufficiently address in detail the total costs of providing broadband universal service. Therefore, their results seem to have limitations for assessing the validity of the broadband USO policy.

2.3. Previous studies on the broadband USO in Korea

Several studies have focused on the broadband USO in Korea by some domestic scholars. First, before the Korean government decided the introduction of the broadband USO, some studies attempted to examine the necessity of the broadband USO in Korea. For example, Lee & Lee (2015) evaluated whether broadband to regard as a universal service based on the essential criteria for imposing universal service requirements in Europe and suggested that the necessity

of broadband universal service was relatively low. By contrast, Jung & Kim (2017) insisted that broadband universal service should be necessary because it is not possible to provide broadband services to all the households even though the competitive market in Korea. Second, after the Korean government's announcement on the introduction of the broadband USO, a few studies attempted to suggest the policy strategies for the broadband USO in Korea. Ko, Jung & Yeo (2019) suggested some issues consider for the successful introduction of the broadband USO policy in Korea, including the scope of the USO (nationwide or regional), the speed, and the financing method.

However, the studies mentioned above have limitations that did not sufficiently address quantitative analyses. They examined the necessity of broadband universal service in Korea, but the necessary cost for the broadband USO as the evidence of their arguments was not explicitly analyzed. While they also emphasized that the high-quality broadband universal service was required, whether the additional investment to increase the speed of broadband USO can be acceptable was not analyzed quantitatively. Therefore, different from the previous studies, this study estimating the cost of establishing networks for the broadband universal service with nationwide coverage could be helpful for decision making in government, such as whether to introduce the USO or what speed level of broadband for USO.

2.4. Summary of the literature review

In summary, the literature review shows that there is a lack of cost studies related to broadband networks for broadband USO through quantitative analysis. Several authors have addressed whether to implement the broadband USO policy and whether the measure could encourage broadband development. Different authors have worked on estimating the cost of providing broadband in rural areas without considering broadband USO. Moreover, there are very few studies regarding the cost of providing broadband universal service in Korea. Therefore, this paper is meaningful as the first attempt to quantitatively calculate the cost of introducing the broadband USO in Korea by proposing the method estimating the cost.

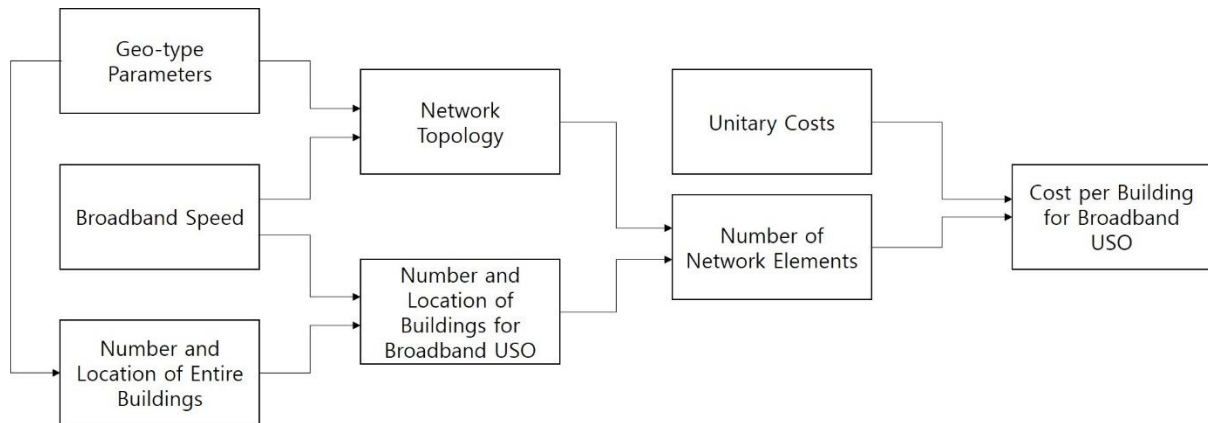
3. Methodology for the Cost of Providing Broadband Universal Service in Korea

This section describes the procedure employed, the features of the geo-types, the network architectures used, and the proposed cost model to estimate the costs of providing broadband universal services in Korea.

3.1. Cost estimation procedure

The procedure employed for estimating the costs of providing broadband universal services in Korea is depicted in Figure 1. The geo-types were classified in nine types across the country, and 23 areas representing each geo-type were selected as samples for estimating the total cost of providing broadband USO in Korea. The specific information about the geo-types is provided in Section 3.2 of the article. Based on each geo-type, it was possible to prepare a network design and define a network topology. Section 3.3 explains the network architecture employed. The number and location of entire buildings, buildings providing broadband currently, and buildings where broadband is non-provided could be derived based on the national broadband coverage data submitted by all domestic ISPs as of 2016. The calculation of the number of network elements was performed through redesigning the optimal broadband access network using information about the network topology and the number and location of buildings. As shown in Figure 1, the cost per premise is based on the total additional cost to achieve a broadband coverage of 100% in Korea. Section 3.4 describes the cost model and different input parameters employed, such as the unitary costs of network elements. The input values for the cost model were obtained from the domestic ISPs and by interviewing some professionals.

Figure 1. Flow chart with the procedure for the cost estimation



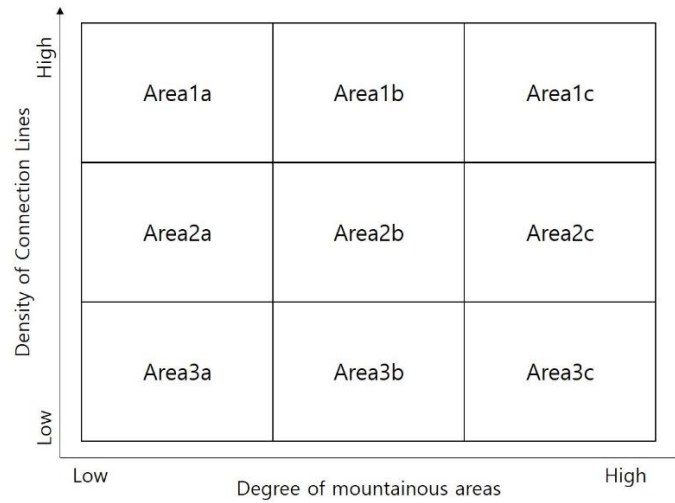
3.2. Geo-type approach

In the previous studies, geo-types were classified considering the characteristics of the United Kingdom (Analysys Mason, 2008) or Europe (Schneir & Xiong, 2016) to calculate the cost of broadband deployment. Therefore, it is not appropriate to apply the geo-type approach to the classification of geo-types in Korea, where has different population density and regional characteristics.

Instead, in this study, to classify geo-types that characterize all of Korea, the geo-type approach used for calculating fixed termination rates in Korea was applied. As shown in Figure 2, according to the case of estimating fixed termination rates in Korea, the Korean regions are classified into nine geo-types, consisting of a high, medium, and low, respectively, based on both the density of connection lines and the degree of mountainous areas in Korea. Because it is not possible to redesign the fixed network in all regions of the country to calculate fixed termination rates, a total of 20 areas representing Korea was selected. Each area should be close to the average for each of geo-types and minimize regional bias.

Since it is not also possible to redesign broadband networks in all regions of the country, this paper accepts the approach mentioned above to estimate the cost of providing broadband universal service. Twenty areas representing Korea, according to the nine geo-type, were also selected. Besides, considering that the households subject to broadband universal services are likely to be located in rural areas and can also be subject to universal fixed telephone service, three areas were additionally selected.

Figure 2. Classification of the geo-types in Korea



3.3. Network architectures

In general, there are three types of fixed broadband access networks: copper, fiber, and cable-based networks (Schneir & Xiong, 2016). Among them, this study considered only fiber-based access networks through FTTH and FTTC technologies, based on the number of broadband connections by technologies in Korea. VDSL network, which can reuse all the existing copper-based access networks, could also be considered generally from the perspective of cost reduction for providing broadband universal service (Falch & Henten, 2009). However, as shown in Figure 3, the number of VDSL connections accounts for only 2.6% of all broadband connection lines in Korea as of February 2020; thus VDSL network is excluded from consideration for this study. Cable-based HFC network is also not considered as an alternative for providing broadband universal services because the major domestic ISPs have almost not used the access technology up to now in Korea⁴.

Figure 4 shows the network elements of the two fiber-based network architectures employed in this study. First, for FTTH, the access network is composed of fiber cables from the central office to the customer premises. Both an ethernet passive optical network (EPON) and a gigabit

⁴ For example, as of February 2020, the biggest ISP (Korea Telecom) in Korea does not have any cable-based broadband connection lines, and the proportion of the HFC broadband connection of the second-largest operator (SK Broadband) and the third-largest one (LGU+) is only 11.4% and 14.4%, respectively, of their total broadband connections.

passive optical network (GPON) is generally considered in the FTTH network architecture in Korea. The optical network terminal (ONT) is also employed in the network architecture. Second, for FTTC, while the fiber cables should be deployed from the central office to the distribution point unit (DPU), the existing copper lines or UTP cables could be used from the DPU to the customer premises⁵. Both EPOIN and GPON are also employed for transmission over the fiber line in the FTTC network architecture.

Figure 3. Number of fixed broadband connections by access technologies in Korea

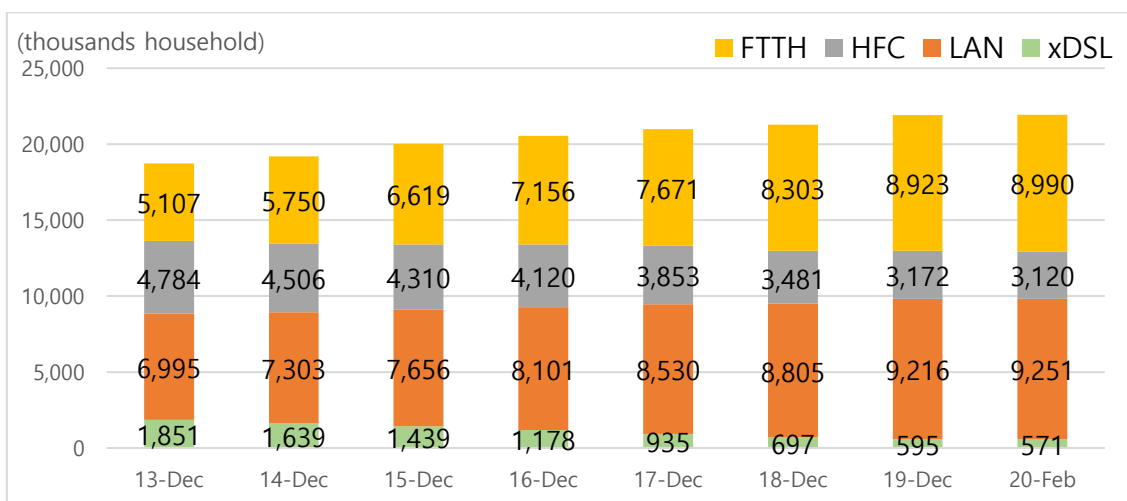
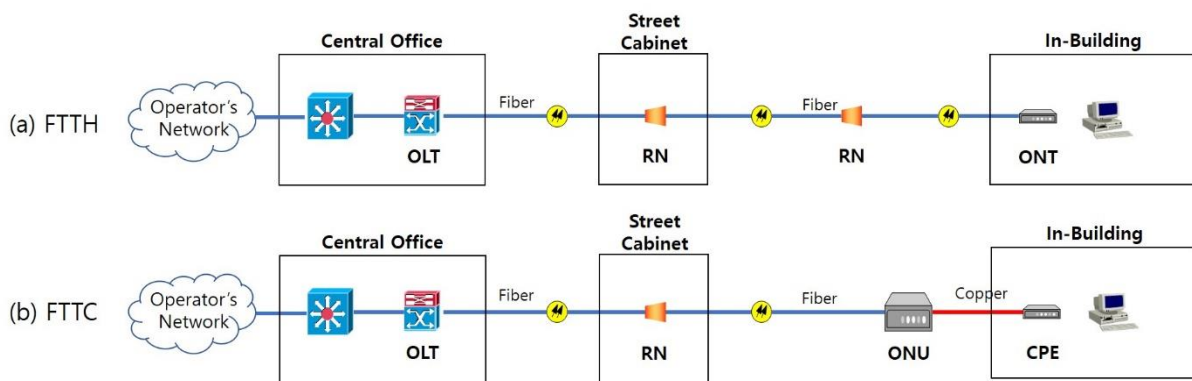


Figure 4. Network architectures for FTTH and FTTC in Korea



⁵ The term 'FTTC network' described in this study is different from the general FTTC concept, which is composed of fiber cables from the central office to the street cabinet. Because the length of the existing copper line is relatively short in the network architecture, the 'FTTC network' mentioned in this study could be closer to the FTTP network that Schneir and Xiong (2016) explained in their research.

3.4. Cost Model

Based on the geo-type mentioned above and the network architecture, this study estimated the total cost of providing broadband universal services in 23 sample areas in Korea. First, the input data employed for this study are as follows: the number and location of entire buildings, buildings providing broadband currently, and buildings where broadband is non-provided at 23 sample areas from the data submitted by all domestic ISPs as of 2016; the data of geographic information system (GIS); the location of the central office and the second remote node (RN) of the biggest domestic ISP at 23 sample areas, by assuming that the largest ISP is regarded as the representative and its location of both the central office and the second RN is fixed for providing the broadband USO.

Second, based on the input data mentioned above, the optimal and efficient access network from the central office to the terminal buildings at 23 sample areas is redesigned under the bottom-up (BU) approach. The designed network is composed of three sections - from the central office to the first remote node (RN), from the first RN to the second RN, and from the second RN to the terminal buildings - and the optimization algorithm redesigns each sub-network⁶. The first network from the central office to the second RN is assumed to be deployed through the fiber cable, and the second network from the second RN to the terminal buildings is redesigned through either the fiber cable (FTTH) or the copper cable (FTTC) by different scenario. In the case of passive infrastructure, only the deployment of poles from the second RN to the terminal buildings is considered from the perspective of redesigning the cost-efficient network. The specification of the network elements employed in this study was initially obtained from the domestic ISPs and decided finally by interviewing some professionals. From the results of the redesigned access network, the amount of each network element, which is necessary for providing broadband universal service at 23 sample areas, is calculated.

Third, the total cost of the broadband coverage of 100% at 23 sample areas was estimated from the amount of each network element, which is calculated from the redesigned network, and the unitary cost of each network element obtained from the domestic ISPs. The cost of deployment of in-building connection lines and the cost of customer premise equipment (CPE) or subscriber

⁶ Although the access network from the central office to the second RN is redesigned under the BU approach without the consideration of the current network architecture of the domestic ISP, the redesigned network does not affect the estimation of the total cost of providing broadband universal service in Korea.

modem for broadband were excluded from the estimated cost because consumers generally pay those costs to use broadband service in Korea. This study also calculated the total cost of providing broadband to current subscribers under the same approach. Finally, it figured the total additional cost of offering broadband universal service at 23 sample areas in Korea as the difference between those two total costs mentioned above. For the analysis of the total cost for the introduction of broadband USO in Korea, the annualized cost, including indirect costs, operating expenses, and cost of capital, was not estimated in this study. The cost to invest core network is also excluded under the assumption that it is not necessary to additionally invest the core network for providing broadband universal service in Korea.

Finally, the cost per building at 23 sample areas was estimated by dividing the above-mentioned total additional cost of providing broadband universal service by the number of buildings where broadband is currently non-provided. Considering that the 23 areas are selected from the nine geo-types across the country, the average cost per building at each geo-type could be then calculated. Therefore, based on the average cost per building and the national broadband coverage data obtained from the domestic ISPs, the total cost for the introduction of the broadband USO in Korea is finally estimated.

4. Results and Policy Implications

4.1. Results

Table 2 shows the findings related to the cost per building by the geo-type, access technology, and broadband speed employed in this study. First, the cost per building for the geo-type Area 3 was higher than for the geo-type Area 1 and Area 2. Since the geo-type Area 3 includes most of the rural areas have in Korea, the result shows that the cost of providing broadband universal service in rural areas is quite higher than in urban areas, which is consistent with previous studies (Schneir & Xiong, 2016; Oughton, 2016). The high cost per building in rural areas also means that the length between the second RN to the terminal building, which should be deployed for the broadband USO, is relatively long due to the current inadequate broadband coverage in rural areas.

Second, there is no single cost-effective access technology for broadband USO across the country. Instead, depending on the geo-type, either FTTH or FTTC was selected as the cost-

effective access technology for the broadband USO, individual case by case. The result of the cost per building through the least-cost technology was almost always lower than other cases, meaning that the technology-neutral approach could contribute to the cost-effective deployment of broadband for USO.

Third, despite the positive relationship between broadband speed and cost per building, the difference in the cost per building between 50Mbps and 100Mbps did not seem to be significant. The result implies that, under the fiber-based broadband access network, domestic ISPs could quickly increase the broadband speed from 50Mbps to 100Mbps without the additional deployment of network elements.

The total costs necessary for providing broadband universal services at the national level have also been estimated by multiplying the number of households located in a geo-type by the average cost per building of the geo-type. Table 3 shows the total costs of the introduction of the broadband USO by the three access technologies and the three broadband speed analyzed in the study. If all the geo-types were to be covered with FTTH, the total cost would be from ₩1.32 trillion (at 20Mbps) to ₩1.34 trillion (at 100Mbps), whereas the total cost would be from ₩1.30 trillion (at 20Mbps) to ₩1.32 trillion (at 100Mbps) at FTTC case. Instead, based on the least-cost technology, the total cost would be reduced about from ₩1.09 trillion (at 20Mbps) to ₩1.11 trillion (at 100Mbps).

Table 2. Investment per building for the broadband USO in Korea (Korean Won)

		FTTH			FTTC			Least-Cost Technology		
		20Mbps	50Mbps	100Mbps	20Mbps	50Mbps	100Mbps	20Mbps	50Mbps	100Mbps
Area1 (High density)	Area1a	759,095	758,682	758,682	1,260,108	1,261,916	1,262,820	722,451	724,259	724,259
	Area1b	520,661	520,661	520,661	937,646	942,094	942,094	469,936	474,384	474,384
	Area1c	778,644	778,644	778,644	1,201,936	1,202,278	1,202,278	740,053	740,394	740,394
	Total	761,971	761,967	761,967	1,250,728	1,251,431	1,252,916	728,902	729,606	729,605
Area2 (Medium density)	Area2a	596,287	596,287	596,287	1,296,368	1,296,368	1,296,368	588,680	588,680	588,680
	Area2b	980,128	979,691	979,691	1,307,479	1,310,560	1,310,560	905,287	908,368	908,368
	Area2c	1,635,329	1,635,329	1,635,329	1,901,213	1,901,509	1,901,509	1,518,901	1,519,197	1,519,197
	Total	1,185,181	1,185,181	1,185,181	1,602,809	1,604,748	1,604,748	1,114,879	1,116,817	1,116,817
Area3 (Low density)	Area3a	1,439,987	1,440,073	1,440,073	1,318,216	1,318,680	1,318,680	1,173,711	1,174,176	1,174,176
	Area3b	928,696	928,696	928,696	741,140	741,140	741,140	623,133	623,133	623,133
	Area3c	1,293,060	1,292,287	1,293,048	1,126,518	1,126,531	1,126,558	989,579	989,592	989,622
	Total	1,338,103	1,338,139	1,338,163	1,311,419	1,311,237	1,311,265	1,100,097	1,099,953	1,099,953

Table 3. Total cost for the broadband USO in Korea (Billion Korean Won)

	FTHH	FTTC	Least-Cost Technology
20Mbps	1,322.4	1,303.8	1,089.3
50Mbps	1,343.1	1,324.0	1,106.2
100Mbps	1,343.2	1,324.0	1,106.3

4.2. Policy implications

The results analyzed in the previous section highlight a series of issues that need to be considered by policymakers. First, calculating the cost of providing broadband universal service with nationwide coverage by the reasonable estimation model could directly contribute to the government's decision making for the broadband USO. For example, the results of this study support that the introduction of broadband universal service is acceptable in Korea in terms of the estimated total costs. The total cost of providing broadband USO at 100Mbps through FTTH technology was at ₩1.34 trillion, which was relatively small compared with the results mentioned in similar previous studies (Bogojevic, 2012; Stock & Whalley, 2019). Besides, as Stock & Whalley (2019) suggested, since the number of eligible buildings receiving broadband speed of less than 100Mbps has declined considerably, the total cost of providing the broadband USO in Korea could subsequently fall compared with the results in this study.

Second, it may be necessary to consider imposing the speed obligation at higher than 50Mbps at least in developed countries from the perspective of the migration from copper- to fiber-based broadband access networks. Although there are many considerations to decide the speed required by USO (Stock & Whalley, 2019), as the broadband access network has migrated to fiber-based network architectures, the government could easily enable to increase the speed of the broadband USO in the future. The results of this study that there is no significant difference in the average cost per building for the broadband USO between 50Mbps and 100Mbps also support that providing broadband universal service at least 50Mbps might be acceptable in developed countries by optical-based broadband access technology. The results also show some evidence that the Korean government's decision, which sets the broadband speed for the broadband USO at 100Mbps, was sufficiently reasonable at least from a cost perspective. For more robust evidence to policymakers, it could also be helpful to additionally analyze whether

the cost-saving created by providing broadband USO at 50Mbps through copper-based VDSL technology is less than the economic benefit generated by providing the service at 100Mbps.

Lastly, in terms of the technology-neutral approach, it could be necessary to consider providing broadband universal services through more cost-effective alternative access technologies. Because the cost of deploying broadband via fixed access networks increases sharply depending on the total length from the street cabinet to the terminal building, the wireless access technologies such as FWA can be a cost-effective alternative, consistent with previous studies (Alleman, Rappoport & Banerjee, 2010; Stocker & Whalley, 2019). Although the total cost of providing fiber-based broadband universal services could be reasonably acceptable in Korea, the Korean government could also consider including wireless access technology as a scope of the technological alternatives for the broadband USO to reduce the costs of the USO policy.

5. Conclusion

The introduction of broadband universal service at 100Mbps since 2020 in Korea is a crucial case to study the necessity of broadband USO. While the importance of both broadband itself and its speed increases in a whole society, the high cost of providing broadband universal service at high-speed still raises a question of whether to introduce the USO. Therefore, the appropriate estimation of the cost of deploying networks for the broadband USO can be helpful for decision making in government. This study attempts to propose an estimation model of the costs of providing broadband universal service in Korea and to introduce how the results by utilizing method can contribute to understanding the Korean case. In particular, since the proposed model was developed based on the bottom-up (BU) approach, which establishes an efficient network using the latest technologies, this paper could suggest the accurate and reliable cost of providing broadband universal service with nationwide coverage in Korea by the estimation model.

The main findings of this study as follows: First, the total cost of providing broadband USO at 100Mbps through FTTH technology was at ₩1.34 trillion, which was relatively small compared with the results mentioned in similar previous studies (Bogojevic, 2012; Stock & Whalley, 2019); thus the introduction of the broadband universal service was reasonably

acceptable in Korea in terms of the estimated total costs. Second, there is no significant difference in the average cost per building for the broadband USO between 50Mbps and 100Mbps, thus the Korean government's decision, which sets the broadband speed for the broadband USO at 100Mbps, was sufficiently reasonable at least from a cost perspective. Those results imply that at least developed countries with relatively high broadband penetration could consider providing broadband universal services at least 50Mbps by fiber-based technologies. They also suggest that the technology-neutral approach could contribute to the cost-effective deployment of broadband for USO.

Despite some meaningful implications, this study also has limitations. First of all, since the broadband universal service has just started in 2020, the relationship between the USO policy and broadband development could not be addressed. Further research is necessary to study the issue quantitatively. Besides, this study focused on estimating the total cost of providing the USO at nationwide coverage, thus did not try to calculate the annualized cost, including CAPEX and OPEX. Further research analyzing the annualized cost for the broadband USO could contribute to the operation of the USO policy in terms of how to fund a USO.

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