Economic Broadband Development through Infrastructure Sharing

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ABSTRACT

Broadband is a public utility with positive effects on competitiveness, employment and growth. Although evidence shows that broadband development is increasing, this increment is not homogeneous between urban and rural areas. The main factor is the high cost for deploying next generation networks in rural areas, and especially the cost linked to civil engineering works. In order to overcome the investment challenges arising in the context of broadband deployment, the European Commission made mandatory the sharing of existing telecommunication and non-telecommunication infrastructures and facilities. This manuscript proposes and presents a novel tool that enables the estimation of the expected savings from exploiting existing infrastructures when deploying a broadband network. This is followed by a number of general principles and recommendations that policy makers and national authorities could embrace to diminish deployment costs and promote broadband deployment.

Keywords: Broadband, Case Study, Cost Reduction Tool, Digital Agenda, Policy Recommendations

INTRODUCTION

Broadband constitutes a key priority of the 21st century as it is an important determinant of economic growth, social cohesion and citizen well-being. Broadband development can have a strong and widespread impact by, for example, fostering and facilitating economic development and improving social networks and structures (Bouras et al., 2013; Khan & Raahemi, 2008; Mack,

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2014). Effects of broadband on economic growth relate to the positive influence in terms of business activities, technology and productivity enhancement, competition increase and upgraded public sector services. At the same time, societal benefits of broadband mainly stem from the fact that the existence of fast and ultra-fast internet provides individuals access to services which were unattainable before broadband, enhancing social inclusion and equal access.

Although evidence shows that broadband adoption is increasing, this effect is not homogeneous. On the contrary, significant differences exist, not only between countries but also within each country between rural and urban areas. At an international level, countries still show non-convergent paths, while even within the most developed countries a persistent digital divide is present between urban and rural areas, as well as between wealthier and poorer regions (Florence School of Regulation, 2011). The heterogeneous coverage of broadband connections among territories as well as the observed inadequacies in the telecommunication infrastructure and accessibility to services among countries, regions or even individuals hamper substantially economic growth, competitiveness, convergence and social cohesion.

It comes as no surprise that the increase of broadband deployment and the simultaneous reduction of observed disparities have become important policy aims, declared and shared by many national and transnational political institutions, regulatory bodies and independent agencies. To this end, the European Commission (EC) drafted the Digital Agenda for Europe as one of the flagship initiatives for Europe 2020 aiming at providing sustainable economic and social benefits from a digital single market based on high-speed broadband services (European Commission, 2015). The ambitious targets of the Digital Agenda aim to achieve 100% coverage at speeds of at least 30 Mbps for all Europeans and subscription of internet connection above 100 Mbps for 50% or more of European households until 2020.

In order to fulfil the above objectives, the Digital Agenda has stressed the need for additional efforts to be made in order to overcome the investment challenges arising in the context of broadband deployment. By introducing policies that reduce the overall cost of broadband development, the Digital Agenda aims at prompting Member States to accelerate the deployment of Next-Generation Access (NGA) networks across Europe. Integral part of those policy initiatives is the development of a common approach on mapping existing physical infrastructures in conjunction with the systematic coordination by national, regional, and local authorities (e.g. using town planning rules and remedies), mandating the sharing of existing telecommunication and non-telecommunication infrastructures and facilities; civil engineering works are commonly referred to as targets of such infrastructure sharing policies since their cost makes up a significant part of the overall deployment cost.

This manuscript presents a novel tool that enables the calculation of the savings during the deployment or the expansion of NGA networks through the sharing of existing and / or common development of new infrastructures. The tool was developed and financed in the context of the South East Europe (SEE) Transnational Cooperation Programme project “SIVA - South East Europe improved virtual accessibility through joint initiatives facilitating the roll-out of broadband networks”, and was pilot tested for a period of two months. The results of the pilot operation are included in this work together with some recommendations that could be embraced to diminish deployment costs.

The remainder of the manuscript is organized as follows: The following section describes the SEE Transnational Cooperation Programme on improved virtual accessibility that ignited the research for this work. Next we describe the problem that triggered the concept of infrastructure sharing. The fourth section presents the Cost Reduction Assessment Tool and its main features, and in the following section we analyze the main results from its pilot operation. Then, we provide some policy recommendations based on the analysis and in the last section we conclude the manuscript and we make suggestions for future work. Finally, The Appendix presents the mathematical formulae and the main assumptions for calculating the amount of the telecommunication items/services that are required for the network development.

THE SIVA PROJECT

The inception of this manuscript is attributed to project SIVA (SIVA Project, 2014a). SIVA stands for "South East Europe improved virtual accessibility through joint initiatives facilitating the roll-out of broadband networks". The Regional Association of Local Governments of Western Macedonia is the lead partner of a consortium that consists of eleven partners and covers seven SEE countries. SIVA project aims to contribute to the improvement of the accessibility of SEE through broadband services, as substitute for and supplementing physical accessibility and thus to the narrowing the digital gap in SEE.

In terms of broadband infrastructure and services, SEE area showcases complex and diverse behaviour. There is a large gap in telecommunication infrastructure and broadband access between SEE area and the rest of Europe. There is also a substantial gap among SEE countries and among rural and urban areas of a country. Access to information, however, is a prerequisite for development and competitiveness, and it has been shown that access to information, broadband connectivity and financing of virtual accessibility are key components necessary for the development, adoption and use of Information and Communications Technology (ICT) in the economy and society. Thus, tackling this problem would help improve integration and competitiveness.

SIVA's initiatives will result to tangible structural long term changes on virtual accessibility strategies in the partners' territories. Partners' virtual accessibility and broadband planning strategies will be improved through the foreseen activities as regards the evidence made available on the quality of experience of broadband access, on the most cost-effective technological solutions to expand broadband coverage, and on the cost savings, simplicity and speed of deployment by promoting the sharing of infrastructures.

RELATED WORK

There is a serious digital gap that is quite evident in terms of telecommunication services and infrastructures between the European Union (EU) as a whole and SEE as an independent area of interest (Antonis et al., 2014a; Antonis et al., 2014b; Herdon et al., 2015). Notably, SEE demonstrates on average a number of 154 internet users per 1000 people, while the EU figure is more than double. What is more, a heterogeneous diffusion of broadband connections is also evident among countries of SEE as well as between urban and rural areas within the same territories; this heterogeneous coverage stems mainly from the fact that market mechanisms fail to address adequately the low population density in rural and remote areas. Inadequacies in the telecommunication infrastructure and accessibility to broadband services in individual countries, or even regions and cities within the same country, significantly hamper competitiveness and cohesion. These problems, explaining to a significant extent the existing digital inequalities among countries and regions within the same territories, have been widely acknowledged both at the EU level and in the SEE area (at a national as well as at a local level).

The existence of these inequalities highlights the necessity for public interventions in order to create economic incentives towards the deployment of high-speed broadband infrastructure. The latter will improve virtual accessibility in SEE territories and reduce the digital gap by achieving service improvement in terms of coverage rate, speed and pricing. Acknowledging the need and importance of policies and action plans to provide better broadband coverage and high-speed services, the EU stresses the need for additional efforts to be made in order to address the investment challenge of high-speed broadband infrastructure - such as the proper design and implementation of Public-Private Partnerships in rural areas (Next Generation Fixed Networks: Eastern Europe, 2014) - which is the main bottleneck tackling and delaying the reaching of broadband targets set out by the EC.

In that context, the reuse of existing physical infrastructures can diminish the capital investments costs for broadband network deployment. It is estimated that around 80% of the costs of deploying new fixed infrastructure are civil engineering costs (i.e. trenching or digging) which can be significantly reduced through proper coordination between national, regional and local authorities, using town planning rules and remedies mandating access to passive infrastructures (Analysys Mason, 2008). Hasbani et al. (2007) refer that in one fixed-network sharing case, multiple cost components would be affected and optimized if two or more operators share their network. Set-up costs could be reduced by as much as 40 percent, and utilization costs could be reduced by 20 percent. Wireless and mobile communication costs can similarly be reduced by infrastructure sharing and proper network planning (Katsigiannis & Valagiannopoulos, 2014; Paul et al., 2010). Diminishing this cost removes an important barrier, and is associated with a significant and positive effect on the economic viability of new and existing broadband networks.

An example of infrastructure sharing is the agreement between Orange and Vodafone to share infrastructure in the United Kingdom and in Spain, while managing their own traffic independently and remaining competitors at the wholesale and retail level (Lefèvre, 2008). According to Vodafone, the UK sharing agreement will reduce capital and operating costs by up to 30 per cent. In Spain, the arrangement will reduce the operators' number of sites by around 40 per cent. In addition, the case study results presented by Pereira & Ferreira (2012), illustrate the importance of infrastructure sharing for new entrants both in Fiber to the Home (FTTH) and Long Term Evolution (LTE). The presented results give important information about the two different solutions in urban and rural areas, indicating that both technologies can provide for sustainable business.

Several research works, like the work by Rajabiun & Middleton (2015), have investigated the technological, regulatory, and business landscape from the perspective of sharing network resources. Frisanco et al. (2008) propose several approaches and technical solutions for network sharing. They introduce a model for estimating savings on capital and operating expenses, and present simulation for various scenarios. Meddoura et al. (2011) investigate the regulatory and technical-economical dimensions in connection with the sharing of mobile telecommunication networks in emerging countries. They analyze the estimated savings on capital and operating expenses, while assessing the technical constraints, applicability and benefits of the network sharing solutions.

Several tools have also been developed based on the infrastructure sharing concept. For example, the tool by Baselinemag (2004) can be used to estimate the cost of a wireless network, while the tool by Homewyse (2015) can be used to calculate the cost of a computer network wiring. But none of these tools can support hybrid networks as our tool does. As the following section presents, there are several more differences compared to our tool. For example, our tool supports the drawing of a network on a map where you can zoom in/out for more detailed description, it also supports technology definition and it is much more parameterized.

THE COST REDUCTION ASSESSMENT TOOL

Based on the importance of infrastructure sharing, the Cost Reduction Assessment Tool provides decision makers and planners a means to calculate effectively the total cost of a broadband deployment project for a specific area taking into account the financial benefits drawn from the utilisation and reuse of the existing infrastructures. This section highlights the main features of this tool and presents the procedure that is required for its usage. The tool is available online at SIVA Project (2014b).

Regarding the technologies that were used for the development of the tool, HTML5 and JavaScript were the preferred technologies for the frontend user interface. The backend part is based on PHP for data management and the MySQL Database Management System for data storing. Finally, the Google Maps JavaScript API v3 was used for the insertion of available fiber optic network infrastructure on the maps (see below).

The tool is designed to be user-friendly; however, detailed information about the proposed network planning and a detailed account of existing broadband infrastructures are required for estimating the total cost of the investment as well as the savings to be expected through the sharing of infrastructures. The source of this information could be an inventory of existing infrastructures such as national cadastres of infrastructures. In case such information is available, the calculation of the total cost for a proposed broadband deployment project can be disaggregated into the following stages:

- Technology definition;
- Network design;
- Definition of fiber optic (FO) network requirements;
- Definition of wireless network requirements;
- Insertion of available FO network infrastructure;
- Insertion of available wireless network infrastructure;
- Selection of related costs (i.e. standby staff, etc.);
- Costs/savings calculations and statistics.

These stages are presented in the following paragraphs along with explanatory screenshots, while the Appendix presents the mathematical model that the tool is based on.

Technology Definition

To begin with, users have to determine which type of technology (FTTH or/and wireless) the network will include through the corresponding drop-down menu (Figure 1).

Depending on the selection, some new tabs will appear on the top of the page, e.g. if only FTTH is selected, the “Definition of wireless network requirements” and the “Insertion of available wireless network infrastructure” stages will be omitted. In order to make a complete presentation of the tool, in our scenario we have selected a hybrid network that combines both FTTH and WiFi technologies.

Network Design

In the “Network Design” stage (Figure 2), which is available only if FTTH technology is used, users can create a graphic representation of the proposed network. They may zoom in the desired area (or enter the address where the network will be designed), draw lines to design the route

Figure 1. "Technology definition" stage screenshot

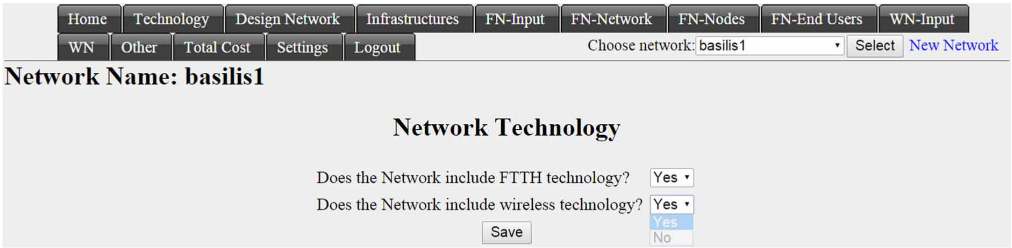
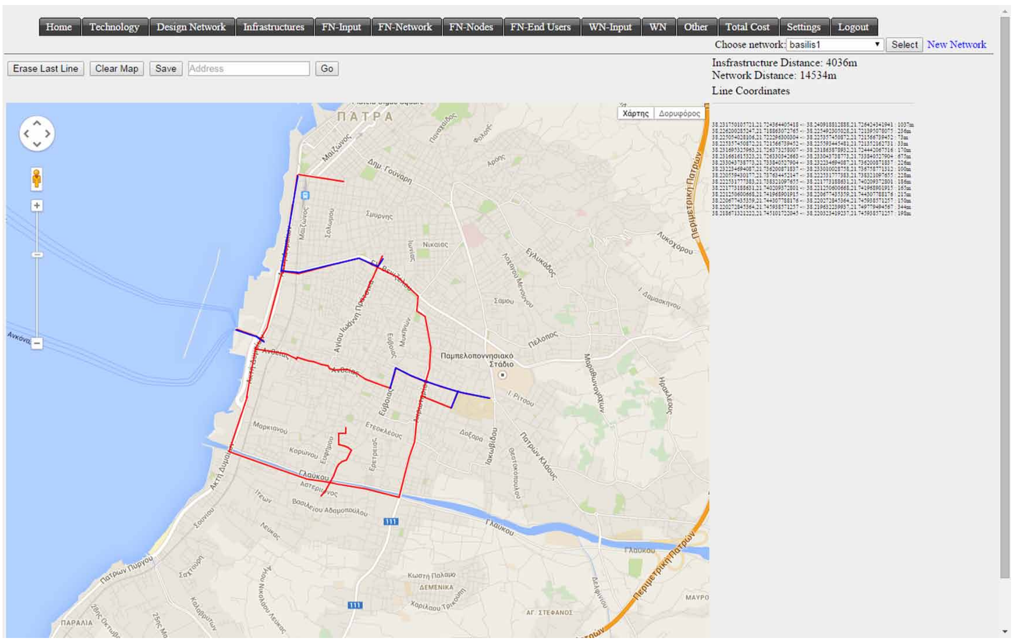


Figure 2. "Network design" stage screenshot

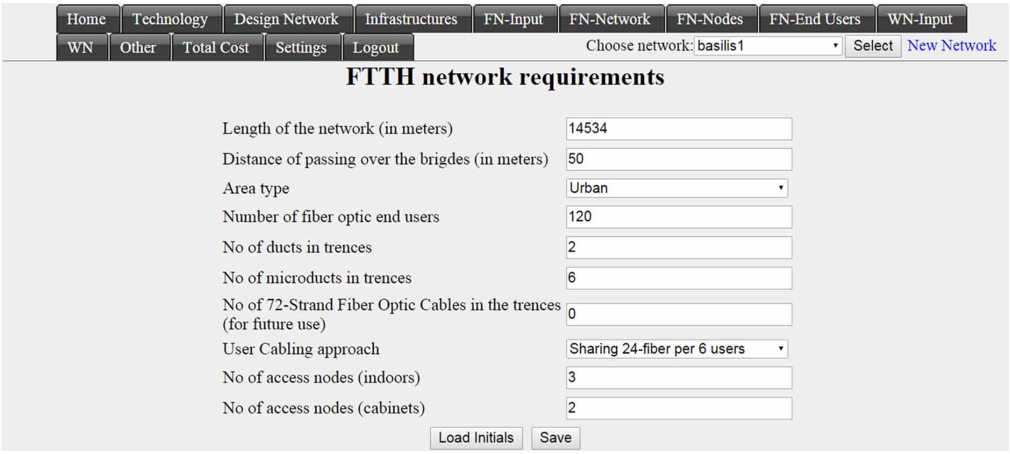


of the network (red line in Figure 2), erase undesired lines or clear the map and start from the beginning. The tool automatically informs the users regarding the total length of the network that has been designed. It also supports the input of available infrastructures through the network route (blue lines in Figure 2).

Definition of FO Network Requirements

Users have to define the FTTH network requirements providing specific details in 10 fields of interest (Figure 3). These fields are used to collect information regarding the length of the network (automatically completed from Stage 2), the distance of passing over bridges (if any), the area type, the number of fiber optic end users, the number of ducts/microducts/fiber optic cables in trenches, the user cabling approach and the number of access nodes (indoors and cabinets). Based on this input, the tool estimates and outlines the infrastructure/equipment requirements and specifications for the construction of the proposed FTTH network.

Figure 3. "Definition of FO network requirements" stage screenshot



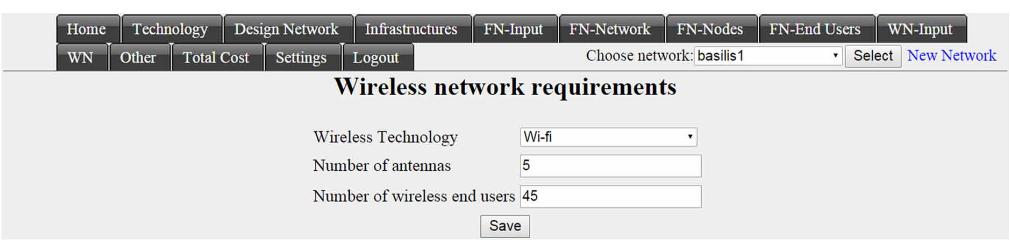
Definition of Wireless Network Requirements

This stage is available only if the option "wireless technology" is selected in the "Technology Definition" stage. Users are required to define the Wireless network requirements and provide input in three fields (wireless technology, number of antennas and number of end users, as shown in Figure 4). This information is used to generate estimates of the necessary infrastructures and outline the requirements for the construction of the wireless network.

Insertion of Available FO Network Infrastructure

Having defined the requirements for the FTTH network, the tool automatically calculates the amount of the telecommunication items/services that are required for the network development, e.g. the number of manholes, optical distribution frames, switches, etc. The tool also provides up-to-date prices for each item/service that can be altered by the users. At this stage users should insert the amount of the available infrastructure for each item/service, i.e. complete the "Available Infrastructure" column in Figure 5. Based on users' insertion, the tool automatically calculates the cost per item/service and the total cost with and without the use of existing infrastructure.

Figure 4. "Definition of wireless network requirements" stage screenshot



Insertion of Available Wireless Network Infrastructure

As in the previous stage, users have to fill in the available amount of the items that already exist and can be utilized for the construction of the wireless network (Figure 6). Based on the automatically-calculated amount of the items required to construct the network as well as their cost estimation, the tool calculates the total cost for the construction of the wireless network with and without the use of the existing infrastructure.

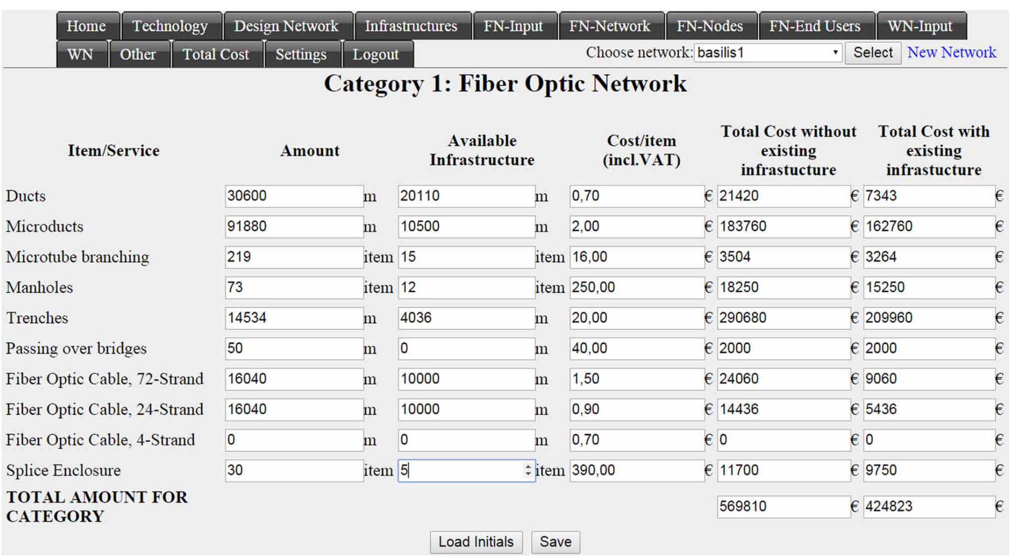
Selection of Related Costs

This stage asks from users to select which other services are required to be included in the cost estimation for the proposed network. As depicted in Figure 7, such services may be precautionary services, repairing works, standby staff, measurements instruments and equipment, system maintenance and instalments documentation. Since these services do not relate to existing infrastructures, they are not used to calculate differences in the cost with and without infrastructure sharing; however they are useful for estimating the total cost for deploying a network and then calculating the (overall) expected impact from utilizing existing infrastructures.

Costs/Savings Calculations and Statistics

The final stage includes the overall estimation of the total cost of the proposed network as well as the breakdown cost per process category. Finally, the tool compares the costs of the proposed investment with or without the utilisation of the existing infrastructures and estimates the financial gains from the reuse of the available facilities (Figure 8).

Figure 5. "Insertion of available FO network infrastructure" stage screenshot


Home | Technology | Design Network | Infrastructures | FN-Input | FN-Network | FN-Nodes | FN-End Users | WN-Input
WN | Other | Total Cost | Settings | Logout — Choose network: basilis1 — Select — New Network

Category 1: Fiber Optic Network

Item/Service	Amount	Available Infrastructure	Cost/item (incl.VAT)	Total Cost without existing infrastucture	Total Cost with existing infrastucture
Ducts	30600 m	20110 m	0,70 €	21420 €	7343 €
Microducts	91880 m	10500 m	2,00 €	183760 €	162760 €
Microtube branching	219 item	15 item	16,00 €	3504 €	3264 €
Manholes	73 item	12 item	250,00 €	18250 €	15250 €
Trenches	14534 m	4036 m	20,00 €	290680 €	209960 €
Passing over bridges	50 m	0 m	40,00 €	2000 €	2000 €
Fiber Optic Cable, 72-Strand	16040 m	10000 m	1,50 €	24060 €	9060 €
Fiber Optic Cable, 24-Strand	16040 m	10000 m	0,90 €	14436 €	5436 €
Fiber Optic Cable, 4-Strand	0 m	0 m	0,70 €	0 €	0 €
Splice Enclosure	30 item	5 item	390,00 €	11700 €	9750 €
TOTAL AMOUNT FOR CATEGORY				569810 €	424823 €

Load Initials | Save

Figure 6. *"Insertion of available wireless network infrastructure" stage screenshot*

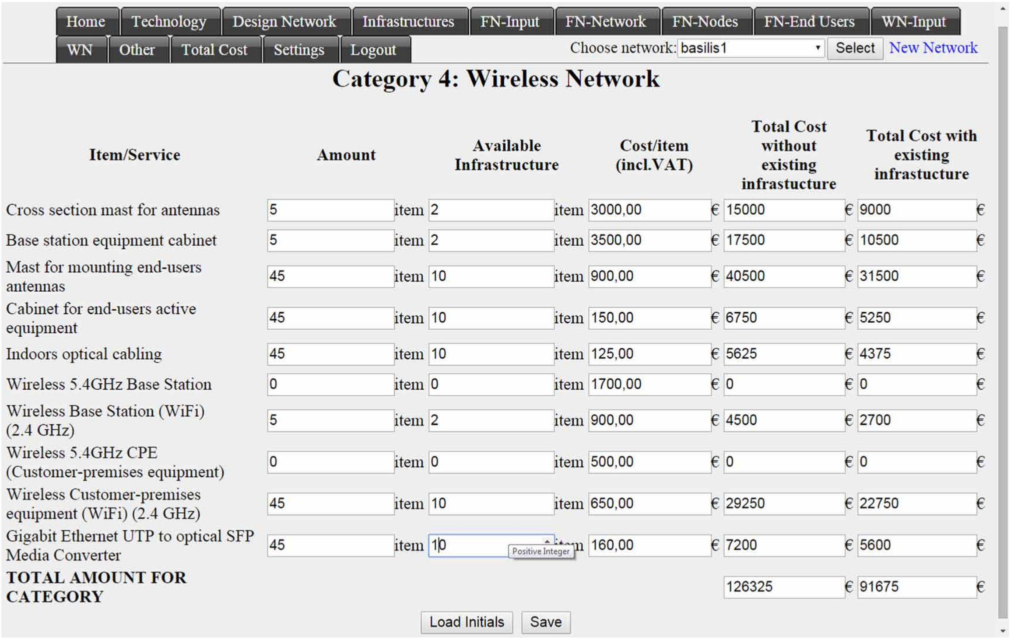
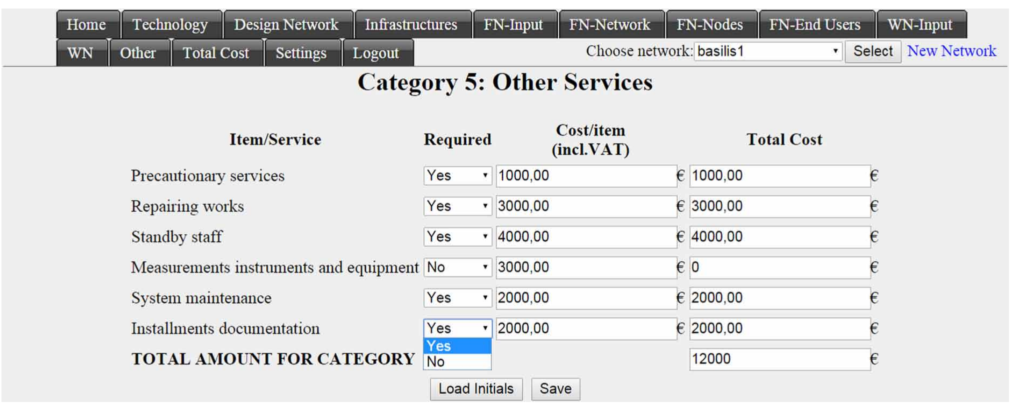


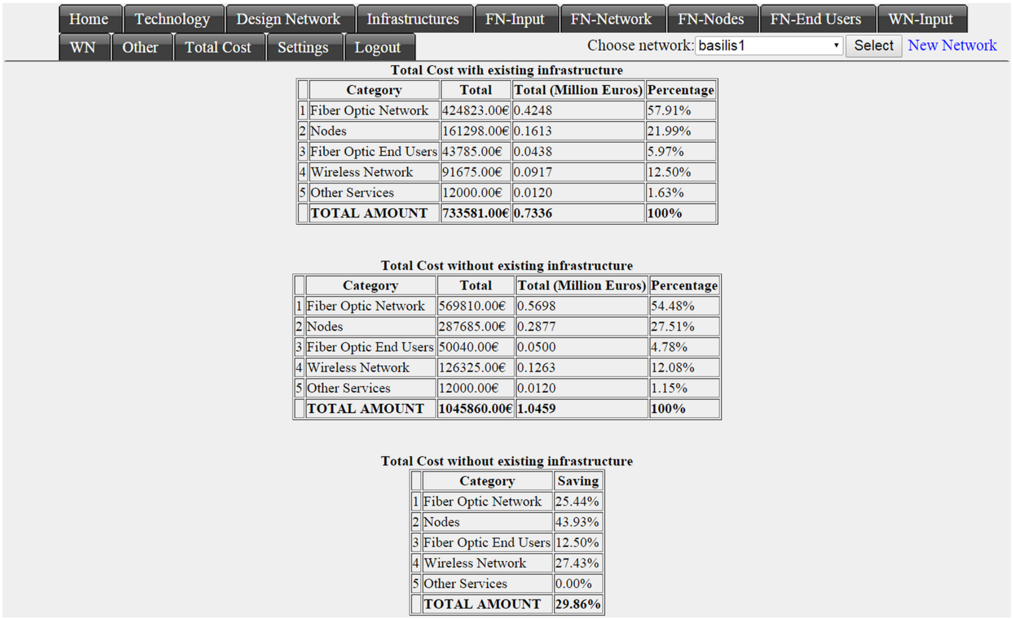
Figure 7. *"Selection of related costs" stage screenshot*



CASE STUDIES RESULTS

The Cost Reduction Assessment Tool was pilot tested for a period of two months, from May until June 2014, in three locations: Heraklion (GR), Molise Region (IT) and Kyustendil (BG). During the pilot operation, three different case studies of proposed broadband network deployments were examined, based on actual data. Among the collected cases, the Greek case refers to the deployment of a hybrid FTTH and wireless network in an urban environment while the other two refer to a FTTH network deployment in a rural environment. Table 1 presents the network

Figure 8. "Costs/savings calculations and statistics" stage screenshot



Total Cost with existing infrastructure

	Category	Total	Total (Million Euros)	Percentage
1	Fiber Optic Network	424823.00€	0.4248	57.91%
2	Nodes	161298.00€	0.1613	21.99%
3	Fiber Optic End Users	43785.00€	0.0438	5.97%
4	Wireless Network	91675.00€	0.0917	12.50%
5	Other Services	12000.00€	0.0120	1.63%
	TOTAL AMOUNT	**733581.00€**	**0.7336**	**100%**

Total Cost without existing infrastructure

	Category	Total	Total (Million Euros)	Percentage
1	Fiber Optic Network	569810.00€	0.5698	54.48%
2	Nodes	287685.00€	0.2877	27.51%
3	Fiber Optic End Users	50040.00€	0.0500	4.78%
4	Wireless Network	126325.00€	0.1263	12.08%
5	Other Services	12000.00€	0.0120	1.15%
	TOTAL AMOUNT	**1045860.00€**	**1.0459**	**100%**

Total Cost without existing infrastructure

	Category	Saving
1	Fiber Optic Network	25.44%
2	Nodes	43.93%
3	Fiber Optic End Users	12.50%
4	Wireless Network	27.43%
5	Other Services	0.00%
	TOTAL AMOUNT	**29.86%**

requirements that were set for each case study, and Table 2 the required (calculated automatically by the tool) and available (inserted by users) infrastructures.

Heraklion, Greece

The case study in Heraklion involves a FTTH network with an overall length of 8.1 km. The network will be deployed in an urban environment and is expected to provide connectivity to 100 end users. In order for the network to be deployed, it is necessary to use two ducts and 7 microducts in appropriate trenches. The number of necessary access nodes amounts to 3 indoors access nodes and 4 telecommunication cabinets. The FTTH network will be complemented with a wireless network, using Wi-Fi technology, which is expected to consist of 30 antennas and is expected to provide services to 500 end users (Table 1).

Table 1. FTTH and wireless networks requirements for the three case studies

	Parameter	Unit	Heraklion (GR)	Molise (IT)	Kyustendil (BG)
FTTH	Length of the network	m	8100	2476	1950
	Distance of passing over bridges	m	0	0	50
	Area type		Urban	Rural	Rural
	Number of fiber optic end users		100	100	50
	No of ducts in trenches		2	1	1
	No of microducts in trenches		7	1	1
	No of 72-Strand FO Cables in trenches		1	1	1
	User cabling approach		Sharing 24-fiber per 6 users	Sharing 24-fiber per 6 users	Sharing 24-fiber per 6 users
	No of access nodes (indoors)		3	2	1
	No of access nodes (cabinets)		4	2	1
Wireless	Wireless technology		Wi-Fi	-	-
	Number of antennas		30	-	-
	Number of wireless end users		500	-	-

Table 2. Required and available infrastructure for the three case studies

	Item/Service	Unit	Heraklion (GR)		Molise (IT)		Kyustendil (BG)	
			Required	Available	Required	Available	Required	Available
Fiber Optic (FO) Network	Ducts	m	17010	14000	2600	2600	2100	1000
	Microducts	m	59535	49000	2600	-	2100	1200
	Microtube branching		122	1	38	-	30	-
	Manholes		27	20	5	-	4	-
	Trenches	m	8100	7000	2476	2476	1950	1500
	Passing over bridges	m	-	-	-	-	50	-
	Fiber Optic Cable, 72-Strand	m	8910	-	2724	-	2200	1200
	Fiber Optic Cable, 24-Strand	m	5304	5304	2838	-	2292	1200
	Fiber Optic Cable, 4-Strand	m	-	-	-	-	-	-
	Splice Enclosure		17	-	5	-	4	4
FO Nodes	Cabinets for access nodes		4	-	2	2	1	1
	Rooms for indoor access node		3	3	2	-	1	-
	Optical Distribution Frames (ODF) Rack cabinets		14	3	8	-	4	-
	Optical Distribution Frames (ODF)		59	5	41	-	21	5
	Splices		1416	-	104	-	104	35
	Cross-Connect (XC patchcords)		1416	-	104	-	104	40
	Fiber Optic patchcords		604	-	76	-	76	15
	Fiber optic cable for ODF interconnection		2	-	2	-	2	-
	Rack cabinet 19" 39U		7	1	4	-	2	-
	Node ethernet switches - 24 ports		7	3	8	-	4	-
	Air conditioning for indoors nodes		3	1	2	-	1	-
	Nodes' interior design		3	1	2	-	1	-
	Node UPS		3	3	2	-	1	-
	Node security system		3	1	2	-	1	-
FO Users	Compact termination box - 4 connectors		100	-	10	-	10	5
	Indoors optical cabling		100	-	40	-	40	20
	Gigabit Ethernet UTP to optical SFP Media Converter		100	-	40	-	40	20
Wireless Network	Cross section mast for antennas		30	24	-	-	-	-
	Base station equipment cabinet		30	24	-	-	-	-
	Mast for mounting end-users antennas		500	500	-	-	-	-
	Cabinet for end-users active equipment		-	-	-	-	-	-
	Indoors optical cabling		18	18	-	-	-	-
	Wireless Base Station (WiFi) (2.4 GHz)		30	24	-	-	-	-
	Wireless Customer-premises equipment (WiFi)		-	-	-	-	-	-
	Gigabit Ethernet UTP to optical SFP Media Converter		18	18	-	-	-	-
Other Services	Precautionary services		✓	-	✓	-	✓	-
	Repairing works		✓	-	✓	-	✓	-
	Standby staff		✓	-	✓	-	✓	-
	Measurements instruments and equipment		✓	-	✓	-	✓	-
	System maintenance		✓	-	✓	-	✓	-
	Installments documentation		✓	-	✓	-	✓	-

According to Table 2, an important characteristic of the proposed project is that a significant part of the infrastructure is already available for most of the categories identified in the tool, i.e. "Fiber Optic (FO) Network", "FO Nodes", "FO Users" and "Wireless Network".

The cost reduction assessment tool utilises the data regarding the necessary infrastructures for a new network and estimates the expected benefits (in monetary terms) from utilizing existing infrastructures. Figure 9 contains a summary of these cost estimations per category, while Figure 10 presents the percentage savings with the use of existing infrastructure. It can be seen that the utilization of existing infrastructures is expected to result in a 72% overall cost reduction (692,000 €). Savings are concentrated in three categories, with "Wireless Network" featuring the most significant individual gains. On the contrary, no gains are expected in the "FO users" category. Even though "Other services" are not (by definition) relevant to infrastructure sharing, and thus no gains are expected in this category as a component of the total cost, they are included in order to increase the accuracy of the total estimation.

Molise Region, Italy

According to Table 1, the case study of Molise region describes the deployment of an FTTH broadband network in a rural area. The designs foresee the deployment of a network with an overall length of almost 2.5km, without bridge crossings. The expected number of end-users is 100 and the selected technology involves the sharing of a 24-fiber per 6 users. The network under design does not include a wireless component.

Table 2 indicates that infrastructure availability is limited only to the "Fiber Optic Network" and "FO Nodes" categories. In the "Fiber Optic Network" category there are only two types of

Figure 9. Heraklion case study: Cost with and without existing infrastructure

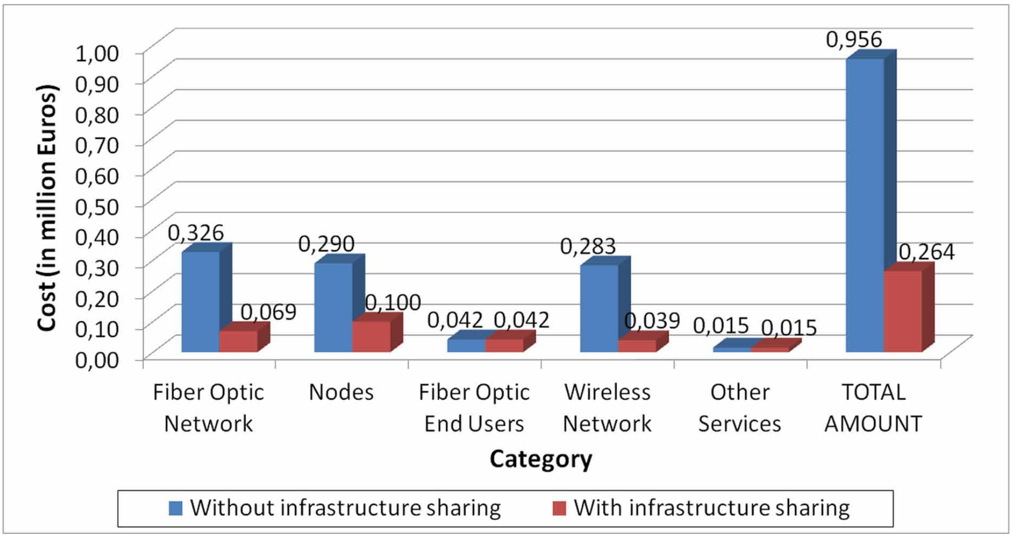
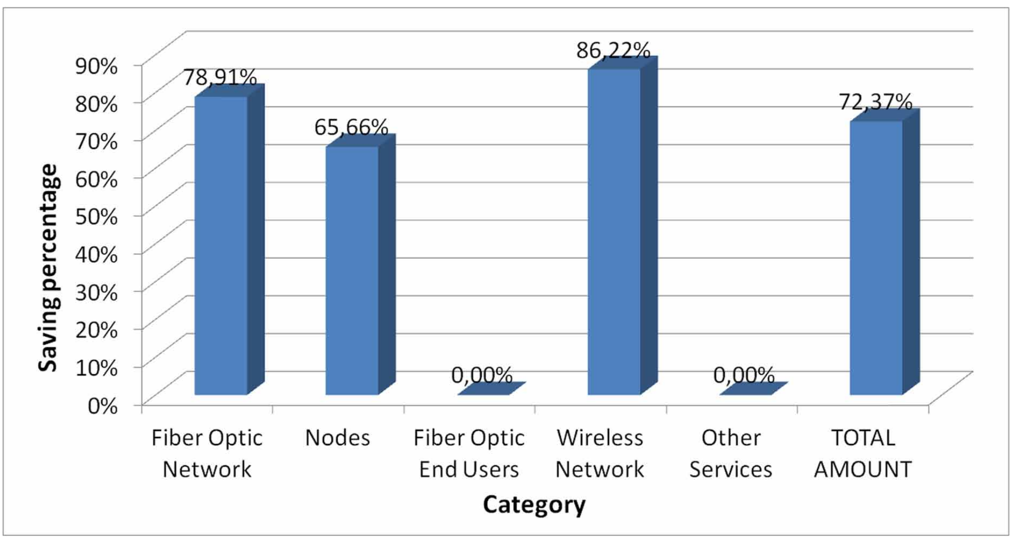


Figure 10. Heraklion case study: Percentage savings with existing infrastructure



infrastructures already installed, and both types are related to passive segments of the network (Ducts and Trenches). The "FO Nodes" category has even less installed elements, i.e. only the two cabinets for access nodes are available.

As it was expected from the characteristics of the existing network and the needs of the proposed network, the tool's estimations reveal that there are significantly more gains to be expected in the "Fiber Optic Network" category (Figure 11). Figure 12 reveals that almost 77% of the cost in this category can be avoided by using existing infrastructures; and this is achieved through only two types of infrastructures. Thus the tool proves very useful in demonstrating

Figure 11. Molise case study: Cost with and without existing infrastructure

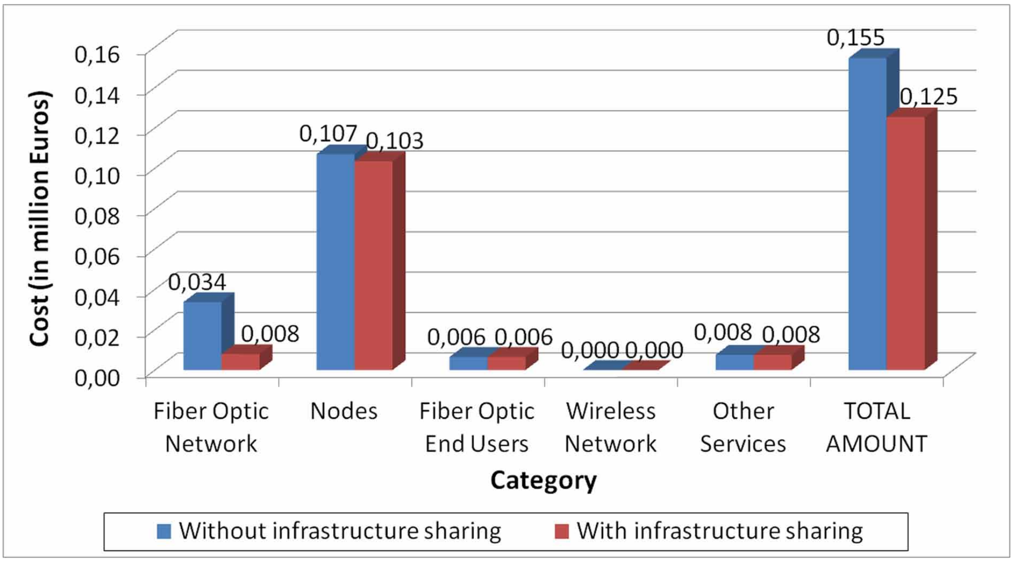
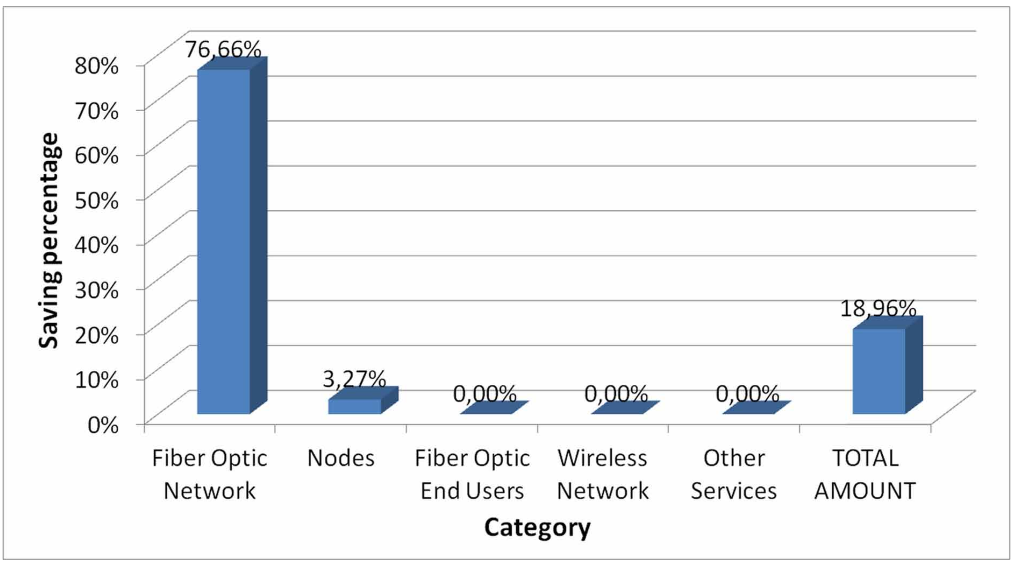


Figure 12. Molise case study: Percentage savings with existing infrastructure



the significant impact of some types of costly infrastructures in the overall network design and deployment. At the same time the tool reveals that there is a small potential for cost savings from the "FO Nodes" category; only 3.27% of the cost in this category is expected to be mitigated through exploiting existing infrastructures. Even with this limited infrastructure availability, the overall cost of the network could be reduced by almost 19% (or 30,000 €).

Kyustendil, Bulgaria

As in the previous case, the case of Kyustendil involves the deployment of a FTTH network in a rural area, with an overall length of 2km, including a 50 meter section crossing a bridge, which is expected to provide broadband access to 50 end-users. The submitted plan does not include a Wireless network, and all infrastructures are confined to the expansion of the fiber optic network (Table 1). As a result, investments will be concentrated in three categories: "Fiber Optic network", "FO Nodes" and "FO Users".

Table 2 contains data regarding the required equipment and infrastructures for the network in the above three categories. The data show that a significant portion of the necessary infrastructures and equipment is already in place, with availability reaching 100% for Splice Enclosures and Cabinets for access nodes.

From Figure 13 and Figure 14 it can be seen that most benefits from utilizing existing infrastructures can be obtained in the "Fiber Optic Network" and the "FO Users" categories. This is not unexpected, since these were also the categories that featured the best availability of relevant equipment/infrastructures (Table 2). On the contrary in the "FO Nodes" category the expected gains are very limited (less than 5%), which can be attributed to the low levels of existing infrastructures. Overall the expected gains for the FTTH network development that were calculated through the Cost Reduction Assessment Tool amount to approximately 26% (or 25,000 €).

POLICY RECOMMENDATIONS

The results of the previous section revealed that infrastructure sharing during the development of broadband networks, irrespectively of the technology, could lead to significant reductions in the overall cost. However, in order to promote the establishment of a market for mandated sharing of physical infrastructures, national regulatory authorities should develop and establish a comprehensive regulatory framework to govern the infrastructure sharing process addressing

Figure 13. Kyustendil case study: Cost with and without existing infrastructure

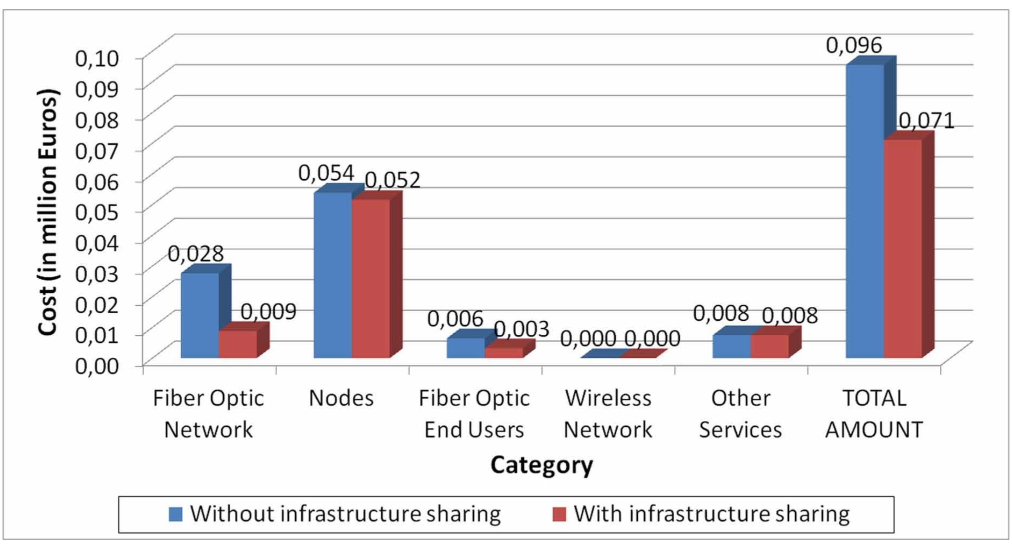
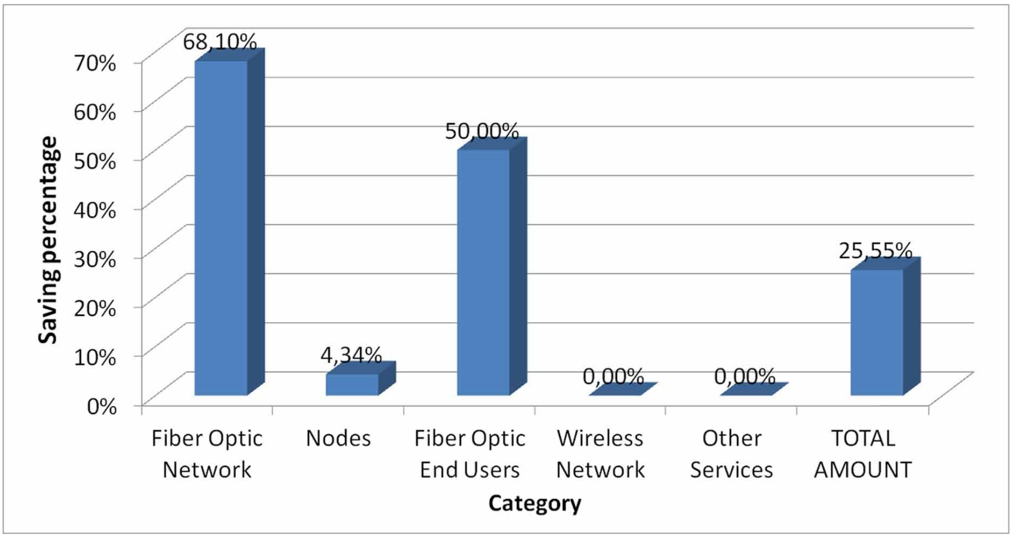


Figure 14. Kyustendil case study: Percentage savings with existing infrastructure



issues such as the determination of regulatory prices, combating anti-competitive behaviours, removing administrative obstacles, e.g. difficulties in obtaining permissions for new base stations or in renewing contracts for existing ones as well as the definition of specifications (for sharing) imposed on operators deploying new facilities. Some guidance to the national policy makers and regulatory authorities may be offered as a starting point in order to assist them set forward an enabling regulatory framework and policies to promote infrastructure sharing. Policy makers and stakeholders should embrace the following key principles and guidelines.

Administrative Issues

Policy makers and stakeholders should try to address the following administrative issues:

- Step up efforts to limit the complexity of the planning-to-implementation process regarding the implementation of the measure of infrastructure sharing. One of the most substantial needs is to determine procedures, obtain approvals and secure rights of way at an initial stage. In that context, public authorities should configure the planning process of infrastructure sharing in order to confront the delays that may arise because of the complexity of the administrative processes, the bureaucracy as well as the great number of various levels of government and public bodies involved in the implementation of the measure;
- As the broadband technology evolution involves significant financial investments in civil works, like fiber, towers, etc., national governments should operate in that direction by stimulating the start-up of local companies for urban wiring facilitating the synergies with other "network" services (gas, electricity, etc). The multi-utility company can be the owner of the broadband network working in joint venture with a National or Regional operator, and facilitating the usage of civil infrastructures and pipelines of other networks (electricity, gas, water supply, traffic light network, public lighting, etc.) to allow easy construction of fixed or mobile broadband networks.

Regulatory Framework and Enabling Policies

Regarding the regulatory framework, stakeholders should take into account the following guidelines:

- Abolish the rules and regulatory provisions in national legislation prohibiting network operators to negotiate access to physical infrastructures by electronic communications network providers;
- Transpose the relevant EU regulations and directives into national legislation so that national regulatory authorities are able to impose infrastructure sharing;
- Establish a pricing scheme that will provide the right incentives for incumbents to open up their facilities and allow access to their infrastructures. Commercially negotiated pricing should prevail, however where market power exists, regulatory authorities should be able to impose mandated access to physical infrastructures at a setting price so as to ensure the emergence of new players and enable sharing;
- Implement licensing frameworks to allow open access providers and create motives for those who have spare capacity on their networks to share that capacity;
- Authorize a central body to manage rights of way and administrative procedures. Such an institutional actor will have a positive impact on the administrative burden faced by operators and any infrastructure provider planning civil works. A new or existing organisation could offer a range of services including a) the provision of information to interested parties; b) the forward of wayleave applications from the operator to the infrastructure owner; c) the distribution of building permits and d) the negotiations between the stakeholders;
- Establish an infrastructure sharing one-stop shop on rights of way to facilitate the coordination of civil works among telecommunication service providers and between operators and other utilities' owners. Where responsible for rights of way, relevant authorities, including local authorities, would provide information on necessary permits, applicable rules and conditions, and so on to this central organization (possibly the National Regulatory Authority - NRA);
- Create and establish necessary enforcement tools to ensure compliance and successful adoption of infrastructure sharing regulations. As an infrastructure sharing relationship between service providers involves elements of both cooperation and competition, the introduction of a dispute resolution mechanism for addressing disputes that may arise between interested parties will ensure the certainty of an adjudicated decision where necessary;
- Improve transparency and information sharing. Market players need to know what infrastructures are available for sharing under clearly established terms and conditions, in order to avoid unfair actions. Regulators should put forward the creation of a cadastre containing details of existing as well as future infrastructure installations available for sharing by other service providers, such as relevant information on the location, the availability of space in existing ducts and other local loop facilities, planned deployment or upgrading works and interconnection. Such a measure will provide alternative operators with the possibility to deploy their fibre networks at the same time as incumbents stimulating competition or to support synergies optimizing resources. Under that scheme, telecommunication providers and utilities owners will be required to provide information and details about their facilities and their shareability;
- Communicate the potential of infrastructure sharing as well as the opportunities arisen for commercial synergies to stakeholders and interested parties.

Legal Provisions

As far as the legal framework is concerned, stakeholders could:

- Determine the legal framework conditions with a view to the provision and access to the sensitive infrastructure data. High resolution infrastructure data and sensitive company details pose high confidentiality requirements. As a result, special care should be given to defining what type of data will be provisioned, how information will be acquired and maintained, when and under what circumstances confidentiality will be maintained and any reasonably anticipated risk associated with the inappropriate disclosure of data;
- Adopt provisions that oblige owners of physical infrastructures, who may be unwilling to participate, to supply the necessary infrastructure details in the cadastre for the telecommunication infrastructure.

CONCLUSION AND FUTURE WORK

This manuscript proposed and presented an innovative cost reduction assessment tool that allows the evaluation of the expected savings from the use of existing infrastructure during the development of NGA broadband networks. In addition, we presented and analyzed the results of its pilot operation in three different locations. The results indicated that the use of existing infrastructures may decrease the total amount that is necessary for the deployment of the network by up to 72%, providing in this way a starting point for policy regulations. To this direction, the manuscript also includes a number of general principles and recommendations that policy makers and national authorities could embrace to diminish deployment costs and promote broadband deployment. It becomes clear that the cost reduction assessment tool using the input from the cadastres of telecom infrastructures is acting as an essential "tool of knowledge" to allow the optimization of economic resources reducing the replication and under-utilization of existing works, as well as the acceleration of the deployment of broadband networks, especially in underserved areas.

As a future step, we intend to extend the tool by including more options for the technology of the broadband networks. With the support of such technologies - like Universal Mobile Telecommunications System (UMTS) / LTE mobile networks and FTTx (not only FTTH networks) - the Cost Reduction Assessment Tool could constitute an important tool for telecom and mobile operators, national and local authorities, decision makers and investors.

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APPENDIX

Mathematical Model and Assumptions

As presented in the previous sections, the Cost Reduction Assessment Tool provides a means to calculate: (i) the deployment or expansion costs of NGA networks, and (ii) savings that could be achieved through the sharing of existing infrastructures. The Appendix aims to shed light on the amount calculations of the telecommunication items/services by presenting the mathematical formulae used and the main assumptions made. To this direction, Table 3 presents the parameters that were used in our analysis and the corresponding requirements that are filled in by the user.

On the other hand, Table 4 includes the formulae that are used for the amount calculations of the telecommunication items/services that are necessary for the deployment of the network, based on the requirements set by the user. The table also includes a justification for each formula used. It is worth mentioning that the formulae were derived from empirical evidence. In detail, the formulae are based on the implementation of eight metropolitan FTTH networks (Agrinio, Aigio, Amaliada, Mesologgi, Nafpaktos, Oiniades, Patras, Pyrgos) and four wireless access networks (Anaktorio, Messatida, Skillounta, Ancient Olympia) in the region of Western Greece. It is also worth mentioning that the user may at any time alter the automatically calculated amount of items in order to match his/her preferences.

Table 3. FTTH and wireless networks requirements and parameters

	Parameter	Units / Values	Requirement
FTTH	*Net_length*	*m*	Length of the network
	Bridge_length	*m*	Distance of passing over bridges
	Area_type	Urban or Rural	Area type
	FO_users		Number of fiber optic end users
	Duct_num		No of ducts in trenches
	Mduct_num		No of microducts in trenches
	FOCable_num		No of Fiber Optic Cables in the trenches
	FOCable		Type of FO cable (72, 24, 4)
	Nodes_in		No of access nodes (indoors)
	Nodes_out		No of access nodes (cabinets)
Wireless Network	*Wireless_tech*	*WiFi or WiMax*	Wireless technology
	AP_num		Number of antennas
	Wireless_users		Number of wireless end users

Table 4. Formulae for calculating the amount of items/services

	Item/Service	Equation	Assumption / Justification / Explanation
Fiber Optic (FO) Network	Ducts	=(*Net_length* + *Bridge_length*)**Duct_num**1.05	Explanation: The factor 1.05 is used for redundancy, and after taking into account that part of the ducts remains within the manholes for protection
	Microducts	=(*Net_length* + *Bridge_length*)**Mduct_num**1.05	Explanation: The factor 1.05 is used for redundancy, and after taking into account that part of the microducts remains within the manholes for protection
	Manholes	=(*Net_length*+*Bridge_length*)/200 (for urban areas) =(*Net_length*+*Bridge_length*)/500 (for rural areas)	Justification: 1 manhole per 200 meters in urban areas to compensate for the increased population density and 1 manhole per 500 meters in rural areas
	Trenches	=*Net_length*	Explanation: Trenches equal to network length
	Fiber Optic Cable	=(*Net_length*+*Bridge_length*)**FOCable_num**1.1	Explanation: The factor 1.1 is used for redundancy, and after taking into account that part of the FO cables remains within the manholes for future branching
	Splice Enclosure	=(*Net_length*+*Bridge_length*)*0.002	Assumption: One splice enclosure per 500 meters
FO Nodes	Cabinets for access nodes	=*Nodes_out*	Assumption: 1 per outdoor access node
	Rooms for indoor access node	=*Nodes_in*	Assumption: 1 per indoor access node
	Optical Distribution Frames (ODF) Rack cabinets	=(*Nodes_in*+*Nodes_out*)*2**FOCable_num***FOCable*/(24*39)	Explanation: Rack cabinet with 39U ODFs, each with 24 terminations. (*Nodes_in*+*Nodes_out*)*2**FOCable_num***FOCable_num* are the cables that reach the ODF from the different access nodes.
	Optical Distribution Frames (ODF)	=(*Nodes_in*+*Nodes_out*)*2**FOCable_num***FOCable*/24	Explanation: Each ODF has 24 terminations. (*Nodes_in*+*Nodes_out*)*2**FOCable_num***FOCable_num* are the cables that reach the ODF from the different access nodes.
	Node ethernet switches - 24 ports	=*FO_users*/23	Justification: 23 users can connect on each switch (one per port) and the remaining post for connection with other switched
	Air conditioning for indoors nodes	=*Nodes_in*	Assumption: 1 per indoor access node
	Nodes' interior design		
	Node UPS		
	Node security system		
FO Users	Compact termination box - 4 connectors	=*FO_users*	Assumption: 1 per FO user
	Gigabit Ethernet UTP to optical SFP Media Converter		
	Indoors optical cabling	=4**FO_users*	Assumption: 4 optic cables per FO user
Wireless Network	Cross section mast for antennas	=*AP_num*	Assumption: 1 per wireless antenna
	Base station equipment cabinet		
	Wireless Base Station		
	Mast for mounting end-users antennas	=*Wireless_users*	Assumption: 1 per wireless user
	Cabinet for end-users active equipment		
	Indoors optical cabling		
	Wireless Customer-premises equipment		
	Gigabit Ethernet UTP to optical SFP Media Converter		