A Novel Tool for Cost-Efficient 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 cause 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 paper 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; cost reduction tool; digital agenda;

I. 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 [1]. 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 [2]. 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. To this end, the European Commission (EC) drafted the Digital Agenda for Europe (DAE) 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 [3]. The ambitious targets of the DAE 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 DAE has stressed the need to overcome the investment challenges arising in the context of broadband deployment. By introducing policies that reduce the overall cost of broadband development, the DAE 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, mandating the sharing of existing 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 paper presents a novel tool that enables the calculation of the savings during the deployment or 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", and was pilot tested for a period of two months. The results of the pilot operation are included in this paper together with some recommendations that could be embraced to diminish deployment costs and promote broadband deployment.

The remainder of the paper is organized as follows: Section II describes the problem that triggered the concept of infrastructure sharing. Section III presents the Cost Reduction Assessment Tool and its main features, and Section IV analyzes the main results from its pilot operation. In Section V we provide some policy recommendations based on the analysis and in Section VI we conclude the paper and we make suggestions for future work.

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II. Problem Description

There is a serious digital gap that is quite evident in terms of telecommunication services and infrastructures between the EU as a whole and SEE as an independent area of interest [4]. 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. The above have a negative impact on competitiveness and cohesion.

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 [5]) 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 which can be significantly reduced through proper coordination between authorities [6]. An example of infrastructure sharing is the agreement between Orange and Vodafone to share infrastructure in the United Kingdom and in Spain [7]. According to Vodafone, the UK agreement will reduce costs by up to 30%. In Spain, the arrangement will reduce the operators' number of sites by around 40%. In addition, the case study results presented in [8] illustrate the importance of infrastructure sharing for new entrants both in Fiber to the Home (FTTH) and Long Term Evolution (LTE). In TS 23.251, 3GPP sets out two approaches to sharing an LTE radio access network: (i) the Multi-Operator Core Network (MOCN) approach, where each network operator has its own core network, and (ii) the Gateway Core Network (GWCN) approach, where the network operators also share the Mobility Management Entity (MME) element of the core network [9].

Several research works have investigated the technological, regulatory, and business landscape from the perspective of sharing network resources. Authors of [10] 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. Authors of [11] 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 described in [12] 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 (e.g. our tool supports the drawing of a network on a map where you can zoom in/out for more detailed description, it supports technology definition and it is much more parameterized).

III. The Cost Reduction Assessment Tool (CRAT)

The CRAT provides a means to calculate the total cost of a broadband deployment project for a specific area taking into account the financial benefits drawn from the utilisation of existing infrastructures. This section highlights the main features of this tool, which is available at [13]. HTML5 and JavaScript were used for the frontend user interface. The backend part is based on PHP for data management and the MySQL Database Management System for data storing. The Google Maps JavaScript API v3 was also used for inserting the infrastructure on the map (see paragraph III.B).

The tool is easy to use; however, 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. In case such information is available, the calculation of the total cost for a proposed broadband deployment project can be disaggregated into the stages presented in the following paragraphs.

A. Technology Definition

To begin with, users have to determine which type of technology (FTTH or/and wireless) the network will include. Depending on the selection, some new tabs will appear on the top of the page. 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.

B. Network Design

In the "Network Design" stage (Fig. 1), 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 of the network (red line in Fig. 1), 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. The tool also supports the insertion of available infrastructures through the network route (blue lines in Fig. 1).

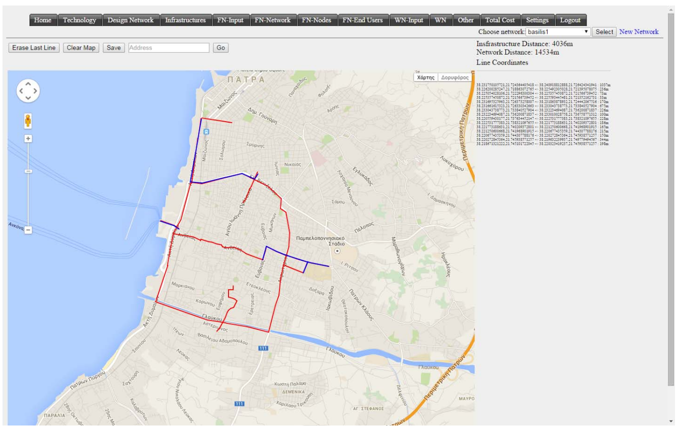


Fig. 1. Stage 2: Network Design screenshot.

C. Definition of Fiber Optic (FO) Network Requirements

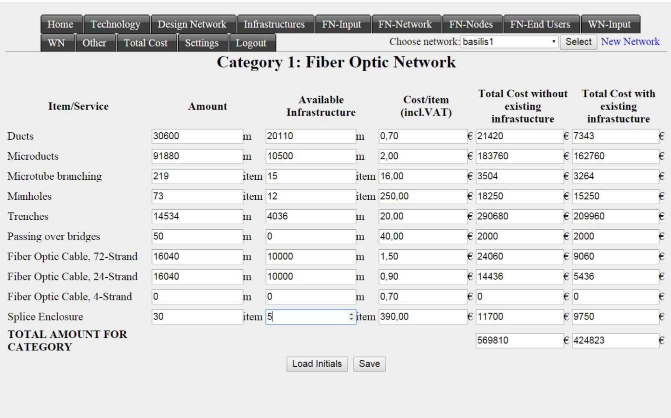
Users have to define the FTTH network requirements providing specific details in 10 fields of interest. These fields are used to collect information regarding the length of the network, the area type, the number of fiber optic end users, the number of ducts/microducts/fiber optic cables in trenches, the user cabling approach and the number of access nodes. Based on this input, in the following stages the tool estimates and outlines the infrastructure/equipment requirements and specifications for the construction of the FTTH network.

D. Definition of Wireless Network Requirements

This stage is available only if 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 - WiMAX / WiFi, number of antennas and number of wireless end users). This information is used to generate estimates of the necessary infrastructures and outline the requirements for the construction of the wireless network.

E. Insertion of Available FO Network Infrastructure

Having defined the requirements for the FTTH network, the tool automatically calculates the amount of the 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.



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	€

Fig. 2. Stage 5: Insertion of Available FO Network Infrastructure screenshot.

At this stage users should insert the amount of the available infrastructure for each item/service, i.e. complete the “Available Infrastructure” column in Fig. 2. Based on users’ insertion, the tool calculates the cost per item/service and the total cost with and without the use of existing infrastructure.

F. Insertion of Available Wireless Network Infrastructure

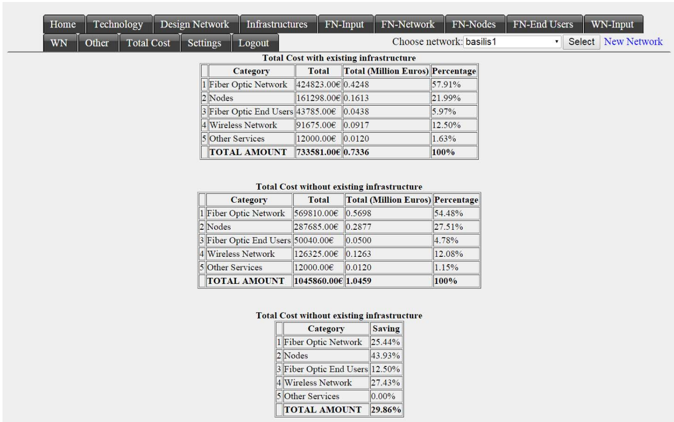
At this stage users have to insert the available amount of the items that already exist and can be utilized for the construction of the wireless network. Factoring on the amount of the items required as well as on their cost estimation, the tool calculates the total cost for the construction of the wireless network with and without the use of the existing infrastructure.

G. Selection of Related Costs

In this stage, users select which other services should be included in the cost estimation for the proposed network. Such services may be precautionary services, repairing works, standby staff, system maintenance, instalments documentation. These services are not used to calculate differences in the cost with and without infrastructure sharing; however they are useful for estimating the total cost of the network.

H. 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 (Fig. 3).



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%**

Fig. 3. Stage 8: Costs/Savings Calculations and Statistics screenshot.

IV. PILOT OPERATION RESULTS

The CRAT was pilot tested from May until June 2014, in two locations: Heraklion (GR) and Molise Region (IT). During the pilot operation, two different case studies of proposed broadband network deployments were examined. The Greek case refers to the deployment of a hybrid FTTH and wireless network in an urban environment while the Italian case refers to a FTTH network deployment in a rural environment. Table I presents the network requirements that were set for each case study, and Table II the required (calculated automatically by the tool) and available (inserted by users) infrastructures. The cost of each item/service was inserted by the users, and was based on real network deployments.

A. 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 and 4 in 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 to provide services to 500 end users (Table I).

TABLE I. FTTH AND WIRELESS NETWORKS REQUIREMENTS FOR THE TWO CASE STUDIES

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

TABLE II. REQUIRED AND AVAILABLE INFRASTRUCTURE FOR THE TWO CASE STUDIES

	Item/Service	Unit	Heraklion (GR)		Molise (IT)	
			Required	Available	Required	Available
Fiber Optic (FO) Network	Ducts	m	17010	14000	2600	2600
	Microducts	m	59535	49000	2600	-
	Microtube branching		122	1	38	-
	Manholes		27	20	5	-
	Trenches	m	8100	7000	2476	2476
	Passing over bridges	m	-	-	-	-
	Fiber Optic Cable, 72-Strand	m	8910	-	2724	-
	Fiber Optic Cable, 24-Strand	m	5304	5304	2838	-
	Fiber Optic Cable, 4-Strand	m	-	-	-	-
	Splice Enclosure		17	-	5	-
FO Nodes	Cabinets for access nodes		4	-	2	2
	Rooms for indoor access node		3	3	2	-
	Optical Distribution Frames (ODF) Rack cabinets		14	3	8	-
	Optical Distribution Frames (ODF)		59	5	41	-
	Splices		1416	-	104	-
	Cross-Connect (XC patchcords)		1416	-	104	-
	Fiber Optic patchcords		604	-	76	-
	Fiber optic cable for ODF interconnection		2	-	2	-
	Rack cabinet 19" 39U		7	1	4	-
	Node ethernet switches - 24 ports		7	3	8	-
	Air conditioning for indoors nodes		3	1	2	-
	Nodes' interior design		3	1	2	-
	Node UPS		3	3	2	-
	Node security system		3	1	2	-
FO Users	Compact termination box - 4 connectors		100	-	10	-
	Indoors optical cabling		100	-	40	-
	Gigabit Ethernet UTP to optical SFP Media Converter		100	-	40	-
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		✓	-	✓	-

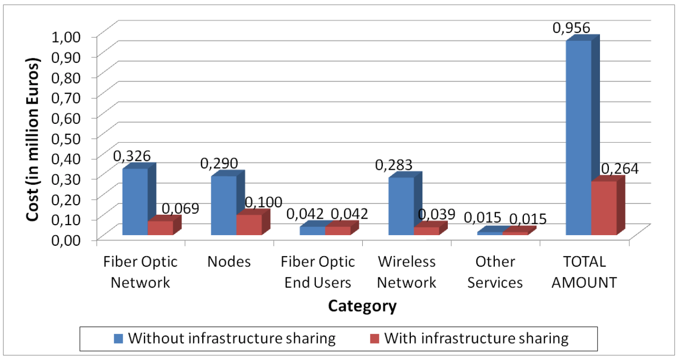


Fig. 4. Heraklion case study: Cost with and without existing infrastructure.

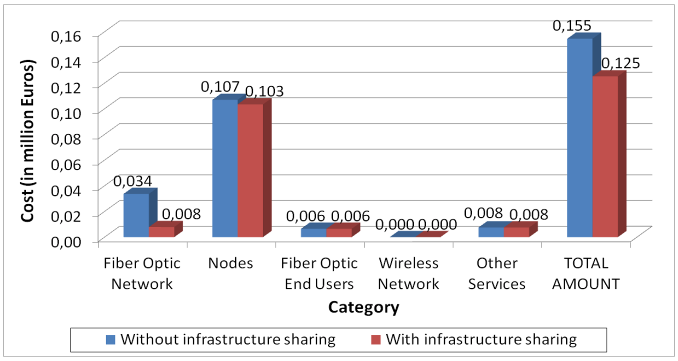


Fig. 6. Molise case study: Cost with and without existing infrastructure.

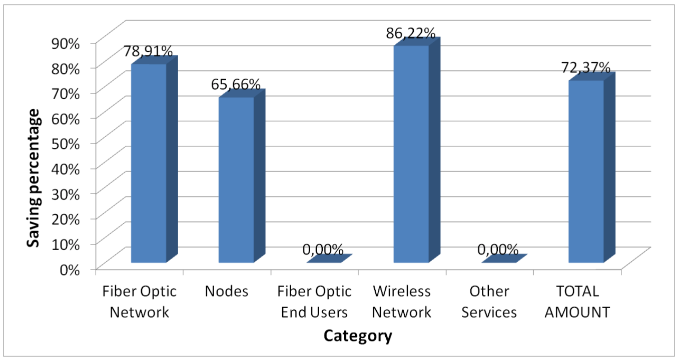


Fig. 5. Heraklion case study: Percentage savings with existing infrastructure.

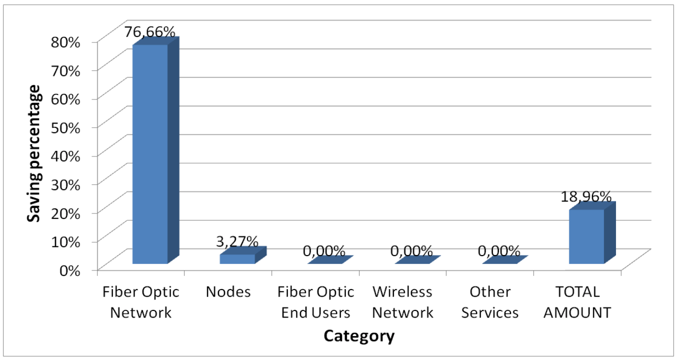


Fig. 7. Molise case study: Percentage savings with existing infrastructure.

According to Table II, 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 CRAT utilises the data regarding the necessary infrastructures for a new network and estimates the expected benefits (in monetary terms) from exploiting existing infrastructures. Fig. 4 contains a summary of these cost estimations per category, while Fig. 5 presents the percentage savings with the use of existing infrastructure. It can be seen that the exploitation 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.

B. Molise Region, Italy

According to Table I, 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 II 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 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 can be 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 (Fig. 6). Fig. 7 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 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 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 €).

V. Policy Recommendations

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. Policy makers and stakeholders should embrace the following key principles and guidelines.

Administrative issues:

- Step up efforts to limit the complexity of the planning-to-implementation process as regards the implementation of the measure of infrastructure sharing in order to confront the delays that may arise.

Regulatory framework and enabling policies:

- Abolish the rules and regulatory provisions in national legislation prohibiting network operators to negotiate access to physical infrastructures.
- 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.
- 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.
- 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.
- Create and establish necessary enforcement tools to ensure compliance and successful adoption of infrastructure sharing regulations.
- Improve transparency and information sharing. 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.
- Communicate the potential of infrastructure sharing as well as the opportunities arisen for commercial synergies to stakeholders and interested parties.

Legal provisions:

- Determine the legal framework conditions with a view to the provision and access to the sensitive infrastructure 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.

VI. Conclusions and Future Work

This paper proposed and presented the CRAT that allows the evaluation of the expected savings from the use of existing infrastructure during the development of NGA networks. The results from its pilot operation indicated that the use of existing infrastructures may decrease the total cost that is necessary for the deployment of the network by up to 72%. It becomes clear that the CRAT using the input from the cadastres of telecom infrastructures is acting as an essential "tool of knowledge" to allow the optimization of economic resources during the deployment of broadband networks, especially in rural areas. As a future step, we intent to extend the tool by including more options for the technology of the broadband networks, such as mobile networks and FTTx (not only FTTH) networks.

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