Fiber and Integrated Optics, 32:251–267, 2013
Copyright © Taylor & Francis Group, LLC
ISSN: 0146-8030 print/1096-4681 online
DOI: 10.1080/01468030.2013.803636

Taylor & Francis
Taylor & Francis Group

Special Section: FTTx

The Impact of Cost and Demand Uncertainty to the Fiber-to-the-Home Business Case

COSTAS TROULOS[1]

[1]School of Electrical and Computer Engineering, National Technical University of Athens, Athens, Greece

Abstract *The business case of fiber to the home exhibits substantial risk. This study evaluates the impact of such risks as construction delays, the city plan, average revenue per user, and take-up rates in the fiber-to-the-home business case, based on experiences and planning of current fiber to the x and future fiber-to-the-home plans in Greece. It does so in the context of the dark fiber, capacity provision, and retail service business models. The findings show that demand-side uncertainty is more critical than deployment risks and that take-up rates have stronger implications to the business case than average revenue per user.*

Keywords average revenue per user, business case, cost modeling, demand-side uncertainty, fiber to the home, next-generation access networks, supply-side factors, take-up, techno-economic evaluation

1. Introduction

The deployment of fiber-optical cables in the access network is a core business strategy for many network providers. Fiber replaces copper in order to improve broadband connectivity and, consequently, quality of service. The access networks then are generally referred to as next-generation access (NGA) networks or “fiber to the x” (FTTx). Depending on the degree that fiber stretches into the access network, NGA networks are called fiber to the home (FTTH), fiber to the building (FTTB), or fiber to the cabinet (FTTC).

The development of FTTH infrastructure sits in the spotlight of the international telecommunications industry. There is tremendous pressure toward network and service providers to upgrade their networks, whereas FTTH investments exhibit significant cost and profit challenges. For these reasons, global FTTH growth is problematic and, with few exceptions, falls behind the expectations of policy makers, the broadband industry, and society. According to statistics released by the Fibre to the Home Council Europe, by the end of 2012, FTTH networks in EU27 exhibited a 21.5% average take-up with 28.9 million homes passed and 6.2 million homes connected to the networks [1]. Network and service providers proceed with caution when designing their NGA plans, and they

Received 7 January 2013; accepted 6 May 2013.

Address correspondence to Dr. Costas Troulos, School of Electrical and Computer Engineering, National Technical University of Athens (NTUA), New Electrical and Computer Engineering Building, 3rd Floor, Room B.3.20, 9, Iroon Polytechniou Street, Zografou, Greece, GR 157 80. E-mail: ktroulos@netmode.ntua.gr

typically follow "wait-and-see" or "cherry picking" in high-demand areas strategies [2]. They are mostly driven by competitive forces rather than forward-looking thinking. The key reasons for this relate (a) to the significant rollout cost and, in particular, to the risk associated with containing the cost to manageable levels and (b) to the uncertainty of commercial demand for high-speed broadband services, and are summarized as follows.

- **Supply-side factors:** Replacing copper with fiber in the access network is a structural upgrade, and the average cost per home passed is substantially high. The average cost per home passed can rise to €1,800 (US$2,378), according to relevant industry studies and reports [3–5], although it is usually relatively smaller, depending on local conditions (re-use of existing infrastructure, rollouts in selected densely populated areas, etc.). The cost for connecting customers is an additional expense that drives the total rollout cost to higher levels. FTTH rollout requires substantial civil works and is labor intensive. Despite the improvements in deployment techniques in recent years, labor still accounts for 50%–70% of the total deployment cost in the outside plant. Labor cost is exposed to construction delays that occur for a number of reasons, such as inefficient administration of rights-of-way by the public authorities, special requirements for traffic management, lengthy negotiations with tenants when connecting a building to the network, as well as construction blunders. Whatever the reason, delays have an explicit impact to the deployment cost, as technical crews stay idle and the rollout cannot progress. In addition, the city plan (e.g., digging restrictions, building density, type of real estate properties—number of floors and dwelling units per building, fragmentation of ownership) is critical for the accurate estimation of the rollout cost. For example, in densely populated areas, homes are generally covered faster by the networks, although in these areas, utility networks, are dense, traffic regulations are stricter, and delays can occur frequently.
- **Demand uncertainty:** A minimum level of demand is usually required by the network providers before investing; otherwise, NGA investments are pushed back until broadband demand matures. A key concern is the estimation of the level of average revenue per user (ARPU) that can support a sustainable business model at a certain level of service penetration. Service penetration or take-up rate is critically important as well in that it represents the portion of activated customers that contribute to the revenue of the operations. These two demand-side factors are strongly correlated: Higher service charges (ARPUs) are likely to result in lower sales (take-up rate). Consequently, FTTH business strategies focus on either ARPU or take-up rate, and rarely on both. Incumbents tend to value more ARPU-based strategies, while newcomers and alternative operators select more aggressive deployment strategies aiming at higher take-up rates.

Internationally, there are plenty of cases illustrating the aforementioned strategic planning of network and service providers. Reggefiber, a major open access network provider in the Netherlands, controls several small retail operators and has recently filed for a merger proposal with the Dutch incumbent KPN [6]. In this way, Reggefiber is selling dark fiber to independent downstream providers, yet it is able to manage, at a certain extent, the retail demand for its access services. In addition, KPN vertically integrates its service operations, thus becoming able to control the entire value chain from physical access to triple-play offerings. National Broadcast Network (NBN) Co., the organization executing the Australian NBN plan, requires from the incumbent Telstra that copper access is replaced with fiber as network coverage progresses. In this way, service penetration is guaranteed as the network expands. The NBN plan in Singapore established wholesale operations with a universal service obligation, making sure that when fiber access becomes available, bitstream will be offered to downstream service providers. Finally, most Swedish and German FTTH networks are deployed with the operational and strategic support of publicly controlled energy utilities, ensuring that delays stemming from the interaction with the public sector are minimized. In most cases, these networks also require a minimum pre-subscription rate in order to deploy fiber infrastructure in a city area [7].

On the policy front, national regulatory authorities (NRAs) and the European Commission work toward establishing a regulatory and investment framework to substantially reduce the risks associated with the rollout of FTTH. Their work involves improving the management of rights-of-ways to reduce delays and encouraging co-investment strategies among competing network and service providers to avoid the deployment of redundant uneconomical access infrastructures [8, 9].

There is a growing body of literature analyzing the business case of FTTH. Industry studies evaluate the on techno-economic reality of FTTH deployments in specific geographic regions [3, 10, 11], while others conclude the need for public intervention in the process [12, 13]. However, few studies elaborate on the impact of specific supply- and demand-side factors to the profitability and sustainability of FTTH networks. In a relevant study [14], ARPU and take-up is found to affect differently the payback period of an FTTH network. The study analyzes the business of a retail provider that deploys FTTH in a greenfield area and concludes that the impact of take-up is a lot more significant than that of ARPU.

This article evaluates the impact of supply- and demand-side factors, such as construction delays, city planning, ARPU, and take-up rates to the business case of the three most popular FTTH business strategies: dark fiber, bitstream, and triple play. The research is based on current FTTx and future FTTH plans in Greece and draws conclusions from the applications of a techno-economic model for a future FTTH network in Livadeia, a typical mid-sized city of Greece. The structure of the article is as follows. Section 2 sets the general context of the broadband and FTTx market in Greece. Section 3 describes the modeling framework used in this research, while Section 4 presents the results and key findings. Section 5 concludes with remarks and recommendations.

2. Broadband Market and FTTx Deployments in Greece

Based on data released in October 2012 by the Greek NRA, EETT, the number of broadband connections in the country was 2,560,414 in June 2012, marking a penetration rate of 22.6% per capita, significantly lower than the EU27 average of 27.7% [15]. Greece ranks 21st in the European Union in terms of broadband penetration per capita. The Greek incumbent OTE maintains a strong 43.1% share of the total market. The local loop unbundled (LLU) connections in the market accounts for 55.7% of the total broadband lines, whereas the wholesale digital subscriber line (DSL) market share declines steadily as LLU shares increase. The remaining access technologies (including FTTH/FTTB) have less than 0.5% of the broadband market.

The availability of optical access networks in Greece is limited, as market players are reluctant to undertake large-scale FTTH/FTTB deployments, trying to capitalize as much as possible on their existing investments in DSL and wireless technologies. Also, they are faced with severe financial challenges as a result of the fierce market competition that followed the liberalization of the market in 2001 [11]. The incumbent OTE launched recently very-high-bit-rate DSL (VDSL) services over an FTTC network that covers select cities across the country. OTE plans to expand its VDSL network to FTTH/FTTB in the future, but no announcements have been made as of yet. CYTA Hellas, the local branch of the Cypriot incumbent, has invested significantly in fiber infrastructure in Crete and northern Greece, while the rest of the network providers offer primarily broadband access over unbundled local loop or deploy fiber to select customers, primarily businesses and office complexes.

Municipal Optical Metropolitan Access Networks (MANs)

The Greek government has initiated a number of projects in the past decade to improve the local community awareness, commercial availability, and service quality of broadband. These initiatives were sponsored mainly by the European Commission's European Regional Development Fund (ERDF), and three of them aimed at stimulating fiber infrastructure deployment. At the national level, the "Call 157" network and service providers to co-finance the expansion of their networks in order to provide a minimum set of services and quality to all settlements with a population over 500. The country was divided in seven lots that were awarded to Hellas Online, Forthnet, and CYTA Hellas. The contract winners deployed a significant amount of fiber to extend fiber access networks closer to the customers and address the requirements of the call. Their deployments often brought fiber cables to the neighborhood (FTTC). At the city level, the public sector funded the construction and the first years of operation of 72 optical access networks in the country, excluding the major cities of Athens and Thessaloniki, via the subsequent Calls 93 and 195 [11]. These networks are commonly referred to as municipal MANs due to the strong commitment and involvement of the municipal authorities in the process. The projects deployed extensive trenching and fiber infrastructure in the prime commercial and select residential areas of the cities and delivered fiber connectivity to public buildings. Special neutral interconnection facilities (tele-houses) to appropriately selected areas in the cities were also built. The long-term objective of these infrastructures is to be incorporated in a future national FTTH plan.

In Sterea Hellas, one of the administrative areas of the country that participated in the calls, optical networks were constructed in the cities of Lamia, Thebes, Livadeia, Atalanti, Orhomenos, and Amfissa. The networks were built in a four-tier architecture, which is outlined below and follows the terminology used in the Calls.

- **Main/core network:** infrastructure interconnecting the main nodes of the network. A main node is the concentration point of the ducts and optical cables that serve the city or a wider area that may include multiple residential settlements (smaller cities or villages in the region). Active equipment is installed in the main nodes in order to provide broadband services to the public sector.
- **Distribution network:** segment of the network that interconnects distribution nodes with the main nodes and with each other. The distribution node is the concentration point of the network for a certain geographical area of the city.
- **Access network:** network that links access nodes with distribution nodes. An access node is the concentration point of ducts and cables connecting buildings to the network in smaller areas, e.g., neighborhoods.
- **End-user network:** network that connects the end-users (i.e., public buildings and services) with an access node. End-users are eventually served via the active equipment installed at the main nodes of the network.

The technical specifications of the networks were predetermined by the financing authority 3rd Community Support Framework–Operational Programme Information Society. The networks were designed to serve initially the public sector, according to the relevant public funding framework, and have consequently expanded to areas where public buildings were present, mainly the city center and other select areas. The network constructions focused at large to the deployment of passive elements (trenches, ducts, optical cables, and optical distribution frames [ODFs]) and to the active equipment necessary to offer services to the public sector according to the contractual requirements. The network nodes were built inside public buildings or in outdoor cabinets in the field. The network construction resulted in lengthy trenches and dense duct systems with an eye on maximizing the positive long-term impact of the infrastructure to the broadband potential of the region. The trenches carry multi-duct systems of 2 and 6 ducts and are able to support up to 4,032 fiber strands.

The network design took into consideration the prospect of incorporating the infrastructure in a future plan that would offer FTTH services in the participating cities. The aim was to maximize the geographical coverage of the passive infrastructure in order to reduce investment requirements of a future FTTH deployment. The technology used was point-to-point Ethernet links, and optical access ports of 100 BASE-X (100 Mbps) were installed in each connected end user (public buildings and services). Wireless technologies (WiFi, IEEE 802.11a/b/g, or WiMAX, IEEE 802.16) were deployed in the cases where the fiber rollout was found to be uneconomical.

Expanding Municipal MANs to Full-Scale FTTH Networks

A future deployment of FTTH that would exploit the existing public infrastructure would follow the same design principles and would use part or all of the existing infrastructure and nodes.

Figure 1 ties the MAN architecture to that of a future FTTH network. As the network expands, it would be reasonable to expect that the distribution and access nodes

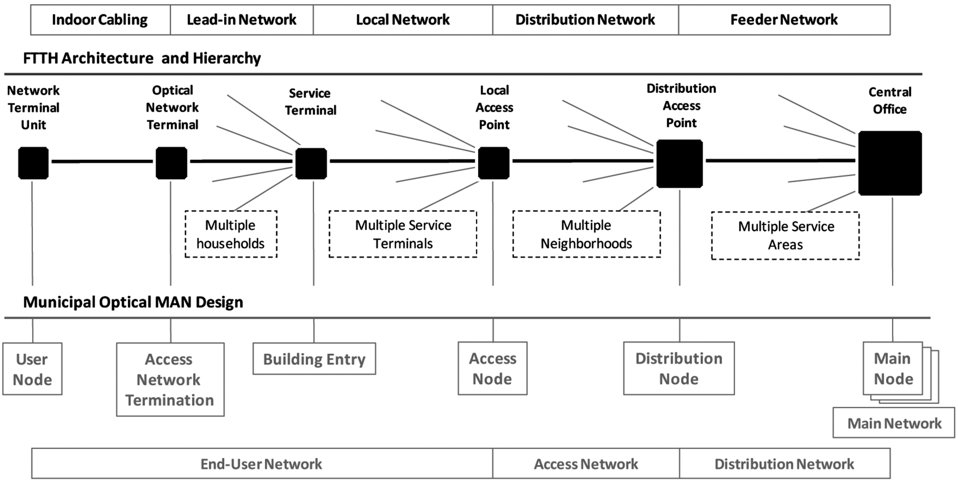

Figure 1. FTTH architecture and municipal optical MAN design.

be upgraded to the higher level as appropriate. Looking at the infrastructure from the left-hand side, the FTTH network is comprised of five distinct segments, as follows.

- **Indoor cabling:** This part corresponds to the cabling inside the buildings that connect an end user to the network. It starts from the access network termination point where the optical network terminal (ONT) is deployed (typically in the building's basement) up to the network terminal unit (NTU). In single-dwelling units (SDUs), the ONT and NTU can be co-located.
- **Drop/lead-in network:** This segment corresponds to the connecting links between individual buildings and the optical access network. Its boundaries are the ONT in the basement and the service terminal, a designated point of entry, outside the building.
- **Local network:** The local network expands at the neighborhood level. It stretches from the local access point (LAP) to multiple service terminals.
- **Distribution network:** The network covers an expanded area of the city that aggregates multiple neighborhoods. It extends from the distribution access point (DAP) up to multiple LAPs.
- **Feeder network:** The network aggregates the optical cabling from multiple DAPs to the network's central office (CO).

3. The Techno-Economic Model

In order to assess the strategic choices presented to a potential operator that considers rolling out an FTTH network, a techno-economic evaluation model was developed and is applied for the city of Livadeia. The present cost and revenue assumptions are based on the experience of FTTX deployment in Sterea Hellas and the general practices of NGA services provision and civil work construction in Greece. The model takes into account capital investments, operational expenses, and revenue projections. It is tailored to evaluate the impact of (a) the uncertainty in the time of deployment (delay), (b) the city plan, (c) the expected ARPU, and (d) the take-up rate to the deployment cost and the overall business case.

Urban Planning and Demographics of the City of Livadeia

Livadeia is a typical mid-sized city of Greece with a population of roughly 20,000. It is a city with a long history that maintains a well-preserved historical center. The city expanded over two principal urbanization waves. During the first urbanization phase in the 1950s, people inhabited Area B, the city's periphery of that time. The second wave of urbanization started in the 1980s when newcomers started settling in Area C, the outer periphery of the city (Figure 2). The city center (Area A) has a dense building plan. The properties in the area are small and highly fragmented and include mainly ground-floor and one-floor establishments. Area B is characterized by medium-sized constructions, with one- and two-floor buildings being the norm. Finally, Area C is sparsely populated with a very low density of establishments, while the buildings are higher (three to five floors) [16].

The length of the city's road system is 88 km. The city has 5,120 buildings and 7,290 end-points (apartments, homes, and businesses). Table 1 shows data gathered from the technical department of the municipality and city planning documentation and outlines the major demographic and urban characteristics of Livadeia.

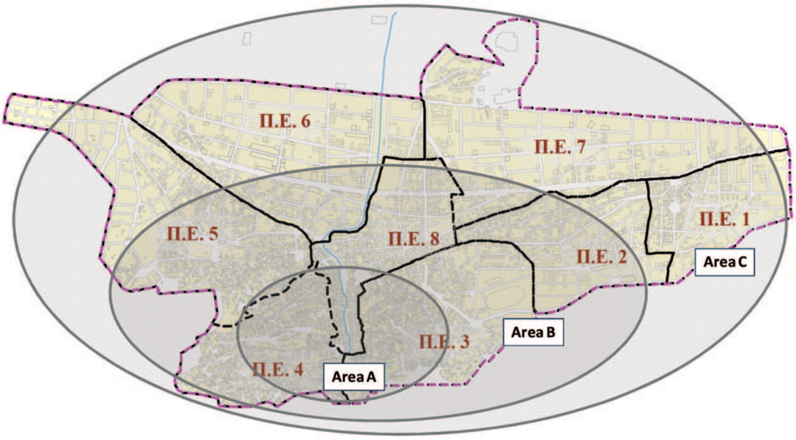

Figure 2. City planning map of Livadeia (color figure available online).

Design Guidelines and Modeling Principles

The model is applied separately for each of the three designated areas of the city and assumes that all optical links are aggregated to the same CO. This modeling strategy is applied as each area has special urban characteristics that contribute significantly to the estimation of the cost of deployment, cost per home passed, and cost per home connected. The model does not use a generic population density function as input to the calculations. Instead, a linear distribution of buildings and user access points per meter of deployment is used. This method more efficiently links network length and user coverage. In general, areas with similar population densities may have significant differences in the rollout cost due to differences in the distribution of multi-dwelling units and SDUs as well as due to the existence of residential clusters.

To evaluate the business case of the FTTH rollout, costs assumptions, risk estimates, and revenue projections are provided to the model in order to calculate the net present value (NPV) and payback period of the investment (Figure 3). The model considers the following four input parameters.

- **Rollout delays:** With the intention to evaluate the impact of delays in construction to the overall rollout cost, the cost is modeled as a function of the material (active and passive equipment) used and the labor required to deliver the work. Delays are modeled as a multiplication coefficient to the labor cost. Delays during

Table 1
Urban plan details of city of Livadeia

Area	Length of road system	Number of end users	Density of end users/10 m	Number of buildings
A	14,652	3,056.00	2.08	2,631
B	29,305	2,335.00	0.79	1,610
C	43,957	1,899.00	0.43	879

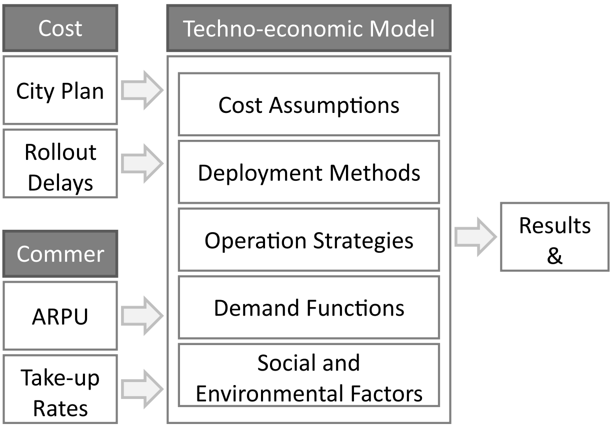

Figure 3. Techo-economic evaluation plan.

construction inflate the overall labor cost, which in turn increases the total rollout cost of the network.

- **City plan:** In an FTTH network, the cost to fully extend fiber to the user premises includes the cost of rolling fiber inside the buildings. Building characteristics, such as number of floors and number of users, are taken into consideration.
- **ARPU:** The ARPU is an important metric for the commercial success of the network. Higher levels of ARPU indicate that users are willing to pay more for the services provided and/or that users purchase advanced add-on services to standard offerings.
- **Take-up rates:** The commercial success of a network is also a function of the penetration rate among the population. Higher take-up rates means that more users subscribe to the network and contribute to the operational revenues.

Modeling Costs

The deployment is modeled via two separate processes. The first process (process A) relates to rolling out the network across the city. This process models the deployment from the CO up to a service terminal that can serve up to four customers. It includes the rollout in the feeder, distribution, and local network. As soon as the fiber infrastructure is deployed in the local network, the corresponding homes are considered as covered or “homes passed” by the network. A 5-year deployment schedule for the entire network is assumed. The second process (process B) models the construction and other tasks relating to connecting end-users to the network. It covers the deployment from the service terminal to the end-user premises, and thus includes the lead-in network and indoor cabling. The two processes are applied simultaneously and are independent. As soon as the network is deployed in an area (process A), customers in these areas may connect to the network (process B). A neighborhood in the model is considered an area with 192 potential users. Naturally, depending on the population and building distribution, the local networks of each neighborhood have different lengths with a direct impact to the average subscriber’s distance from the LAP.

The operational life of the passive infrastructure is considered to be 35 years [17], while the active equipment requires upgrade or replacement every 5–7 years. The oper-

Table 2

Indicative costs of passive infrastructure rollout

Passive infrastructure	Cost (€)	Cost (US$)	Economic life (years)
Mini trenching per meter	12	15.90	35
Indoor cabling per floor	200	264.20	35
DAP outdoor cabinet per unit	5,000	6,605.50	35
LAP outdoor cabinet per unit	8,000	10,568.80	35
Hatches/handholes	400	528.50	35

ational overhead per annum is 2% for the passive equipment, 5% for the connectivity active equipment, and 8% for the service equipment. Drawing from the experience and best practices of rolling out FTTX networks in Greece, Table 2 presents an indicative list of the passive infrastructure costs.

Modeling Revenues

The study analyzes three widely adopted business models in the FTTH market. They are characterized by different degrees of vertical integration and service offerings.

- **Retail service providers (RSPs):** RSPs manage vertical integrated operations and offer all range of retail triple-play services. RSPs operate at layer 3 (L3).
- **Communications service providers (CSPs):** CSPs manage the passive and active equipment of the network and offer bitstream services to downstream RSPs. CSPs operate at layer 2 (L2).
- **Dark fiber providers (DFPs):** DFPs manage the physical infrastructure and offer dark fiber products to CSPs and RSPs. DFPs operate at layer 1 (L1).

The evaluation of each business model implicitly considers the effects of competition by applying the model for different levels of service penetration. Also, the model considers a reasonable profit for the operations depending on the business model by selecting different levels of weighted average cost of capital (WACC). WACC expresses the opportunity cost of money invested:

- the WACC for an RSP is assumed at 12%, according to the conditions in the Greek market and the recent WACC projections of the incumbent OTE by Citi estimates and Merit's report on OTE for 2011 [18, 19];
- the WACC for a CSP is taken at 10%, considered to be a reasonable value according to [20];
- the WACC for a DFP is taken at 6% on the basis of the estimates of Strategy @ Risk Ltd [21, 22].

With regard to ARPU, the baseline scenarios for each business model are depicted in Table 3. The flat cost of dark fiber is considered as the ARPU of the infrastructure provider, without variations per user (business versus residential). For the CSP, ARPU is the price of the bitstream service per subscriber. Finally, the ARPU for an RSP is calculated by adding a 15% premium on the DSL-based triple-play services, according

Table 3
ARPU for each business scenario

ARPU (infrastructure provider)	€16.00	US$21.20
ARPU (communications provider)	€31.54	US$41.70
ARPU (service provider)	€55.54	US$73.40

to general commercial practices across Europe. The model is applied for penetration rates from 10% to 100% with a 10% step.

Evaluating the Business Case

To evaluate the business case, the discounted cash flow (DCF) method is employed to calculate the NPV of the investment. The NPV calculates the value in the present day of all future cash inflows (revenue) and outflows (investments and expenses). The NPV of an investment for i years (periods), given the cost of capital r, is calculated via the following mathematical formula:

$$\begin{aligned} NPV_i &= \sum_i DCF_i, \\ DCF_i &= \frac{Ci}{(1+r)^i}. \end{aligned} \tag{1}$$

For multi-year projects, the NPV of the project is computed by accumulating the DCF of the operation for every year. In this respect, the NPV represents the profitability of the investment and informs project stakeholders whether a project can produce profit higher than that of other similar projects evaluated for the same WACC. The higher the NPV of the project, the more attractive the investment is. A negative NPV means that the project will underperform and should not be undertaken. The accumulated DCFs—cash balance—are generally negative in the first years of operations. The point in time that the cash balance moves to positive ground represents the payback period for the investment.

4. Results and Findings

The total deployment cost of a full-scale FTTH network in the city with 100% penetration (connected premises) is €9 million (US$11.9 million), while rolling out the access network to cover all households will require €5.8 million (US$7.7 million). The cost breakdown per city area, shown in Table 4, demonstrates that network deployment in lower density city areas is not necessarily linked to higher investment requirements. As more users connect to the network, the cost of investment in low-density areas becomes smaller compared to the medium- and high-density areas (Figure 4). The financial gains of shorter network length in smaller city areas (Areas A and B) are offset by (a) lower requirements in the feeder and distribution networks, (b) more cost-effective connections of end-users in multi-dwelling units compared to individual SDUs and low risers, and (c) lower number of end-users. Nevertheless, user density remains a fundamental factor for the cost per home connected (Figure 5). Finally, the average cost per home connected follows a decreasing trend as service penetration increases.

Table 4

Rollout and total network costs for city of Livadeia

City areas	Rollout cost, 100% coverage	Total network cost, 100% penetration	Cost per home passed, 100% coverage	Cost per home connected, 100% penetration
Area A	€1,550,424	€2,818,770	€507	€922
Area B	€1,761,928	€2,705,289	€755	€1,159
Area C	€1,704,864	€2,470,309	€898	€1,301
Area A	US$2,048,265.15	US$3,723,877.05	US$669.80	US$1,218.05
Area B	US$2,327,683.08	US$3,573,957.30	US$997.43	US$1,531.15
Area C	US$2,252,295.83	US$3,263,525.22	US$1,186.35	US$1,718.75

The levels of the ARPU and penetration rates affect significantly the extent of the payback period as well as the levels of profitability (NPV) of the investments in a 35-year horizon (Figures 6 and 7). The outlook of L3 operations (i.e., RSPs) seems more attractive compared to L2 and L1 operations. It should be noted, however, that L3 operations exhibit higher commercial risk and, generally, lower penetration rates in a real environment. Evaluating the attractiveness of the business should account for the realistic expectations of service penetration. For example, L2 operations with 70% take-up rate are equivalent to a L3 operation with 35% penetration on the ARPU baseline. Also, L1 operations with 100% penetration rate (e.g., a possible national broadband plan with a guaranteed L1 take-up) are equivalent to L2 operations with 47% penetration or L3 operations with 26% take-up rates.

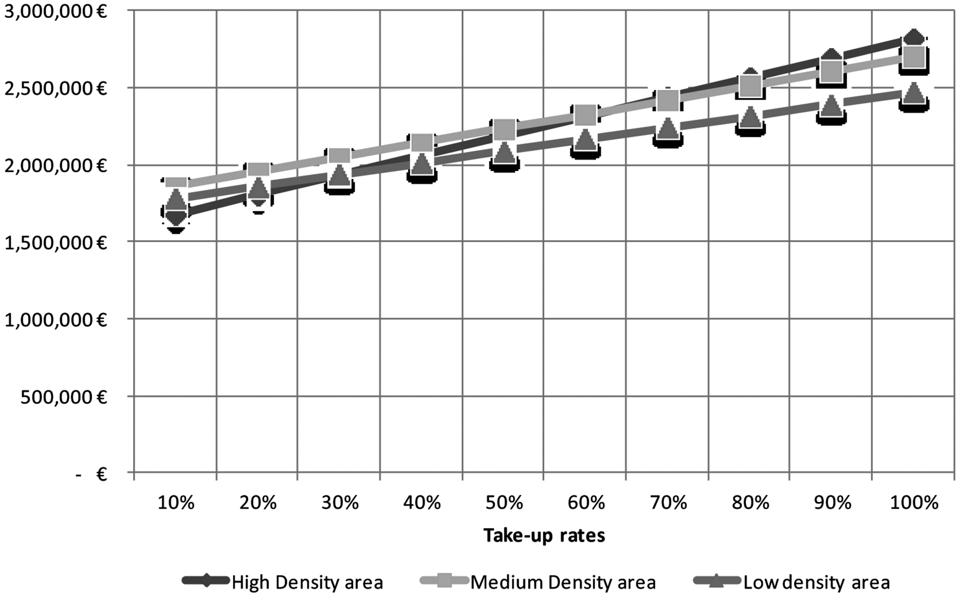

Figure 4. Total network rollout costs for different service penetration levels.

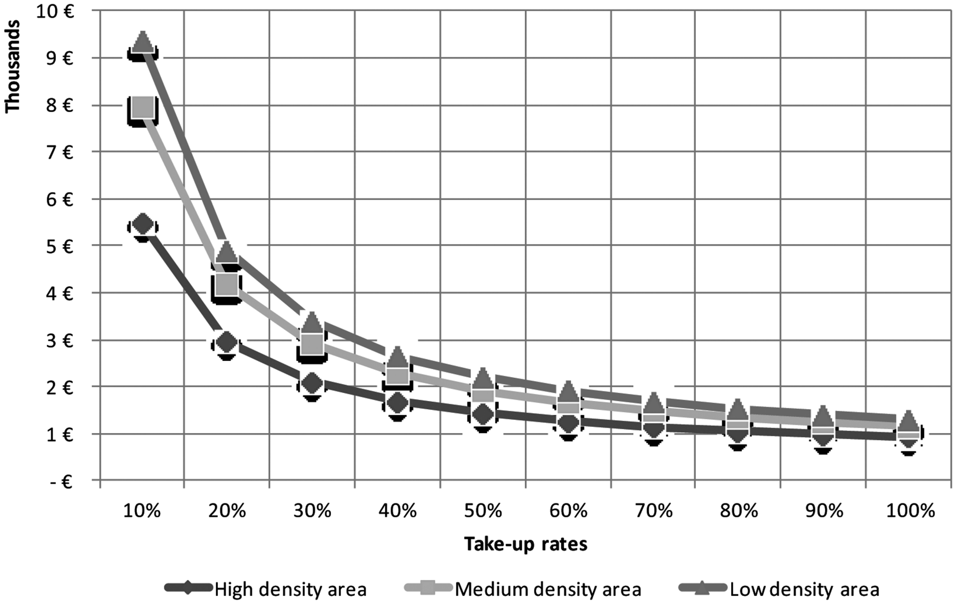

Figure 5. Network deployment cost per home connected.

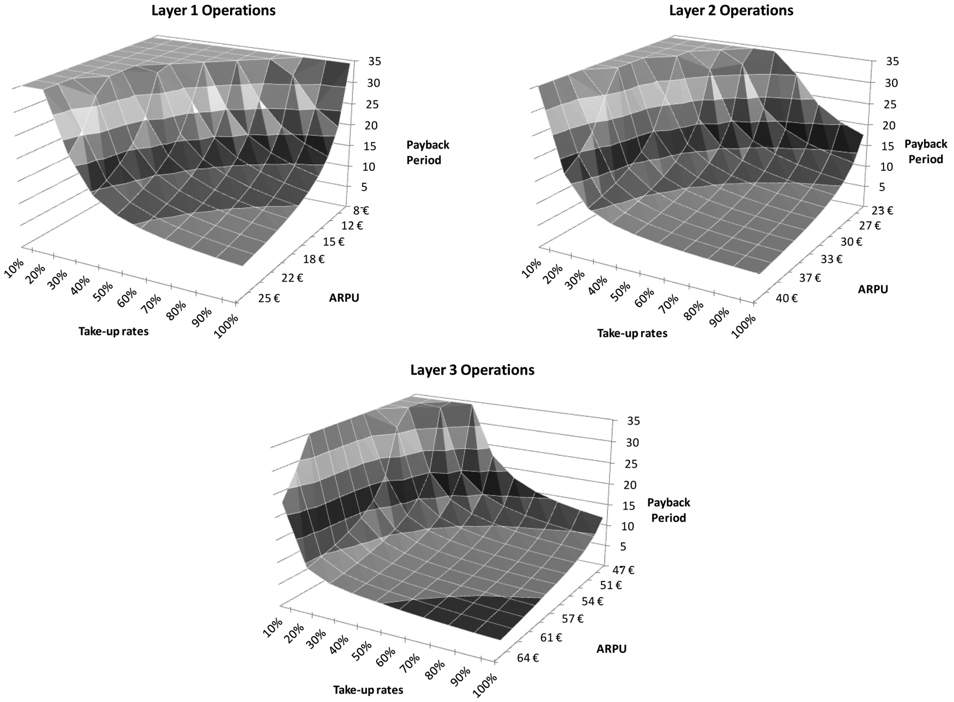

Figure 6. Impact of ARPU and take-up rates on payback period.

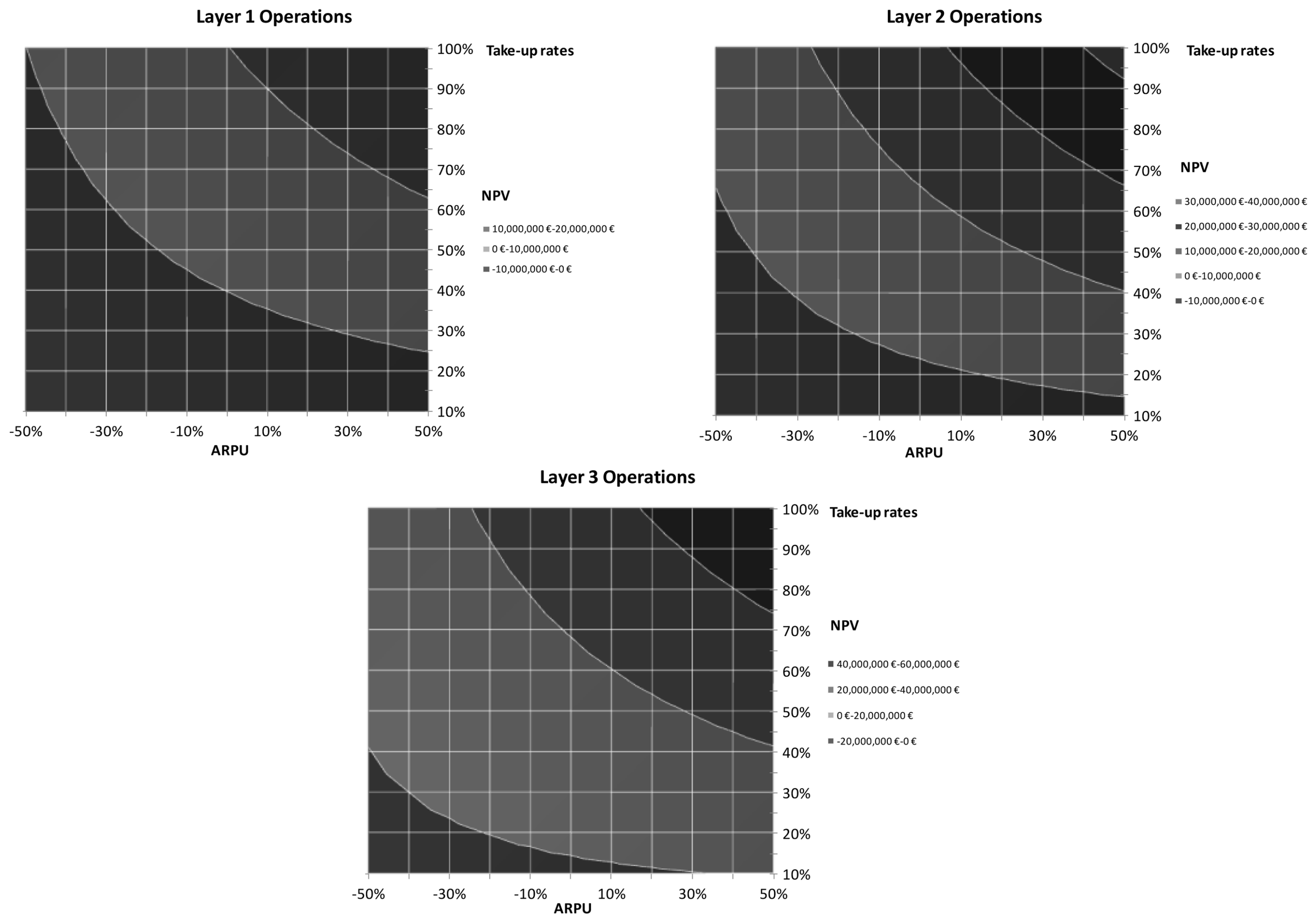

Figure 7. Impact of ARPU and take-up rates on NPV.

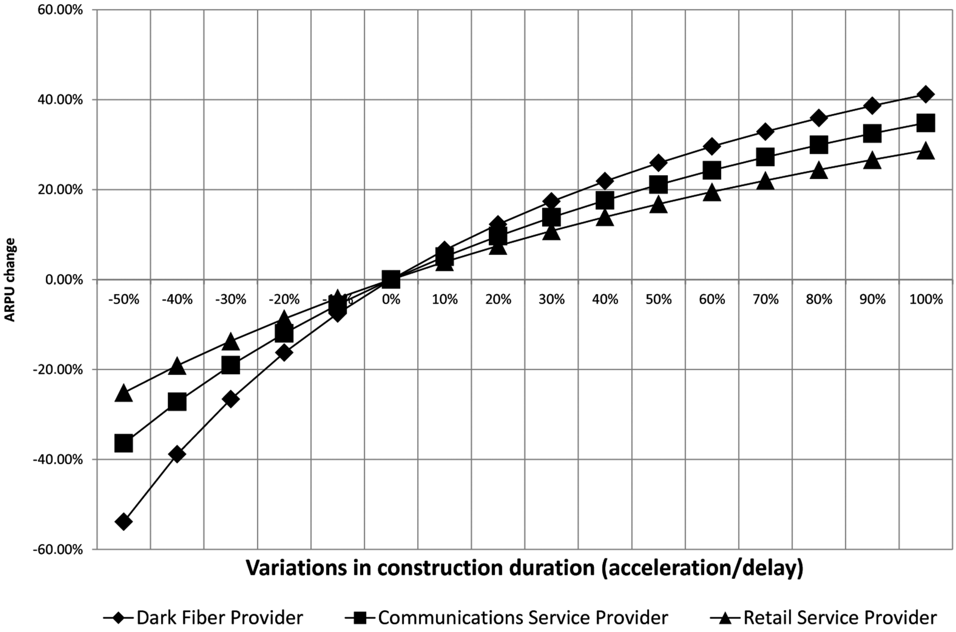

Figure 8. Effect of delay on ARPU to preserve payback period.

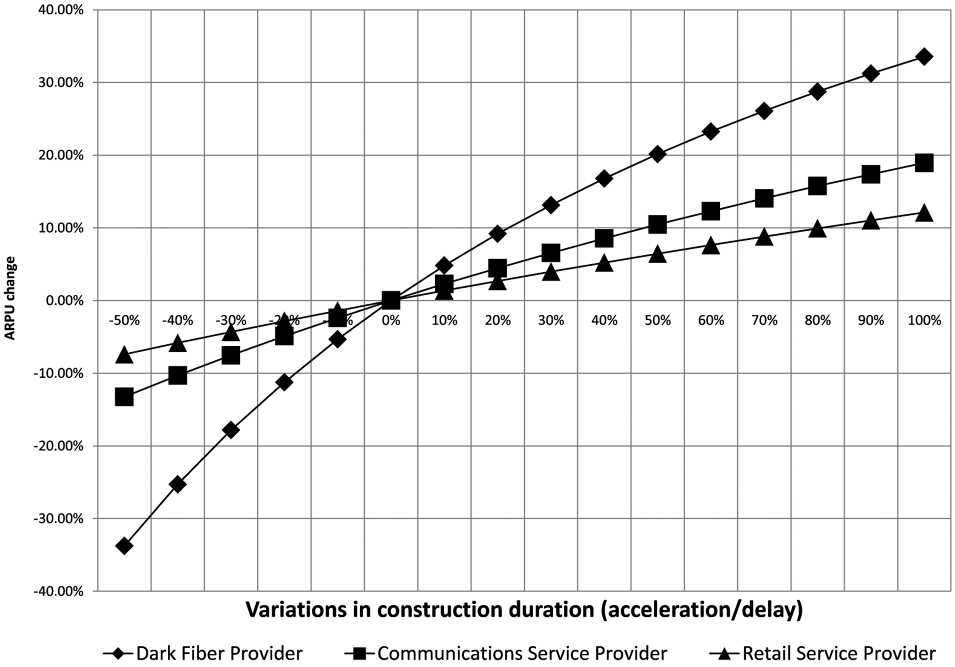

Figure 9. Effect of delay on ARPU to sustain the same profitability level.

This study's results demonstrate that the FTTH business case is more sensitive to take-up variations rather than the level of actual ARPU. For example, at the ARPU baseline and with 40% penetration rates, CSPs can improve their 17.9-year payback period by 3.75 years with a 10% ARPU increase or 5.2 years with a 10% increase in penetration. A simultaneous increase by 10% in ARPU and take-up results in a 7.12-year payback period gain.

Finally, the calculations demonstrate that the variations of ARPU and take-up have different consequences at different levels of commercial operations. In lower take-up levels, ARPU changes contribute more (positively or negatively) to the business case compared to operations with higher penetration rates. By analogy, networks that operate at low ARPU levels have more to gain from an increase in service penetration compared to networks operating in the top ARPU zones.

Construction delays result in significant increases in deployment costs and, consequently, have a negative impact to the business case. The impact of delay or acceleration of the FTTH projects to the three business models is assessed by calculating the change in ARPU necessary to maintain the same levels of profitability and payback period for the investment. As seen in Figures 8 and 9, construction delays have different influences per business models. The DFP business model is more susceptible to construction delays, while the RSP business model is the most enduring in delays and cost increases. Finally, for the same level of delay, maintaining the levels of profitability requires smaller ARPU increases compared to maintaining the same payback period.

5. Concluding Remarks

This research analyzes the implications of four major techno-economic factors—city plan, construction delays, ARPU, and take-up rate—to the business case of an FTTH network under three major service scenarios: retail, capacity (bitstream) and dark fiber. The RSP model seems the most attractive financially, if the profitability and payback period are taken into consideration. Nevertheless, RSP operations exhibit higher risk with regard to actual penetration rates, and as such, the decision of a suitable model can be more complicated. Providers should analyze the demand potential of an area and, based on that and other social and business factors, decide what business setup (ARPU and expected penetration rates) is the most appropriate.

The discussions on the business case of FTTH today focus mainly on deployment cost elements. Concerns over costs (due to the special characteristics of the city plan or construction delays) are of course valid. Rolling out FTTH networks requires a significant amount of money, and increasing costs translate to significant capital requirements. However, the impact of demand-side factors is found to be critically important as well. The ARPU and the take-up rates substantially influence the business case.

The international discussion on expediting the deployment of fiber broadband should also address demand issues to support the sustainable commercial exploitation of fiber access networks in the long-term. Policy incentives for co-investment schemes aiming at reducing costs and facilitating large-scale rollouts are plans looking in the right direction. However, their successful implementation would require setting up the commercial grounds (demand stimulation, social awareness) to achieve increased take-up rates and ARPU.

Finally, open-access business models, i.e., business models based on selling capacity services and dark fiber to competing downstream providers, can increase the level of network usage and cover a significant part of the investment. Structuring a service portfolio with retail and wholesale services (bitstream and dark fiber) can be an attractive business strategy to improve the FTTH business case.

References

1. Fibre to the Home Council Europe. Accessed from http://www.ftthcouncil.eu/resources.
2. Troulos, C. 2012. Driving FTTH deployments. *Broadband Communities Magazine* 33(5):20–23.
3. Milner, M. 2009. Fibre-to-the-premises cost study. Milner Consulting Limited, Wellington.
4. Troulos, C. 2010. FTTH cost of deployment—case: Seine-et-Marne. Accessed January 6, 2013, from *Broadband Prime*, http://www.broadbandprime.com/2010/06/ftth-cost-of-deployment-case-sein-et-marne.html.
5. Troulos, C. 2011. Lessons from the Australian NBN. Diffraction Analysis report, Paris.
6. Hesseling, D., and Vermeulen, T. 2011. Access to networks through competition law: The case of KPN–Reggefiber. *Network Industries Quarterly* 13:14–16.
7. Troulos, C., and Maglaris, V. 2011. Factors affecting municipal broadband business strategies. *Telecommunications Policy* 35:842–856.
8. European Commission. 2010. Commission recommendation of 20 September 2010 on regulated access to next generation access networks (NGA) text with EEA relevance. Accessed December 22, 2012, from http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32010H0572:EN:NOT.
9. European Commission. 2012. Results of the public consultation on how to reduce the cost of roll out of high speed broadband. Accessed January 3, 2013, from http://ec.europa.eu/information_society/newsroom/cf/dae/itemdetail.cfm?item_id=8868.
10. NBN Co. 2012. Corporate plan 2012–15. Accessed December 27, 2012, from http://www.nbnco.com.au/assets/documents/nbn-co-corporate-plan-6-aug-2012.pdf.
11. Troulos, C., Merekoulias, V., and Maglaris, V. 2009. A business model for municipal FTTH/B networks: The case of rural Greece. *Info* 12(3):73–89.
12. Brusic, I., Lundborg, M., Reichl, W., Ruhle, E. O., and Ehrler, M. 2010. Cost-benefit analysis for a municipal optical fibre network in the city of Krk, Croatia. SBR Juconomy Consulting AG, Vienna.
13. Kyriakidou, V., Katsianis, D., Orfanos, I., Chipouras, A., and Varoutas, D. 2011. Business modeling and financial analysis for metropolitan area networks: Evidence from Greece. *Telematics and Informatics* 28:112–124.
14. Felten, B. 2009. *Open Access Makes Economic Sense*. Report. Boston: Yankee Group.
15. EETT. 2012. Broadband in Greece–2nd Semester 2012. Accessed January 6, 2013, from http://www.eett.gr/opencms/opencms/EETT/Electronic_Communications/TelecommunicationServicePurchase/broadbandServices/.
16. Theorima. 2006. $\Gamma\varepsilon\nu\iota\kappa\acute{o}\Pi o\lambda\varepsilon o\delta o\mu\iota\kappa\acute{o}\Sigma\chi\acute{\varepsilon}\delta\iota o$ [General City Plan]. Municipality of Livadeia, Livadeia.
17. FTTH Council Europe. 2008. Developing a generic approach for FTTH solutions using LCA methodology. Report. Genval: FTTH Council Europe.
18. MarketAll. 2011. Citi cuts OTE target to 3.80 on higher WACC; At hold. Accessed January 7, 2013, from http://www.marketall.eu/markets/2277-citi-cuts-ote-target-to-380-on-higher-wacc-at-hold.
19. OTE. 2011. OTE SA. Report. Accessed January 6, 2013, from http://www.merit.gr/phocadownload/userupload/21232f297a/Ote%20Report%201Q11.pdf.
20. Olsen, B. T., Katsianis, D., Varoutas, D., Stordahl, K., Harno, J., Elnegaard, N. K., Welling, I., Loizillon, F., Monath, T., and Cadro, P. 2006. Technoeconomic evaluation of the major telecommunication investment options for European players. *IEEE Network* 20(4):6–15.
21. Strategy@Risk. WACC, uncertainty and infrastructure regulation. Accessed January 7, 2013, from http://www.strategy-at-risk.com/2010/02/08/wacc-and-infrastructure-regulation.
22. Riess, A. 2008. The economic cost of public funds in infrastructure investment. *EIB Papers* 13(1):82–113.

Biography

Costas Troulos was born in Piraeus in 1973. He received his electrical and computer engineering degree from the National Technical University (NTUA) of Athens, Greece, in 1997 and his Ph.D. in public policies for the development of fixed-line next-generation access networks from the same university in 2012. He also holds a Master of Business Administration obtained in 2006 from Louisville University, Kentucky, USA. He is a researcher at the Network Management and Optical Design Laboratory of the NTUA and works as a Senior Analyst with Diffraction Analysis and Senior Consultant at Broadband Prime. He has 15 years of experience in telecom operations and consulting. His principal research interests include next-generation access networks, telco transformation, business strategy and public policy.