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A case study for Egnatia Odos S.A.

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Traditional investment analysis approaches such as discounted cash flow and net present value do not capture the flexibility in the investment evaluation. In this paper, Real Options (ROs) are used to capture the value of flexibility in the evaluation of optical fibre investments along a motorway.

The ROs methodology is applied for a real life investments' scenario associated with "Egnatia Odos S.A." strategic decision to deploy optical fibre backbone network along the national motorway "Egnatia Odos". The focus is on low competition areas for broadband services provision which are characterized - especially in the access network - by low customers densities, longer loop lengths, lower duct availability and therefore higher infrastructure cost compared to high competition areas. In such areas high investment costs will be incurred promoting broadband.

The results obtained using the ROs methodology enable the company's senior management to identify conditions for which entry into the broadband market would be profitable. These results also indicate that using traditional approaches for evaluating telecommunications investments may provide wrong recommendations.

1. Introduction

A telecom operator's challenges providing profitable deployment of broadband services differ a lot with respect to high competition and low competition areas. In high competition areas the battle between broadband network operators has already started and the question is how market share will evolve.

The main challenge for a telecommunication network investor is to roll out its investment at the right time. This timing depends on broadband services penetration, network infrastructure cost, area characteristics, applications offered, expected tariff evolution, customers' willingness to pay, demand forecasts, evolution of expected market shares and of course investor's technical skills.

In comparison to dense urban areas and their business-industrial surroundings that are characterized by high competition conditions, urban and suburban areas are low competition ones, characterized by lower subscribers densities, longer loop lengths, lower duct availability and therefore higher infrastructure cost, especially for the access part of the network.

In low competition areas high investments cost will be incurred promoting broadband. In many countries including Greece, there is a high level of political interest to provide broadband access and backbone networks in areas where the prerequisites for offering broadband services are not fulfilled under pure market criteria.

This work examines the economics and risks associated with a broadband network investor roll out along the longest (680 klm) motorway in Greece called "Egnatia Odos".

We use the ROs methodology to take into account the managerial flexibility related to the timing of the investment decision for "Egnatia Odos S.A." (EO), the investor. The methodology of ROs is trying to quantify the managerial flexibility during the investment deployment process. Although real options theory is increasingly used in other industries, such as R&D and pharmaceuticals, it has not widely been applied in the telecommunications industry, while is ripe for this methodology, [J. Alleman 2002]. For a review of ROs applications in real life investment Information and Communication Technology (ICT) projects the interested reader is referred to [G. Angelou & A. Economides, 2004].

A few words about the investor [Iatropoulos, Th., 2004]

EO was created in September 1995 and its aim is the management of design and construction, the operation, maintenance, and exploitation of the Egnatia Motorway, its Vertical Axes as well as of other projects within or outside the Greek territory.

Egnatia Motorway is a modern closed motorway 680 kilometres long and 24.5 metres wide over the greatest part of its length following a new alignment and running across Epirus and Northern Greece from Egoumenitsa to Evros. The Egnatia Motorway is one of the largest road construction projects in Europe.

Nine major vertical axes connect the motorway with Albania, FYROM, Bulgaria and Turkey. Furthermore, 5 ports and 6 airports are serviced by the road.

The remainder of the paper is organized as follows. In Section 2 a brief review of the ROs theory as well as its analogy with economics characteristics of an investment's scenario is provided. In Section 3 the business scenarios for EO are presented. In Section 4 we present a market analysis and demand forecasting for the geographical area of interest. In Section 5 we apply the ROs methodology to justify and extract the optimum investment deployments plan as well as quantify investments performance. Finally, in Section 6 we conclude giving some proposals for further work.

2. Real Option Methodology Review

In this section, we present an introduction to the methodology of real options and we explain the analogy between a financial call option and an investment project. A financial option is the right, but not the obligation, to buy (call option) or sell (put option) an asset at some point within a predetermined period of time for a predetermined price. The opportunity to invest in a project, called real option, is analogous to a call option to acquire a claim to the cash flow value of a completed and operating project by paying a specified cost as the exercise price.

The three basic criteria for a real option applicable to our investment problem are the following [Dixit & Pindyck, 1994]:

- Uncertainty in the future cash flows resulting from the broadband infrastructure rollout at time *T*.
- A large discretionary and irreversible investment at time *T* (new optical network components and civil works costs).
- Flexibility in timing. The operator can decide to invest or not depending on the information gathered until time *T*.

Spending money to exploit a business opportunity is analogous to exercising an option on, for example, a share of stock. It gives the right to make an investment's expenditure and receive an investment's asset, the value of which fluctuates stochastically. The amount of money spent for investment corresponds to the option's exercise price (X). The present value of the project's asset (total gain of investment) corresponds to the stock price (V). The length of time the company can defer the investment decision without losing the opportunity corresponds to the option's time to expiration (T). The uncertainty about the future value of the project's cash flows (the risk of the project) corresponds to the standard deviation of returns on the stock (σ). Finally, the time value of money is given in both cases by the risk-free rate of return (r_f). The project's value as calculated by the real option methodology is the same with the value calculated by the NPV methodology when a final decision on the project can no longer be deferred (expiration date of the option) [Trigeorgis, 1996].

The following table summarizes the parameters' analogy between a call option and an investment project.

Investment Opportunity	**Variable**	**Call option**
Present value of a project's assets or Present Value of cash flows from investment	V	Stock price
The amount of money spent for the investment, Investment expenditure required to exercise the option (cost of converting the investment opportunity into the option's underlying asset, i.e., the operational project)	X	Agreed Exercise price of the Option
Length of time where the investment's decision may be deferred	T	Option's time to expiration (i.e., the maximum length of the deferral period).
Time value of money	r_f	Risk-free rate of return
Variance (Riskiness) of the investment's project assets	σ^2	Variance of returns on stock

Table 1. Parameters' analogy between a call option and an investment opportunity

The total value of a project that owns one or more options is given by Trigeorgis (1999):

Expanded (Strategic) NPV = Static (Passive) NPV + Value of Options from Active Management

The flexibility value named as *option premium* is the difference between the NPV value of the project as estimated by the Static or Passive NPV method (PNPV) and the Strategic or Expanded NPV (ENPV) value estimated by the Real Options method.

The value of an option to defer stems from two factors:

- Uncertainty is resolved over time, at least partially;
- The time value of the money, that is the interest earned on money that could have been invested from the start.

The higher the level of uncertainty, the higher the option value because the flexibility allows for gains in the upside and minimizes the downside potential. For more background information on real options from the capital budgeting literature the reader is referred to Dixit & Pindyck [1994] and Trigeogis [1996].

3. Investments scenarios analysis for EO

The transportation network of EO can be used for the installation of optical network backbone infrastructure along it. The commercial exploitation of this network is a business activity to be analyzed in this work.

The business choices of EO for the commercial exploitation of Egnatia motorway through the deployment of broadband infrastructure and services along the axis, are investigated hereafter. The business model for broadband service provision along Egnatia is presented in Figure 1.

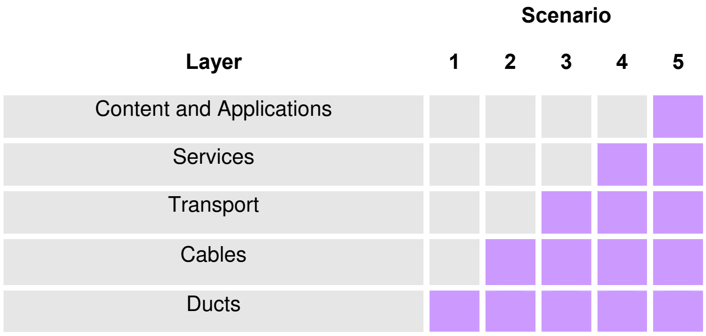

Figure 1. Business scenarios deployment for Egnatia Odos S.A.

In the first scenario EO - owner of the ducts along Egnatia motorway - decides at a specific point in time to rent them to a telecom operator (e.g. OTE, Vodafone). In this scenario EO is not involved in any business activity related to the provision of infrastructure or broadband services directly but receives an agreed fee (a fixed monthly rent or a variable amount based on the revenue created by the use of the ducts).

In the second scenario EO decides to install optical dark fibres looking afterwards for their commercial exploitation.

The third scenario is a step ahead as the company decides to light the optical fibres. This means that the customers are able to buy wavelengths [Canarie]. Hiring wavelengths requires the installation, operation, management and maintenance of active equipment.

In the fourth scenario the company enters, in addition, the market of network services provision, like Fast Internet and VPN.

Finally, in the fifth scenario there is also content and applications provision through the optical fibre network. The company further to the role of Network Access Provider undertakes the role of Application Service Provider.

In this work we investigate the second scenario trying to apply a ROs methodology for the estimation of optimal investment's deployment strategy as well as the investment's performance.

The company decides to enter the market of broadband networks possessing the option to defer investment of **dark fibre installation** up to time T. During this period many of the investments uncertainties could be - at least partially - resolved making the realization of the investment either more or less favorable. The balance, however, between the pros and cons of waiting should be verified against the impact of revenue loss due to the delayed market entry or the emergence of other competitors. We analyze competition issues for the area of interest to verify ROs applicability and possibility to defer. **The target here is to find the optimum time to enter the new market of broadband backbone networks as well as to estimate the investment's performance.**

Service definitions

EO provides (renting or leasing) dark fibre to interested customers, installing fibre cables to the building (FTTB). The service type is limited to the installation of fibre cables. It is the customers' responsibility to install active optical equipment to light the fibre and maintain the network services on the fibre. In general, customers interested in using dark fibre include those who possess (or are capable of finding) the technical skills to "light" the dark fibre.

In the literature, so far, investment's evaluation in BroadBand technologies upgrade from ADSL (Asymmetric Digital Subscriber Loop) to VDSL (Very High Data Rate Subscriber Loop), services in suburban areas using ROs is examined in the works of [Elnegaard & Stordahl, 2002], [Elnegaard 2002] and [Kalhagen & Elnegaard 2002]. They capture the value of flexibility in future VDSL rollout investments in a suburban type of area concluding to similar results of, EURESCOM P-901 [2000] project.

Technical Description

Fibre to the building is delivered by two basic architectures: the direct connection from the central node to the customer's building via a dedicated optical fibre for each subscriber (home run) and star topology where a common fibre segment of the distribution network is shared among several customers through a remote connection node, which is located between the customers and the central distribution node.

This architecture can be either active or passive, depending on power availability in the remote node. The customers in the active topology can be served either through a common single wavelength or through individual wavelengths per customer via WDM (wavelength division multiplexing) devices [Reed, 1992].

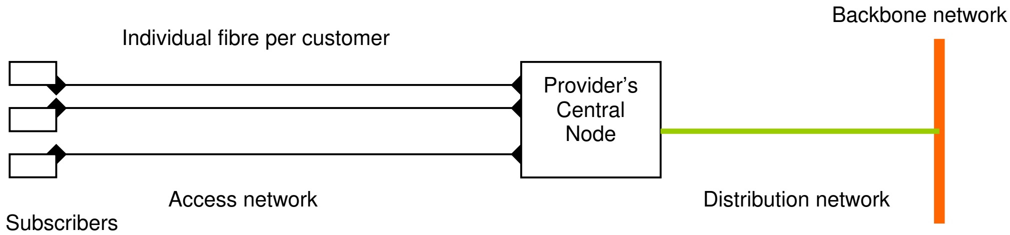

Figure 2. Home Run network topology

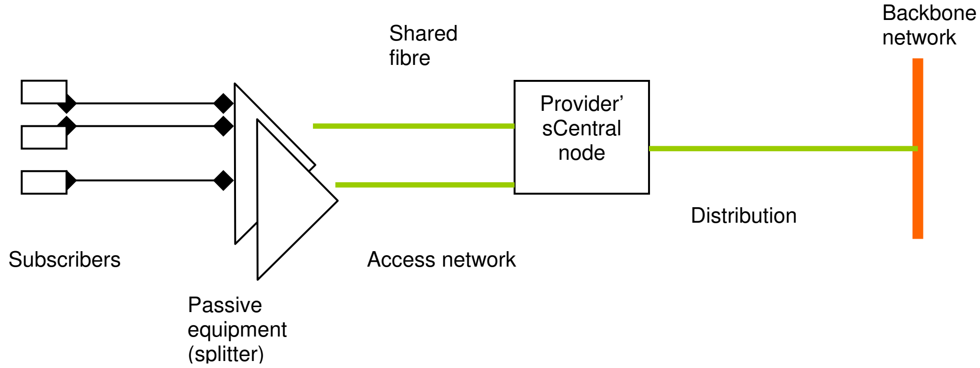

Figure 3. Passive star topology (PON)

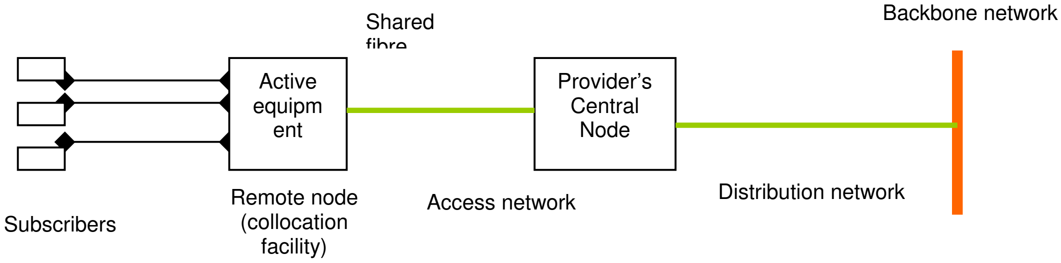

Figure 4. Active Star network topology

Independent of the network topology, each fibre is terminated in the central connection node on specific equipment, which should support various network technologies (Fast/Gigabit Ethernet, SONET, ATM) connecting the access network to the provider's distribution network. In the customer side the fibre is terminated in specific equipment (Customer Premises Equipment).

Additional fibre terminations are required in case a remote node is used. Finally, economies of scale can be achieved through an optimal selection of network topology according to the specific network requirements.

In this study we adopt the "home run" topology.

4. Market Analysis and Demand Forecasting

For the market analysis we investigate demographic, social and economic data of the areas across Egnatia's track. In addition, the amount of possible dark fibre customers is forecasted. These customers can be public or private organizations, other authorities and certainly various companies of all sizes.

4.1. Area definitions

We examine the area of East Macedonia & Thrace and specifically the part to the east of Kavala. The reason for this selection is related to the completion of civil works in this part of the road allowing the deployment of optical fibre infrastructure.

The area is characterized as rural with four (4) major cities Kavala, Xanthi, Komotini, Alexandroupolis on the track of Egnatia. In the cities, subscriber density is in the range of 1.000 to 4.000 habitants per km^2, while the average living unit is an apartment building with 8 flats.

The following area specific data are summarized in Table 2.

Prefecture/City	**County Population**	**Principle City population**
KAVALA/Kavala	145.054	60.802
XANTHI/Xanthi	101.856	45.118
RODOPI/Komotini	110.828	46.586
EVROS/Alexandroupolis	149.354	49.176

Table 2. Area Characteristics
Source: e-Business Forum (March 2003)

4.2. Market Analysis

The area under consideration includes the eastern part of Northern Greece (Region of Eastern Macedonia and Thrace). Based on a recent survey ordered by the Greek Research and Technology Network (GRNET, March 2003) on the use of information and communication technologies (ICT) by SMEs (1 to 250 employees), ICT penetration is presented in Table 3:

Total population of SMEs	Enterprises using computers	Enterprises using PC network	Internet Connection	ISDN connection	e-mail	WEB presense
21.923	5.700	1.666	4.516	3.573	3.332	842

Table 3. ICT penetration among SMEs in the region of Eastern Macedonia and Thrace
Source: e-Business Forum (March 2003)

Potential users of broadband services (Fast Internet) are primarily the enterprises with Internet connection. Internet penetration in the region is 20,6%, allowing a significant growth margin.

Considering the backbone networks available today in Greece the sole long haul fibre optic network is operated by the main telecom incumbent OTE, connecting the metropolitan area networks of Athens and Thessaloniki (extended to Crete via a submerged cable). The main interest of the telecom providers is focused in the areas of Athens and Thessaloniki, where 59% of the SMEs are located. In these areas two to three telecom providers beyond OTE are expected to deploy private fibre optic networks (Vivodi, Tellas, Attica Telecommunications).

Further to the topology constraints other factors that prohibit the deployment of fibre networks by parties other than OTE to remote areas like Eastern Macedonia & Thrace are the difficulty in getting rights of way (ROW), the complicated local loop unbundling (LLU) processes, the restricted access to leased lines.

Considering the penetration of Internet in Greek households, a study carried out by VPRC revealed that *"Based on people above 15 years of age the total number of Greek Internet users is 1.704.936 people (+/- 1,6%). This figure corresponds to 19,3 % of the total polulation in year 2002, while in 2001 the figure was 10,15%. The EU average is 37,7%. Among those who use a computer in Greece, Internet penetration has raised from 50,2% in year 2001 to 66,8% in 2002, an increase of 33%"*. In rural areas penetration rates have doubled from 4,3% in 2001 to 9,7% in 2002.

Figures from Analysys (2002) predict that the demand for broadband services in Greece by 2006 will reach 20% of the total number of Internet users. Figures from other sources (mainly local Internet providers) show that this percentage will be 4-5% in year 2004 and not higher than 10% by year 2006. Experts of the broadband sector in Greece estimate that broadband penetration in the region of Eastern Macedonia and Thrace will not exceed 2% to 4% of the total number of Internet users in years 2004 and 2005. This estimation is based on the fact that the main incumbent (OTE) is the sole provider of infrastructure adequate to provide broadband services in the area and OTE's strategy for the next two years is the deployment of ADSL. The services that can be delivered over ADSL are mainly the basic connectivity services (Fast Internet and VPNs). The demand for content delivery (video streaming, video/audio on demand, time shifted TV) and application services (video conferencing, internet games) comes next with lower priority due to the lack of content, complications in ownership and copyright protection issues, administration costs in managing the contracts with content providers that the network provider must bare.

Greece is ranked first among EU members in TV watching, while the use of complementary devices (video and DVD) is growing fast.

The company has already installed ducts alongside the road - is the owner of the infrastructure for passing fibre optic cable. Fibre cables will be used to cover internal company needs. These needs involve the operation and control of telematics applications in specific segments of the road (tunnels, bridges) for traffic management, collection of tolls, etc. Additional fibre cables can be installed in the ducts that will be rented or leased to potential customers.

Considering the capacity of the fibre, renting a pair of dark fibre to an individual client for connecting two or more locations, will generally be adequate [Barnejee & Sibru, 2002]. In the backbone segment fibre cables may have capacities of 192 fibres or more. Based on the above, serving a number of 200 customers of dark fibre over the same backbone in the period 2005 – 2014 (10 years) seems realistic.

Clients of dark fibre in the region include:

From the public sector:

Counties, Prefectures, Municipalities. The "SYZEFXIS" network is aimed in connecting 1766 local authority agencies, providing transfer of data, voice and video. It is built on the infrastructure currently provided by OTE, the main telecom incumbent. The OTE network in the region is not yet upgraded to provide high-speed broadband links. The links in the city of Alexandroupolis can reach speeds of 256Kbps, which permits moderate performance for streaming video or teleconferencing applications.

Citizen's Service Centers (ARIADNE network). It is built over the SYZEFXIS network and is aimed in improving communication and quality offered by public agencies to the citizens. It will connect 1.000 centers.

Hospitals and Health Centers. A modern high speed wide area network is required to connect the integrated information systems of the recently announced "Regional Health System". Funded by the IST Framework Programme (Action 2.6) the network will provide electronic patient file, telemedicine, teleconferencing, etc.

Public Organizations (Post Offices, Regional Authorities, Administration Offices).

From the Education sector:

Hellenic Education Network (EDUnet). The network will connect schools of primary and secondary education. It is linked to the Greek Research and Technology Network GRNet in seven nodes (Athens, Thessaloniki, Patras, Heraklion, Larissa, Ioannina, Xanthi).

Greek Research and Technology Network (GRNet). It is intended to provide advanced services (multimedia applications, distance learning, teleworking, virtual libraries and labs) to the academic and research community of the country. The administration team of GRNet aims in linking all eligible institutes via a high speed fibre optic backbone network (10Gbps over Gigabit Ethernet).

Greek Universities Network (GUNET). It connects 18 Universities and 14 Technological Institutes. The implementation of an alternative backbone network using fibre optic cables is planned as an upgrade to the existing network that will allow the provision and support of telematics applications, such as the dissemination of digital content to the users of the network and the provision of synchronous (on-line seminars) and asynchronous (production of digital content) learning.

South-Eastern European Research & Education Networking (SEEREN)[1]. SEEREN's major objective is to establish the South-Eastern European segment of the Pan-European academic and research network, in accordance with the principles and practice used in the implementation of the GEANT network[2]. SEEREN currently includes a 2Mbps terrestrial line connecting Athens to Belgrade and a 5.2 Mbps terrestrial line connecting Athens to Sofia. The need for upgrading the bandwidth is vital for its users.

From the private sector:

Enterprises and organizations (banks, travel agencies, insurance companies, security and emergency service organizations, transportation companies, airline companies, telecom and network services operators, car dealers, hotel chains, etc.).

Banks are using the existing infrastructure to connect branch offices to their central information systems. They will be interested in upgrading the capacity of their links to provide higher connection speeds. The use of fibre optic technology will allow the provision of services such as voice transmission over a private network, video conferencing and easier disaster recovery, since their main system will be connected via a fast link to a remote site (the disaster location).

Enterprises located in the industrial zones of Kavala, Xanthi, Komotini and Alexandroupolis will be interested in getting connected via high speed links to other locations (logistics centers, branch offices, agencies, dealers, affiliated companies, banks, ISPs, ASPs, business partners, customers and suppliers).

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[1] http://www.seeren.org/

[2] A multi-gigabit pan-European data communications network, reserved specifically for research and education use (http://www.dante.net)

Telecommunication providers (OTE, Vodafone, Med Nautilus, Tellas, Forthnet, Vivodi, Lannet, Teledome, Q-Telecom, ACN, TIM and others), Internet and Applications Services providers are potential customers.

TV Broadcasting stations

Local stations will be interested in using broadband networks for video transmission.

Corporate customers will generally benefit from the use of broadband networks in a number of ways:

- *A server consolidation to a central location will be feasible.*
- *The customer will be able to connect to multiple providers (ISPs and ASPs) in order to secure alternative routes.*
- *Outsourcing of IT services to an ASP will be feasible - the ASP will be directly connected to the same fibre optic network.*

Individual users

In distant communities the use of home entertainment is very popular. The demand for high speed Internet, pay-TV, video is rather high. Home users will mostly be interested in content and application service delivery.

The Framework Programme IST [Hellenic Task Force for Broadband], since December 2003 has opened the following calls for funding (Action 4.2):

- Activities for the dissemination of information on the awareness of broadband services in rural and remote regions.
- Activities for building infrastructure for the implementation of broadband networks.
- Activities for building hot spots in distant and less developed areas.
- Activities for building metropolitan area networks.

Local authorities will be urged to take advantage of the funding programs and start being aware of the benefits of broadband networks and services. An increase in the demand for broadband services is expected soon after the infrastructure is available. However, digital content is not available at the moment (apart from a restricted network in Athens) and only corporate users will be the first broadband customers[3].

Large enterprises operate their own networks, mostly VPNs. They can be interested in connecting their branch offices over a high speed fibre optic network that will provide:

SDH rings – for fault tolerant connections

Ethernet to the Office – the fibre cable will extend till the office. The customer premises equipment (Ethernet ports) will be provided by the company. The customer will no longer own any hardware or network components but will be the user of a service (according to a SLA)

xDSL – these technologies can be ADSL or SDSL for the time being.

Services like high speed Internet (Fast Internet) and VPNs can be implemented over SDH, Gigabit Ethernet, xDSL. VPNs built on high speed networks will allow broadband services like voice transmission and video to be offered to the users of the VPN.

<u>Assessment of the potential users of dark fibre (case 1) or network services (case 2).</u>

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[3] Home users are the biggest market segment that will demand content and applications. This means that the provision of high bandwidth applications can be delayed until more content providers and content delivery agents appear in the market.

Among the user groups identified in the previous section the following characteristics are important in the selection process for potential customers in each of the above cases:

- Category of customer (corporate or private users)
- Size (number of users)
- Principle job function or industry (technical, academic, commercial)

In general, customers interested in using dark fibre include those who possess (or are capable of finding) the technical skills to “light” the dark fibre. This segment includes the universities, the educational network operators (GRNet, GUNet, SEEREN), ISPs and ASPs (OTENET), telecom operators (OTE, Vivodi, MedNautilus, Forthnet).

Customers with non-technical expertise like health institutions, post offices, regional authorities, etc. will mostly be willing to use the network service rather than managing fibre optic equipment. The same applies to most customers of the private sector like banks, service organizations, industrial and commercial firms. They would rather have an Ethernet port in each location and outsource the network service to an external provider.

The same applies to several ISPs and telecom operators like Telepassport and Sparknet, who do not wish to be involved in managing the network infrastructure.

It is noted that the prospects for prefectures and municipalities to get EU funding to build their own MANs have improved. This development creates a potentially large customer base in the dark fibre sector.

4.3. Dark fibre demand forecast and pricing evolution

Several experts of the broadband sector in Greece as well as executives of telecom operators and Egnatia Odos S.A. were interviewed to estimate broadband penetration in the region of Eastern Macedonia and Thrace. The effort of finding the appropriate mix between demand and tariff rates for each business case identified three take-up scenarios for dark fibre demand estimation that are matched against three pricing evolution scenarios respectively.

A minimum number of customers must exist in order for the investment to be sustainable. The main incumbent (OTE) applies a monthly rate of about 13.000 €[4] for connecting two nodes at a speed of 34Mbps.

The fact that the fibre permits transmission rates of many Gigabits per second means that a monthly rate in the range of 12,000 € to 14,000 € would be attractive to the customers already using links of 34Mbps or higher.

Customers asking for dark fibre will most likely be willing to pay an additional cost for the extra bandwidth. This may not be essential in the beginning but they will be able to develop new services and applications on the new infrastructure.

We consider an aggressive pricing policy (SCENARIO 1), aiming to a larger number of dark fibre customers, a policy that is similar to the one applied by the incumbent (SCENARIO 2) and finally a high subscription positioned against a lower forecasted demand (SCENARIO 3).

[4] Actually, for a similar distance between the two nodes like our case, a flat monthly rate per node and a variable rate based on the distance between the connected nodes are applied.

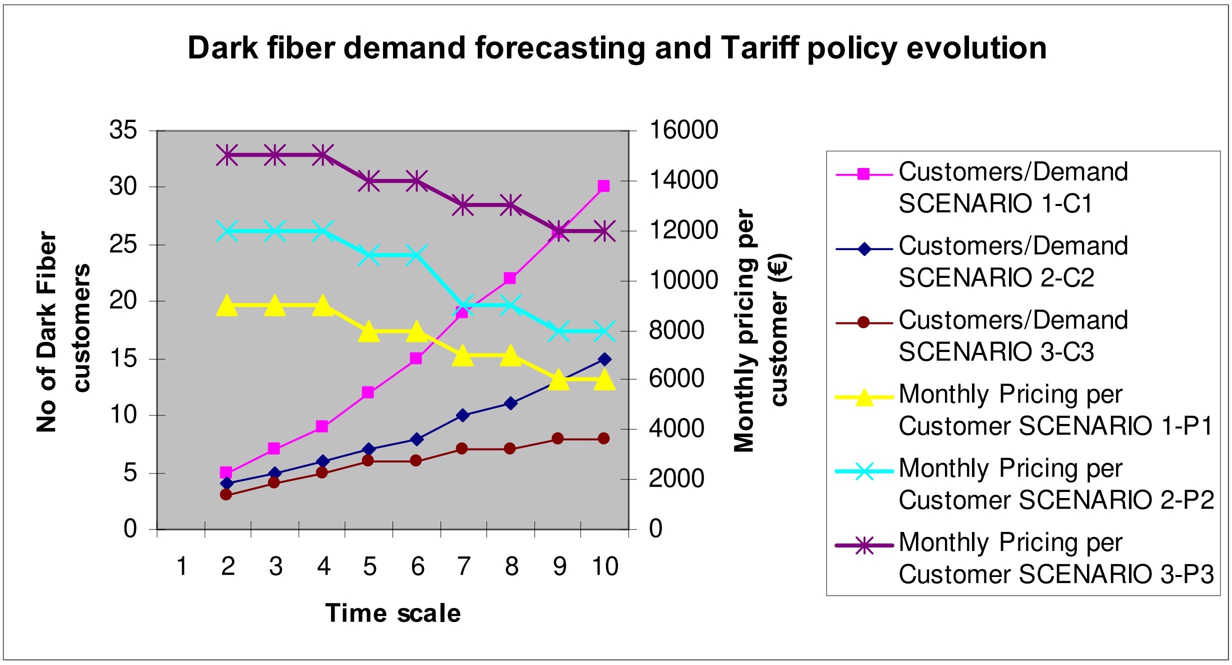

Figure 5. Demand forecasting and Tariff evolution

Business Cases Assumptions

- The analysis horizon is 10 years, from early 2005 until and including 2014.
- The discount rate, *r*, used to compute the passive NPV (ignoring the deferral flexibility) is 8%, while the risk free discount rate r_f is 4%.
- The time required to commence the provision of dark fibre and start collecting revenues once the investment decision is made, is one year.
- The company can delay dark fibre network deployment up to 3 years.
- The annual dark fibre tariffs are given in figure 5.
- The initial technical investment cost for the dark fibre backbone network deployment as well as the infrastructure cost for the access and distribution networks is given in appendix A.

5. Analysis of Business Cases

5.1. *Scenario 2 – Dark Fibre network deployment investment*

5.1.1. *DCF approach analysis*

For each of the take-up scenarios Net Present Value has been calculated for immediate market entry in the field of dark fibre. The NPV values for the three take-up scenarios that correspond to immediate market entry, by investing in 2005, are given in table 4, while a detail analysis is included in Appendix B.

NET PRESENT VALUE ANALYSIS	
NPV of CFs (r=8%) Scenario 1	**-1.663.623 €**
NPV of CFs (r=8%) Scenario 2	**-1.762.559 €**
NPV of CFs (r=8%) Scenario 3	**-1.191.454 €**

Table 4. Net present values for the three take-up scenarios

As seen, traditional investment analysis identified that dark fibre deployment for commercial exploitation should not be initiated, since NPV values are negative. There is, however, managerial flexibility in the timing of the investment – it can be deferred. This aspect is not considered in the NPV analysis.

The methodology of real options is now introduced in order to quantify this managerial flexibility in timing for deploying the investment plan. For the investment analysis we adopt the "option to defer the investment", in order to investigate its sustainability and determine the optimal deployment strategy in the context of time.

5.1.2. Real Options analysis

In the one stage investment scenario that contains a real option to defer there is a possibility but not an obligation to perform a large discretionary and irreversible investment in a new product or service at time $t \leq T$. This possibility of deferral gives rise to two sources of values. First, paying later than sooner we can earn the time value of money of investment cost. Second, while waiting the world changes the present value of the operating cash flows may change indicating finally the non-profitability of the investment.

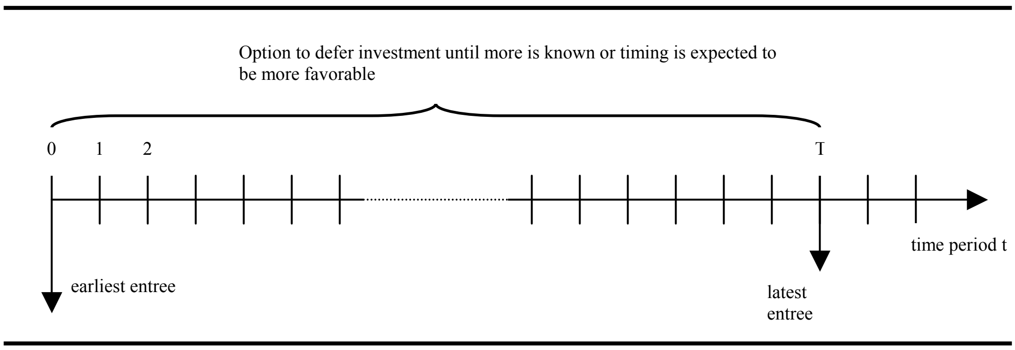

Figure 6. One stage investment for EO possessing option to defer

In such situations, the question is not whether the investment should be made or which out of several alternatives should be chosen, but when to exercise the option held, meaning when to implement it.

The first application of ROs in such business scenarios, involving real life Information Communication Technology (ICT) investments is presented by [Benaroch & Kauffman, 1999 & 2000]. It focuses on an analysis of the timing of the deployment of point-of-sale (POS) debit services by the Yankee 24 shared electronic banking network of New England.

In our case EO faces the option to enter the new market at a time period of t=0 to t=T. During this period the company, possessing an option to defer, has to decide when is the optimum time to invest in dark fibre, entering the new market.

Our application aims in identifying the optimum time for the deployment of broadband services along the Egnatia axis by taking into account uncertainties such as:

- Broadband demand
- Broadband services pricing
- Capability of the company to enter a new market, considering the lack of internal expertise and experience in the particular technologies. The appropriate business partnerships should be determined.

By deferring the investment, EO could lose market share and revenues. Moreover, it could be quite late when the company decides to enter the market. On the other hand, the region of interest faces low competition and this factor is expected to be quite limited, though quantitative analysis should verify it.

The main competitor (OTE), although it holds a dominant position in the region, is mainly focused in the provision of ADSL services in high competition areas (with dense population). Interviews with broadband experts in Greece conclude that the main competitor OTE will delay the broadband service provision in sub-urban and rural areas beyond year 2006, [Iatropoulos, Ath., 2004].

The "Egnatia Odos" motorway, along which an optical fibre backbone network will be installed, is located out of dense urban areas, the prime focus of other broadband network investors. In particular, it passes through areas with low level of business activities except Thessaloniki.

In addition, the duct construction corresponds to more than 40% of the overall cost of an optical fibre network. In this sense, EO has a strong competitive advantage, compared to other possible telecom investors in the area, facing for the moment no or little competition by the incumbent and other network operators.

Of course EO has still to construct the network branches from the backbone track to the customer premises.

Hence, by waiting EO will not lose significant market share; at least until OTE or some other competitor (e.g Vodafone, Vivodi, Tellas) decide to enter that market. Naturally, by waiting EO will lose some revenues. More importantly, waiting too long could lead to market share gains by competitors who had no prior presence in the market. Having compiled the information received by interviewing company executives and broadband experts in Greece, we concluded that the waiting period to achieve the best timing for market entry cannot exceed 3 years.

Thus, from EO's perspective a decision to enter the broadband business can be a matter of timing. It is examined whether EO can afford to wait since there are no credible threats in the markets (regions) of interest. This assumption is made since the area under investigation is considered as a low competition one.

By waiting, EO expects that uncertainties, related to the acceptance of broadband services in the regions along Egnatia's track and the sustainability of additional irreversible network infrastructure investments, would be resolved. In turn, EO could learn more about the potential returns on such investments. For example, the acceptance rate for such services might increase as customers become more aware of these services. In parallel, EO could take actions to lower its market entry risk (e.g. by seeking corporate alliances for common exploitation of the specific North Greek regional market).

With these concerns in mind EO is addressed to the question: how long should EO wait to enter the broadband market and what is investment's performance in the optimum time entry?

ROs Analysis Framework Study

In this section we apply real options analysis to EO's investment decision and assess claims concerning the main benefits and drawbacks of this approach. We first discuss methodological issues involved in establishing the suitability of real options analysis to EO's situation and in eliciting relevant information for the analysis.

The primary analysis findings indicate two major conclusions: (1) NPV value for immediate entry by EO and (2) the suggestion of optimum time to enter the market based on the analysis of the deferral option value possessed by EO.

In order to verify the existence of option value in EO's case, the following questions must be answered:

What kind of option does EO possess? EO possesses an *American deferral option* on a *dividend paying asset*. The asset underlying this option is the potential stream of revenues from an investment opportunity that will materialize only once EO enters the broadband market any time starting in 2005, where the dividends are the revenues lost during the time EO deferred entry into this market.

Where did the option come from and at what cost? Unlike a financial option that is purchased for a cash fee, EO obtains its deferral option at no direct cost. Generally, a firm could obtain a deferral option at no cost if it faces no credible competitive threat of loosing the deferred investment opportunity [Dixit and Pindyck, 1994]. This is clearly true in the case of a monopoly. In case of a duopoly, the option exists for the "leader" among two competitors who made indirect investments in building up over time managerial competencies, reputation, technical infrastructure, etc.; if there is no clear leader, both firms may have the option, but only the first mover would enjoy its full benefits.

Hence, as far as project valuation decision-making is concerned, EO's option cost is the opportunity cost of delaying entry - the revenues lost during the deferral period - and a negligible opportunity cost born by the slim risk of losing the investment opportunity to other competitor like OTE.

Where does EO's option value come from? The option value stemmed from EO's belief that it could resolve some of the uncertainties. Such uncertainties are: the broadband services demand in the region of interest and the capability of the company to enter a new market. At present, there is an internal lack of experience in such technologies and the appropriate business partnerships must be identified.

Alternatively, the option value comes from the managerial flexibility in investments deployment.

EO has the ability to wait and learn more about the investment, to be able to better assess it and subsequently avoid it if the expected revenues turned out to be unattractive. EO could passively observe how the broadband business evolves in other parts of the country and actively try to lower the risk of expected revenues.

From a real options perspective, the intuition behind the evaluation principle for solving an investment-timing problem, like the one under investigation, is as follows:

Holding a deferrable investment opportunity is equivalent to holding an American call option. At any moment, the investor can own either the option (investment opportunity) or the asset obtained upon exercising the option (operational investment).

Holding the option unexercised (postponing investment) for time t has two competing effects: V is lowered by the amount of foregone cash flows and market share lost to competition and X is lowered because it is discounted during the deferral period, t. Depending on the magnitude of these two tendencies, the value of the option exercised at time t, Ct, can be higher or lower. If information arriving during deferral indicates that V is likely to exceed original estimates, investment can be justified by the rise in the payoff expected from investing; otherwise, the irreversible sunk cost (X) can be avoided by not investing, at a loss of only the cost of obtaining the deferral flexibility.

To find whether an early exercise at time t is more profitable, we use the standard Black-Scholes to calculate the prices of European options that mature at T and t, C_T and C_t, and then set the American price to be the higher of these two. Of course, to compute Ct, the value of the underlying asset used in Black & Scholes formula must be V less the foregone revenues due to delay.

Consequently, the following decision rule leads to the optimal investment strategy, given today's information set [Benaroch & Kauffman, 1999 & 2000].

Decision Rule: *Where the maximum deferral time is T, make the investment (exercise the option) at time t*, $0<t^*<T$, for which the option, Ct*, is positive and takes on its maximum value.*

$$Ct^* = \max_{(t=0\ldots T)} Ct$$

To analyze the investment decision of “Egnatia Odos S.A.” in 2005, we used interview data provided by company executives and experts in the broadband sector in the country to arrive at specific assumptions concerning the parameters needed by the Black-Scholes model. Interview questions were geared towards revealing the various estimates, assuming that the actual entry would occur sometime between 2005 and 2008. As a result of these discussions and guided by the related literature on broadband networks investment analysis (e.g. P-901), we consider three different values of volatility, 20%, 40%, 60% to express the range of potential revenues on the high and the low level of values.

Using Black-Scholes, we calculated the option value for different exercise dates ranging from zero to 3 years at intervals of one year, utilizing the parameter values and assumptions shown in Table 5.

Calculation of Optimal Investment time for EO to enter in Broadband Networks Market using ROs methodoloy (SCENARIO 1: PRICING 1, DEMAND 1) σ=40%, rf=4%										
Length of deferal period	0	1	2	3	4	5	6	7	8	9
Year	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Net Present Value analysis (no managerial flexibility)										
Vt (Vo less revenues foregone during waiting)	4.259.177 €	3.828.048 €	3.273.658 €	2.616.635 €	No more to defer					
Xt (Discounted Investment Cost) rf=4%	5.922.800 €	5.695.000 €	5.475.962 €	5.265.348 €						
NPV for each entry year	-1.663.623 €	-1.866.952 €	-2.202.303 €	-2.648.713 €						
ROs analysis resutls (managerial flexibility)										
C_T (option maturing at time T=3years)	203.701 €									
Ct (option maturing at time t)*		156.200 €	231.666 €	203.701 €						
Max (C_T, Ct)		231.666 €	231.666 €	231.666 €						
Suggested deferral time (in years)	0	1	2	3						
V: The present value of revenues (discounting factor 8%)										
X: The initial (sunk) technical investment cost is 5.922.800 €,										
σ: Volatility of the expected revenues is 40%										
T: The maximum deferal period in years is from 2005 to 2008										
discounted rate rf: 4%										

Table 5: Optimal investment time calculated using Black & Scholes formula

The results can be summarized as follows:

- The value of the project investment option, CT, exercised at maturity, T=3, is 203.000 € indicating a positive value for the overall investments performance, as shown in Row CT ;
- The value of the deferral option, Ct, reaches its maximum for a deferral of two years at 231.000 € , as shown in Row max(Ct, CT).

The conclusion is that the optimal timing for performing the optical fibre deployment along the Egnatia motorway is 2006. Even more importantly, the strategic NPV value as calculated by the ROs methodology is positive indicating a more than 100% improvement for the passive NPV value for the same time period. It is seen that the decision maker can end up with very pessimistic NPV values when ignoring the value of information gathered overtime and the resulting flexibility in investment.

In the following table we present the ROs analysis results for all demand-pricing scenarios for volatilities values (σ) 20% (low uncertainty), 40%, 60% (high uncertainty). As seen, for any scenario and volatility value the optimum investment timing is 2006.

Option to be excersiced 2006				
NPV analysis		ROs analysis rf=4%		
		σ=20%	σ=40%	σ=60%
NPV Scen. 1	-1.866.952 €	8.277 €	156.200 €	416.873 €
NPV Scen. 2	-2.015.416 €	4.714 €	126.436 €	365.356 €
NPV Scen. 3	-1.427.172 €	33.064 €	269.490 €	590.280 €
Option to be excersiced 2007				
NPV Scen. 1	-2.202.303 €	16.389 €	231.666 €	572.778 €
NPV Scen. 2	-2.349.893 €	10.489 €	194.281 €	511.094 €
NPV Scen. 3	-1.776.643 €	48.268 €	361.114 €	767.540 €
Option to be excersiced 2008				
NPV Scen. 1	-2.648.713 €	10.439 €	203.701 €	536.797 €
NPV Scen. 2	-2.752.221 €	7.436 €	178.278 €	492.041 €
NPV Scen. 3	-2.221.433 €	33.751 €	328.618 €	737.439 €

Table 6. Optimal investment time calculated using Black & Scholes formula

It is seen that a high uncertainty of 60% dramatically influences the value of flexibility especially in Scenario 3. However, a low volatility of 20% means that the expected deviation from the default assumption on expected return is small. As expected, the difference between "traditional" NPV values and the adjusted NPVs for all scenarios is much smaller for a low volatility, since there is little likelihood of new information that can skew the default bad case of dark fibre investment.

5.2. *Scenario 3 – Dark Fibre & light fibre network deployment investment*

In the third scenario , EO takes the role of network infrastructure and services provider by renting bandwidth. Beyond bandwidth, other network services can be provided such as Ethernet to the home (ETTH) or to the building (ETTB) for big customers.

General guidelines discussion for Real Option to Growth analysis

In these cases, the investments' project to be evaluated is in two phases/stages possessing one or more real options. In the first stage there is again an option to defer an entree fee capital expense up to a time T_1, which give the opportunity to grow, expand, upgrade the investment in a second stage or even to defer this stage up to a time T_2. Hence, the initial stage is considered as a paying entrée fee for acquiring the right of possessing one or more options to be exercised at a later stage spending on a large discretionary investment.

In ICT literature, first Taudes [2000], investigates the options methodology for evaluating "software growth options" in a real life investment scenario. In this case, the initial investment on this platform is considered as an entry fee that gives the right for further investment on new applications based on it (option to growth). They consider the overall investment opportunity for the software platform upgrade as:

Value of a software platform = NPV of fixed application portfolio (entree fee, stage 1: platform development) + option value of future implementation opportunities.

Similarly, EO invests immediately the dark fibre possessing afterwards, an option to growth, to be expired up to time t=T in a second stage of the business plan by investing in the lighting of the fibres and entering in a new business market. In this case the investment deployment plan is two-staged where the second stage presents the option to growth.

As before, the cost of growth option for EO by waiting a time period of 3 years to install active equipment is related to revenues as well as revenues lost from the implementation of the second stage of the investment.

Real Option to Growth in further investment opportunities after three years takes value from uncertainties to be resolved such as, broadband service penetration, customers' willingness to pay in the area of low competition level and technical competence and skills of EO to install and maintain active equipment. The investment analysis of such scenario is subject of further work.

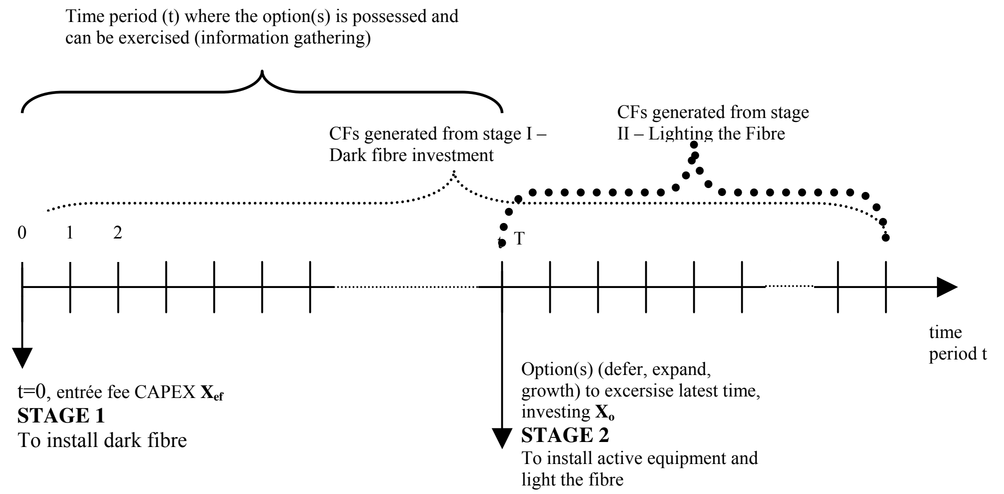

Figure 7: Two- stage investment scenario with option to growth in the second stage

6. Conclusions and Future work

We have shown that a considerable impact on the NPV of future investments can be expected when taking into account the uncertainty and the flexibility in timing. This will inevitably alter the way by which an operator should plan medium and long term infrastructure rollouts.

Using conventional NPV calculus may provide misleading results and a wrong focus with respect to investment portfolios. Rollout projects, that might turn out to be a valuable part of future project portfolios might be abandoned completely using a conventional NPV methodology. This is an important learning as the competition between investment projects and funding within large companies is often high.

In case of lack in flexibility due to high competition or if a project is highly profitable there is no option value. The real options approach is therefore not applicable in such cases.

Broadband network investors in Greece like OTE, Vodafone, Tellas, Vivodi, are focusing on dense urban areas of Athens and Thessaloniki as well as the 500 kms backbone network connecting the two largest cities of Greece.

For this reason, we consider that the area along Egnatia motorway is not likely to be the prime focus of the aforementioned big competitors. Therefore, we consider that there is a inherent flexibility in such investments compared to high competition areas where the investor must act faster in order to get a competitive advantage.

The real options methodology has the strength, that it can be applied directly in already prepared detailed cash flow statements found everywhere. The methodology does therefore not discard the "old" framework but augments it in order to capture new insight, which is of high importance in decision-making under high uncertainty.

In this paper, we examine one of the business scenarios for EO. It is the subject of further work to consider more complicated cases with more options interactions. For example, in the third scenario, we shall consider a two-staged investment plan. In the first stage, EO posses the option to defer up to time $t=T_1$ the installation of dark fibre for its commercial exploitation. A market analysis is performed to identify possible customers for this stage. Such customers may be OTE, Vodafone, Med Nautilus but also other public and private organizations and companies. In the second stage, EO invests in active optical fibre equipment entering the market of bandwidth and network services. For this investment EO owns the option to growth from period T_1 up to T_2 in business terms by offering higher-level telecommunication services. Growth options refer to a situation where early investment is a "prerequisite or a link in a chain of interrelated projects, opening up future growth opportunities" [Trigeorgis 1993]. The loss of revenues and market share due to delayed entry in both the backbone and network services provision through lighting the fibres, should be investigated. The balance between the loss of revenues and market share on one hand, as well as the managerial flexibility in the deployment of investments and the cost reduction on the other hand, should be verified.

Furthermore, [Benaroch 2002] suggests a framework of identifying shadow real options during an IT project's deployment and operational stages in order to find the optimal investments configuration, handle more efficiently the investment's risk and increase so its overall performance. We are planning to apply and test this framework for EO broadband investments scenarios.

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Appendix A

COST MODELING (prices do not include VAT)

(Calculations are based on figures provided by [Canarie Inc.],[FAQ on Dark Fibre] and Egnatia Odos S.A. executives [Iatropoulos Th., 2004])

Dark Fiber Cost Modelling

*The distance between Kavala and Alexandroupolis is 172 Klm. We assume that the average distance for connecting two customer points in the cities (one customer point in each city) is 100 klm.
This figure includes the average length of the distribution netwrok, 5 klm from the backbone to the collocation facility plus 2 klm from the collocation facility to the node.

Backbone network (two fiber cables of capacity 96 fibres each)
Fiber cable cost: 0.12$ x 0,74 x 96 x 2 = 17.05€/m
Installation cost: 15$ x 0.74 = 11.1 €/m (using existing ducts)
Total construction cost: 28.15 €/m or 28,150 €/klm x 172 klm = 4,841,800 €
Annual O&M cost: 2% of installation cost = 96,836 €

Distribution network (two fiber cables of capacity 96 fibres each)
Fiber cable cost: 0.12$ x 0,74 x 96 x 2 = 17.05€/m
Trench excavation costs: 35$ x 0.74 = 25.9 €/m (we consider the area as semi-urban)
Installation cost: 15$ x 0.74 = 11.1 €/m
Total construction cost: 54.05 €/m or 54,050 €/klm x 10 klm = 540,500 € (For the average distance between two nodes we assume a total branch length of 5 klm x 2 = 10 klm in the distribution network)
We consider one node for each of the cities (Kavala, Ksanthi, Komotini, Alexandroupoli)
Annual O&M cost: 4% of installation cost = 21,620 €

Access network (one cable of capacity 12 fibres from the collocation facility to the office)
Fiber cable cost: 0.15$ x 0,74 x 12 = 1.33€/m
Trench excavation costs: 35$ x 0.74 = 25.9 €/m (we consider the area as semi-urban)
Installation cost: 15$ x 0.74 = 11.1 €/m
Total construction cost: 38.33 €/m or 38,330 €/klm x 4 klm = 153,320 € (For the average distance between two nodes we assume a total branch length of 2 klm x 2 = 4 klm in the access network)
Annual O&M cost: 4% of installation cost 6,133 €

We assume that Egnatia manages the installation and operation using own staff. O&M costs include personell costs.
Marketing, promotion & advertising is kept internal as part of the overall corporate activities (Egnatia Odos manages the business development through a special Department within its main organizational structure).

The scenarios to select the appropriate customer composition with regard to pricing structure are aimed to cover the investment costs in a period of 6 years. Thereafter, a separate entity (independent company) can be established to further develop the bus

Appendix B

Passive NPV analysis – Immediate entry in 2005 (values in €)

Time Scale	0	1	2	3	4	5	6	7	8	9
Year	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
DEMAND ANALYSIS*										
Customers/Demand SCENARIO 1-**C1**		**5**	**7**	**9**	**12**	**15**	**19**	**22**	**26**	**30**
Customers/Demand SCENARIO 2-**C2**		**4**	**5**	**6**	**7**	**8**	**10**	**11**	**13**	**15**
Customers/Demand SCENARIO 3-**C3**		**3**	**4**	**5**	**6**	**6**	**7**	**7**	**8**	**8**
PRICING ANALYSIS*										
Monthly Pricing per Customer SCENARIO 1-**P1**		9000	9000	9000	8000	8000	7000	7000	6000	6000
Monthly Pricing per Customer SCENARIO 2-**P2**		12000	12000	12000	11000	11000	9000	9000	8000	8000
Monthly Pricing per Customer SCENARIO 3-**P3**		15000	15000	15000	14000	14000	13000	13000	12000	12000
REVENUES ANALYSIS										
C1-P1	0	540000	756000	972000	1152000	1440000	1596000	1848000	1872000	2160000
C2-P2	0	576000	720000	864000	924000	1056000	1080000	1188000	1248000	1440000
C3-P3	0	540000	720000	900000	1008000	1008000	1092000	1092000	1152000	1152000
COST ANALYSIS										
Construction Cost - **CP1**	5922800	613280	306640	306640	459960	459960	613280	459960	613280	613280
Annual O&M cost - **CP1**		28952	41218	53483	71882	90280	114811	133210	157741	182272
Increase (%)						0	0	0	0	0
Total investment COST - CP1	**5922800**	642232	347858	360123	531842	577752	764496	622828	809572	835330
Construction Cost - **CP2**	5922800	459960	153320	153320	153320	153320	306640	153320	306640	306640
Annual O&M cost - **CP2**		22819	28952	35085	41218	47350	59616	65749	78014	90280
Increase (%)						5%	5%	5%	5%	5%
Total investment COST - CP2	**5922800**	482779	182272	188405	194538	210704	384569	230022	403887	416766
Construction Cost - **CP3**	5922800	306640	153320	153320	153320	0	153320	0	153320	0
Annual O&M cost - **CP3**		16686	22819	28952	35085	35085	41218	41218	47350	47350
Increase (%)						5%	5%	5%	5%	5%
Total investment COST - CP3	**5922800**	323326	176139	182272	188405	36839	204265	43279	210704	49718
CASH FLOWS ANALYSIS										
CFs SCENARIO 1	**-5922800**	**-102232**	**408142**	**611877**	**620158**	**862248**	**831504**	**1225172**	**1062428**	**1324670**
CFs SCENARIO 2	**-5922800**	**93221**	**537728**	**675595**	**729462**	**845296**	**695431**	**957978**	**844113**	**1023234**
CFs SCENARIO 3	**-5922800**	**216674**	**543861**	**717728**	**819595**	**971161**	**887735**	**1048721**	**941296**	**1102282**
NET PRESENT VALUE ANALYSIS										
NPV of CFs (r=8%) Scen. 1	**-1.663.623 €**									
NPV of CFs (r=8%) Scen. 2	**-1.762.559 €**									
NPV of CFs (r=8%) Scen. 3	**-1.191.454 €**									