Real Options Valuation for Planning OXC Introduction

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Abstract: Real Options Valuation is an investment decision technique originating from the economic world of the stock options and aimed at valuing uncertain investments. This paper uses ROV for planning OXC introduction in a European backbone.

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1. Using investment decision techniques for long-term network planning

Long-term network planning can be considered as a strategic investment decision problem. Among several investment decision techniques described in economic literature, Net Present Value (NPV) is best known and most widely adopted. This technique compares the initial investment of the project with the expected revenues, taken into the required minimal return on investment. A positive NPV indicates that the required return is earned on the initial investment and that additional value is created, over the life time of the project.

The network planning problem we study in this paper is the introduction of an Optical Cross Connect (OXC) in an existing network. This decision involves a lot of uncertainty. Real Options Valuation (ROV) is a relatively new investment decision technique, originating from the economic world of the stock option valuation and aimed at incorporating uncertain evolutions (like stock option values). Real options allow us to attach a value to the options that become apparent during the life time of an investment project, like expanding, reducing or stopping the project.

2. Real Options Valuation

An *option* can be defined as the right for a limited time, to buy or sell the underlying value for a predetermined exercise price. Exercising the option (i.e. buying or selling the underlying value) is always optional; it is a right, not an obligation. This right holds for a predetermined time, till the so-called *exercise date*. The underlying value is the asset which the option concerns, this may be assets, real estate, precious metals, ... The *exercise price* is the price for which the option can be exercised by its holder. This is not to be confused with the *option price* which is the price to buy the option itself. A well-known stock option pricing formula was suggested by Black and Scholes (B&S) [1]. It determines the option value C, based on the exercise price of the option X, the value of the underlying stock S, the variance of the return on the stock σ^2, the risk-free interest rate r and the time until the expiration of the option t, see formula (1). *N()* denotes the cumulative normal distribution, *ln()* is the natural logarithm.

$$C = SN(d1) - Xe^{-rt}N(d2) \qquad d1 = \frac{\ln(S/X) + rt + \sigma^2 t/2}{\sigma\sqrt{t}} \qquad d2 = \frac{\ln(S/X) + rt - \sigma^2 t/2}{\sigma\sqrt{t}} \tag{1}$$

When using the translations of Table 1 real options can be treated in the same way as stock options and can therefore be valuated using B&S formula. This is often done in literature, however, we should be aware of some assumptions for stock options that might not always hold for real options. First of all, stock option valuation is based on arbitrage-free pricing (i.e. financial transactions that make immediate profit without any risk do not exist). This is difficult to prove for real options, as those are not traded. Secondly, B&S assumes that stock prices S follow a Brownian motion $dS = \mu S dt + \sigma S dw$ with constant annual expected return μ on the stock and standard deviation σ on that return, dw is a Wiener process. Therefore, considering real options we should prove that the NPV of the cash flows generated by the project follow a Brownian motion.

Table 1: Real options compared to stock options

	Stock option	**Real option**
X	exercise price of the option	investments required to carry out the project
S	value of the underlying stock	NPV of the cash flows generated by the investment project
σ	volatility of the stock	risk grade of the project
r	the risk-free interest rate	risk-free interest rate
t	life time of the option	time period where company has the opportunity to invest in the project

3. Planning OXC introduction

Real Options Valuation is especially useful for two-phase investment decisions, with an optional second phase (e.g. only performed if market situation is favourable). This explains the suitability of ROV for uncertain investment problems. By the time of the second phase of the investment, the market situation is already more clear, so that an well-advised decision can be taken.

In this paper, we study the introduction of an OXC in an existing network with growing traffic demand as a two-phase decision. First we need to decide on the introduction of the OXC itself (only including interface cards needed to switch the current traffic). Afterwards we have the option to expand the OXC with extra interface cards if needed. We consider a European backbone network with 16 nodes and 22 links (see also Fig. 1) and we want to decide in which nodes OXC introduction is beneficial. If the OXC is introduced, the best timing for the expansion is determined. Initially WDM point-to-point systems are used on all links, if an OXC is introduced in a certain node, its transit traffic passes the node optically. We consider the time frame between 2002 and 2008. The initial traffic is given by the IP traffic from the traffic model of [2], afterwards it is assumed to grow 70% every year. On average links are only filled to 60% of their capacity. Network equipment costs are considered relative to the cost of a WDM mux/demux (based on [3] and [4]). To calculate expected revenues, we have used a linear price model. The price for 1 Gbps of traffic was set to 2,6E-09 (relative to unit cost of WDM mux). This value was determined by assuming a discounted pay back period of 5 years for an IP router routing 15 Gbps upon introduction and witnessing a 100% annual traffic growth (discounted revenues earned over 5 years equal initial router cost).

Before applying B&S, we need to check whether the expected cash flows follow a Brownian motion. The considered cash flows are given by the product of the routed traffic and the price earned by the operator per traffic unit. If the price is considered constant and the traffic changing, the total revenue will not necessarily follow the changes in the traffic (traffic can no longer be routed if it exceeds the capacity). This limits the applicability of B&S formula in the considered case. However, if we assume the traffic to be more or less stable and the price changing, B&S assumptions are fulfilled. This assumption approximates the reality if we consider a market with several operators. Price changes leading to a change in traffic will in this case be followed by another price change by the competitor so that the overall traffic demand in the network of a single operator is to be considered constant. Prices will largely follow changes in the equipment cost, equal for all operators.

In Table 2 we indicate the value of introducing an OXC in Brussels (node with 85% transit traffic for considered routing scheme), similar to the approach followed in [5]. The first phase of the project is performed in 2002 and comprises the installation of an OXC and the needed interface cards at that point in time. Phase two is the introduction of additional cards in order to be able to accommodate all traffic expected till the end of 2006. Column 1 of the table indicates the considered time periods. Column 2 indicates the value of the first phase of the project. This is the value of installing the OXC, without considering that it might be upgraded later on. Column 3 gives the value of the second phase, when calculated by the NPV method. This means that the second phase would be performed anyhow at the considered time, it is not optional. Summing column 2 and 3 leads to the value of column 4, the total value of the project indicated by NPV. The value of the second phase seen as an option is given in column 5. Column 6 indicates the overall project value with optional second phase (column 3 + column 5). Using real options, we need to decide whether or not to introduce the OXC in 2002 and at that point in time we see the option of expanding it later. The decision whether or not to expand is not taken in 2002. It is clear from the table the overall project value with the optional second phase is positive for all considered timings of phase 2 (all values in column 6 are positive) so that OXC introduction should definitely be considered in Brussels. The biggest value is found for introduction in 2004, so that this should be considered the best timing for upgrading the OXC. By then, the additional initial investment of the OXC can be compensated by additional revenues from the additionally routed traffic, whereas further postponing the introduction would lead to an important loss of revenue.

Table 2: Project value according to several investment decision techniques

	NPV phase 1	NPV phase 2	NPV entire project	Option value phase 2	Entire project value with optional phase 2
2002	-3,17	-94,44	-97,60	7,34	4,18
2003	-3,17	-87,51	-90,67	17,22	14,05
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
2005	-3,17	-95,8	-98,96	20,37	17,21
2006	-3,17	-117,69	-120,86	10,80	7,64

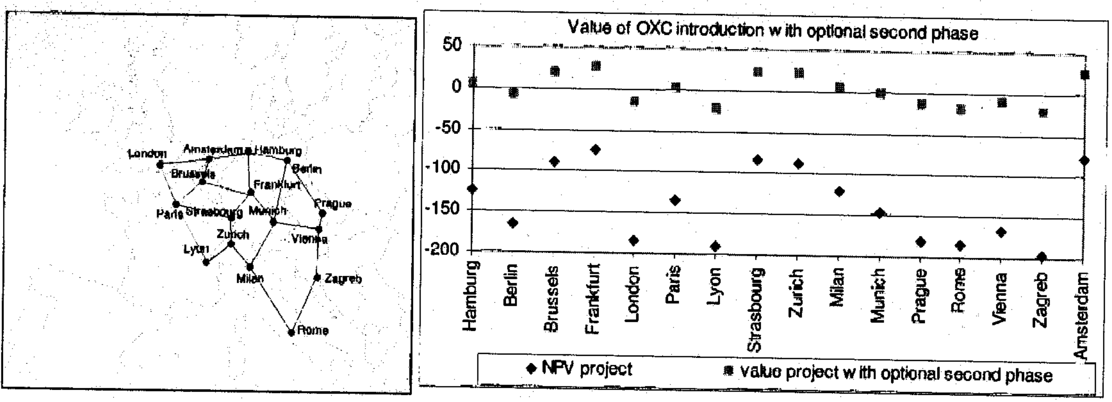

Fig. 1: Considered network topology and project values for introducing OXCs in different nodes

Similar calculations as the ones indicated in Table 2 were performed for all nodes in the considered network and the results are given in Fig. 1. Based on NPV (entire project fixed beforehand) no OXC would be introduced in the entire network (similar to the negative values in column 4 of Table 2). However, when modelling the OXC upgrade as an optional second phase, it is beneficial in half of the nodes. We see a negative project value for the nodes Prague, Vienna and Zagreb, where the overall traffic is too low to justify OXC introduction. In Berlin, Munich, London, Lyon and Rome, there is too little transit traffic for the considered fixed routing scheme. OXC introduction is beneficial in those nodes where the overall traffic is big enough (traffic demand exceeds router capacity at least within next 2 years) and the fraction of transit traffic surpasses 60%. If OXC introduction is beneficial, the optimal timing for the optional second phase was shown to be 2004 for all nodes, except for Paris where it was 2005. Of course, this optional timing is very dependent on the considered traffic growth rate (annual growth of 70% considered here).

4. Conclusions

This paper evaluates the use of real options valuation for planning OXC introduction in a backbone network. This relatively new technique is compared with the traditional Net Present Value approach. NPV uses expected cash flows, discounted at the required interest rate. However, NPV is unable to correctly evaluate projects that comprise an optional follow-up investment. Real Options Valuation, on the other hand, is aimed to valuate projects where uncertainty is involved. Such projects might not be profitable at first, but anticipate on profitable follow-up investments that might happen in case of success. ROV is conceptually superior to the traditional NPV method, but also has some disadvantages. First of all, it is often very difficult to detect a real option. Secondly, correctly estimating the option value is also difficult as the possible gain obtained by exercising the option should be clearly indicated. Valuing real options using Black and Scholes formula is quite straightforward, but its assumptions should be tested carefully.

We were able to apply B&S for valuating the introduction of OXCs in the backbone of a European operator applying variable prices. OXC introduction was beneficial in those nodes where the expected overall traffic demand exceeds the router capacity within the next 2 years and the fraction of transit traffic surpasses 60%. ROV also allowed us to determine the most suitable timing the introduction, implicitly making the trade-off between postponing the investment till the additional initial investment of the OXC is compensated by additional revenues from the additionally and advancing the introduction to avoid revenue loss because of insufficient node capacity.

5. References

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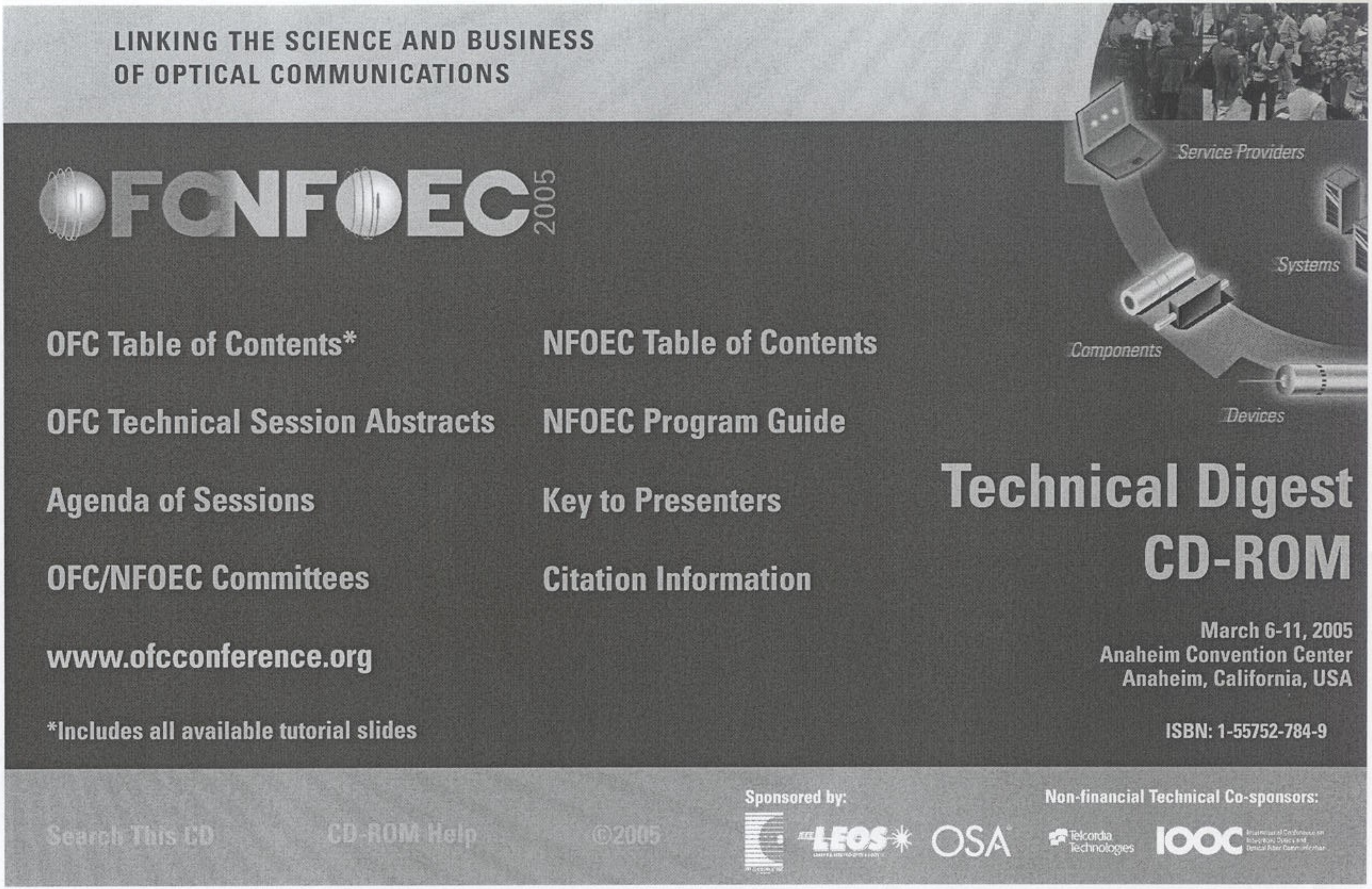

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