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A Real Options approach for prioritizing ICT business alternatives: A case study from Broadband Technology business field

Abstract

This paper provides a methodology for finding the optimum deployment strategy for ICT business activities in the context of initial infrastructure projects, which support a number of future investment opportunities. It treats these opportunities as real options (ROs) and assumes that there is a competitive threat that can influence them negatively, or even worse, eliminate their value. We take into account that the competitors' rate of arrival and erosion of competitiveness, during the waiting phase for the ROs to invest, follow a joint-diffusion process with the investments' revenues. The proposed methodology is applied to a real life broadband technology business activity showing how it can be formulated and solved.

Keywords: Decision analysis, methodology, Investment, Telecommunications, real options, broadband investments.

INTRODUCTION

Information and Communication Technologies (ICT) lie at the convergence of Information Technology, Telecommunications and Data Networking Technologies. The valuation of these ICT business activities is a challenging task because they are characterized by high-level uncertainty and rapidly changing conditions.

The basic inadequacy of traditional quantitative cost-benefit analysis methods, like Net Present Value (NPV) and other Discounted Cash Flow (DCF), is that they ignore or cannot properly capture management's flexibility to adapt and later revise decisions in response to unexpected market developments (Trigeorgis, 1996). Traditional DCF methods make implicit assumptions about an "expected scenario" of cash flows and presume management is passively committed to a particular "operating strategy" (e.g. to initiate the project immediately and operate it continuously at base scale until the end of its pre-specified expected useful life).

The real-world ICT markets, however, are characterized by change, uncertainty and competitive interaction, where the realization of cash flows will probably differ from what management expected initially. As the information arrives and uncertainty about market conditions and future cash flow is gradually resolved, management may have valuable flexibility to alter its operating strategy in order to capitalize on favorable future opportunities so as to mitigate downside losses.

Traditionally, there have been three approaches to dealing with uncertainty and complexity in capital budgeting: sensitivity analysis, simulation and decision tree analysis (Bhagat, 1999). Sensitivity analysis, which is performed by changing one variable at a time is easily implemented and understood, however it is not a perfect method since it ignores interdependencies among variables. Simulation, while it takes into account interdependencies among variables, makes it difficult for the decision maker to interpret a distribution of NPVs since there is no rule for translating that profile into a clear-cut decision for action. Also, it cannot deal with asymmetries in distribution, which are introduced by the management's flexibility to revise its prior operating strategy as more information about project cash flows becomes available over time. Finally, decision tree analysis is able to accommodate the flexibility, for example, to abandon an investment plan at certain discrete pre-specified points in time. This is based on an expectation of cash flows and their probabilistic estimates that can be quantified at the time of the initial decision. However, its main problem is that while the risk of the project may change over time and so the discount rate, it assumes a constant value for the latter for the whole period of the investment. In addition, decision tree analysis can easily become unmanageable when actually applied in most realistic investment settings, as the number of different paths through the tree expand geometrically (Trigeorgis, 1996).

Real Options (ROs) address this inadequacy of these traditional capital budgeting methods and offers management the flexibility to take actions which can change aspects of the project over time (Trigeorgis, 1996). An option gives its holder the right, but not the obligation, to buy (call option) or sell (put option) an underlying asset in the future. Financial options are options on financial assets (e.g. an option to buy 100 shares of Nokia at 90€ per share on January 2007). ROs are the extension of the options concept to real assets. For example, an ICT investment can be viewed as an option to exchange the cost of the specific investment for the benefits resulting from this investment. By adopting the philosophy of managerial flexibility (also called active management) the possibility of experiencing losses is decreased while the possibility of profiting increased. This is achieved by resolving part of the overall investment's uncertainty by waiting and learning about the changing business conditions over time (Benaroch, 2002). A first condition for the applicability of the ROs approach is the existence of uncertainty about the outcome of an investment. While almost any investment is subject to uncertainty, the flexibility to react to resolved uncertainty is not necessarily present. The lack of such flexibility would imply that no option existed at that point. As a third provision, the investment needs to be at least partially irreversible. Thus, if the investment fails to perform in the anticipated way, costs cannot simply be recovered; otherwise the total transaction would be 100% risk-free. For a general overview of ROs, Trigeorgis (1996) provides an in-depth review and examples of different ROs. For more practical issues the reader is referred to Mun (2002). Examples, of how ROs can be applied in broadband investments analysis, and especially technological upgrades from ADSL (Asymmetric Digital Subscriber Loop) to VDSL (Very High Data Rate Subscriber Loop) are the works of Elnegaard and Stordahl (2002), Elnegaard (2002), Kalhagen and Elnegaard (2002) and the EURESCOM P-901 (2000) project. In addition, Iatropoulos et al. (2004) have applied ROs to examine the economics and risks associated with a broadband network investor roll out along the longest (680 klm) motorway in Greece called "Egnatia Odos". In this paper we intend to contribute to this work by analysing competition modeling and multioptions analysis. Furthermore, Angelou and Economides (2005) provide a literature review of the ROs applications to real life ICT investments analysis.

Since its liberalization, the structure of the telecommunications markets has changed from monopoly to oligopoly, where a number of market participants are present. The real life ICT business activities do not belong exclusively to only one firm but may also be shared by other competitors. Viewing ICT projects as ROs, this paper develops a methodology for evaluating ICT investment decisions in the presence of both uncertainty and competition. We adopt financial option theory and enhance it with competition modeling theory in order to guide decision-making regarding the management and evaluation of ICT investments. Our target is to develop a RO model closely related to ICT industry characteristics so as to support ICT evaluation under competitive conditions. The exogenous competition modeling should take place while the number of players (market participants) is increasing (Zhu, 1999).

Previous research has applied exogenous competition modeling to shared investment opportunities where the anticipated competitive loss can be viewed as the impact of dividends on a call option (Kester, 1984;

Trigeorgis, 1996; Kumar, 1999). Examples include the opportunity to introduce a new product, which is influenced by the introduction of close substitutes, or to penetrate a new geographic market without barriers to competitive entry.

The firm has to weigh the value of waiting against the possible erosion in value due to competitor's actions, which it cannot influence. The firm has to determine what information is available about the competition. If for example the firm knows in advance the strategies of its competitors and their impact on the firm's value function, the situation is completely deterministic. However, this case is quite unrealistic. In reality, competitors are randomly entering the market and exercising their ROs. The firm might have a rough idea about the intensity of competition and its impact without having complete information about when and how other firms act. Trigeorgis (1996) and Kumar (1999) model competition exogenously assuming that the competitors are entering into the market following Poisson distribution. They assume that the underlying asset (investment value V), under random competitive arrivals, can be modeled as a mixed diffusion-jump process. Other research on competition modeling by Boston and Pointon (1999) models technological breakthrough by Poisson jumps.

We also assume that the competitors are entering the market randomly according to an exogenous Poisson distribution. We build on the assumptions in existing literature by considering that: i) the expected arrival rate of competitors and ii) the impact of each competitor's arrival, during the waiting periods that follow a joint diffusion process with investment revenue. So far in the literature, the aforementioned parameters have been considered as constant. Finally, we provide a compound RO model for a competitive environment..

A good example of an ICT market which is dominated by a strong player is the Greek telecommunications market. It is dominated by the incumbent fixed telephony operator OTE (Hellenic Telecommunications Organization) (Kantor Capital, 2005; ITI, 2005). Since the liberalization of the Greek market in 2001, an increasing number of new players have entered the market and started competing with the incumbent OTE in value-added services. There are about 12 more players who possess a low share of the market, however, none of them pose a significant threat to OTE. Nevertheless, each of them may subtract some value from the overall business value of any new investment opportunity from OTE if the latter remains "inactive". For any new value added service, there is a market "pie" concerning its business activity that is usually growing over time. Some parts, of the whole "pie" will be subtracted by competitors as they are entering the market. So, OTE faces a tradeoff between the value of the flexibility it has to wait and the value of the possible competitive erosion during that waiting period. OTE's management has to determine whether it should exercise the option to implement the investment opportunity early or whether it should follow the "wait-and-see" (WaS) strategy despite the competitive damage caused by its competitors' entry into the market.

The rest of the paper is organized as follows. In Section 2, we provide a compound ROs model under competition modeling. In Section 3, we provide a real life case study where we examine the various deployment alternatives by applying our methodology to illustrate its application. Finally, in Section 4, we conclude and suggest possible future research.

A COMPOUND ROs MODEL UNDER THREAT FROM COMPETITION

A. Life cycle of an investment opportunity and ROs

The lifecycle of an investment starts at the inception stage. During this period the investment exists as an implicit opportunity for the firm that can be facilitated by a prerequisite investment (Figure 1). The firm posses a shadow option;.during the recognition stage, which we also call the "Wait-and-See" (WaS) period, the investment is seen to be a viable opportunity. The opportunity can be treated as a RO. The building stage follows upon a decision to undertake the investment opportunity. In the operation stage, the investment produces direct and measurable payoffs. Upon retirement, the investment continues to produce indirect payoffs, in the form of spawned investment opportunities that build on the technological assets and capabilities it has yielded. When these assets and capabilities no longer can be reused, the investment reaches the obsolete stage. Each stage of the investment opportunity is relevant to a number of operating and growth ROs, such as option to defer, stage, lease, or expand (Benaroch, 2002). The reason for this is that each type of RO essentially enables the deployment of specific responses to threats and/or enhancement steps. In addition, each stage of the investment is also experiencing a variety of risks. These risks include firm-specific risks, competition risks, market risks, and environmental and technological risks (Benaroch, 2002). Firm-specific risks are determined by endogenous factors such as a firm's ability to align its ICT projects portfolio to its business strategy and the skills level of its ICT staff. Competitive risks include risks posed by competitors who may make preemptive moves to capture market share or make similar investments that may dilute the value of a firm's current IT project portfolio. Market risks include uncertainty about customer demand for services that are enabled by a firm's ICT projects. ROs analysis provides "assistance" for risk handling and mitigation. In particular, by deferring the investment's implementation and acquiring information passively (e.g., observe) or actively (e.g., market research, lobbying) we can learn about potential risks. Learning-by-waiting helps to resolve market risk, competitive risk, and firm firm-specific risk. In this paper we quantify the value of learning-by-waiting in terms of competitive risk. We model competitive risk during inception, recognition and part of the operation period where the RO to invest is possessed by the market players, Figure 2.

----------------------------Figure 1 ---------------------------

---------------------------Figure 2 -----------------------------

ICT investments provide this managerial flexibility to expand or launch other applications across different platforms. Prior research has shown that software platforms may not generate value directly, but enable other value-added applications (Taudes et al., 2000). ICT infrastructure projects may involve a "wait-and-see" component that gives ICT managers the option to defer decisions for future investment opportunities until some uncertainty is resolved (Benaroch and Kauffman, 2000; Panayi and Trigeorgis, 1998).

The total value of a project that owns one or more options is called Expanded (Strategic) Net Present Value (ENPV) and is given by Trigeorgis (1999):

$$ENPV = Passive\ NPV + Value\ of\ Options\ from\ future\ opportunities \qquad (1)$$

B. A single ROs model under competition threat

We model competitive threat up to the operation period where competitors may still enter the market. The target is to estimate the RO value, and define the optimum time to invest, taking into account that competitive threat can decrease, or even more, eliminate its value to the owner.

Inception period (t_s) - Competitors may enter the market and subtract part of the investment opportunity that could be available to the firm under investigation. The inception period starts at t_i (i.e. when the analysis process is taking place, t_i=0). We define the term *Elimination Threat from Competitors (ETC)* for modeling the competitive conditions in the market during this period, where the firm is only "watching" without being able to preempt its future competitors.

Recognition (WaS) period - The WaS period starts at t_s when the option is available to the firm. The maximum WaS period, T, is separated in two sub-periods, as seen in Figure 2. In the first sub-period, the firm is not investing and is waiting for the resolution of some of the uncertainties associated with this investment opportunity. The second sub-period starts at $t_s + t_e$ when the firm exercises its option, where t_e is the real exercise time of the option (implementation of the investment opportunity). Finally, the part of the operation period where the firm can still face Competitive Threat (CT) is $T-t_e$. We define two terms for modeling the competitive conditions: i) *Preemptive Threat from Competitors* (PTC) and ii) *Preemptive Capability of the Firm* (PCF). PTC indicates the threat, which is experienced by the firm during the WaS period of the option, from other competitors entering the market and decreasing or even more eliminating the option value. PCF indicates the capability of the firm to preempt the subsequent competitors after its entry time at $t= t_e$ into the market.

During these periods competitors may enter the market randomly causing degradation of the investment opportunity for the firm. We call this competitive erosion. We assume that competitors are entering the market randomly following a Poisson distribution. The business target of the firm is to exercise its option at the optimum time in order to compensate for competitive threat and manage uncertainty. An important characteristic for each business opportunity is to provide the firm with the ability to preempt subsequent competitors' entry after its entry into the market. The final investment revenue that will be available to the firm is given by

$$V_f = V - I_{ci} - I_{cwte} - I_{co} \qquad (2)$$

where I_{ci}, I_{cwte}, I_{co} is the total competitive erosion during the inception, WaS and operation periods respectively. Assuming expected competitor's arrivals $n_i=\lambda i^*(t_s-t_i)$ during the inception phase, $n_w=\lambda_w^*(t_e-t_s)$ competitors' arrivals during the waiting phase and $n_o=\lambda o^*(T-t_e)$ competitors' arrivals during the operation phase, the overall option value when it is exercised at $t=t_e$ is given by:

$$\begin{aligned} OV_{cte} &= \max\left(V_f - X, 0\right) = \\ &= \max\left[V(1-c_i)^{n_i}(1-c_w)^{n_w}(1-c_o)^{n_o} - X, 0\right] \end{aligned} \qquad (3)$$

where λ_i, λ_w, λ_o are expected arrivals rates of competitors during inception, WaS and operation periods respectively. Finally, c_i, c_w and c_o are competitive erosion parameters during these periods. They indicate the expected competitive erosion that each competitor's entry in the market will cause to the firm's investment revenues value during inception, waiting, and operation periods and they are given by ($V_{before\ entry} - V_{after\ entry}/V_{before\ entry}$).

Angelou and Economides (2006[b,c]) analyze the cases for PCF as well as the correlation between V and competition parameters. Especially, in the case of "No PCF", it is more preferable to wait until time T, since V_f will be the same independently of the option exercise strategy. In the case of "Full PCF", there are two effects negatively correlated between each other: i) the uncertainty control assured by both the ROs analysis and the managerial flexibility to deploy investment in a longer deferral period, and ii) the PTC that may fully eliminate the option value for the firm. Finally, in case of "Partial PCF", by early investment a level of preemptive capability can be achieved. It might be optimal for the firm to invest earlier in order to ensure the highest possible level of revenue from the investment. Of course, it is still a matter of compensating between managerial flexibility and competitive threat as before.

The incentive to invest earlier can also be applied when WaS strategy results in significant revenue losses from the operation phase that overcome the value of the uncertainty control provided by the ROs approach. A divided yield parameter may indicate these revenues losses. Here, we assume that this divided yield is zero.

Competition parameters can be either positively or negatively correlated with V. Someone may assume that the bad business conditions compared to the favorable ones experience no network externalities effects. Also, the bad business conditions indicate no achievement of the critical mass for customer demand indicating a relatively small reduction in the overall investment opportunity available to the firm. The opposite can also be true in the case of favorable business conditions. In addition, there can be cases, where while the market value appears appealing, the competitors cannot extract significant option value. Particularly, when competitors do not have the adequate ICT infrastructure to fully utilize their own investment opportunity's benefits, an increase in the overall market value V might finally decrease the part of the market share that a specific competitor can subtract from the firm.

We consider a joint diffusion process for the c_w, λ_w V and X in Figure 3, while we assume that in the rest competition parameters are constant. We adopt an extended log transformed binomial model (ELTBM) with 4-parameters that follow a joint diffusion process (Gamba and Trigeorgis, 2001). We focus on a one-step diffusion process. In practice, the single-step diffusion analysis is appropriate for investments where management has limited opportunity to influence the outcome of the investment and reviews investment status per half or year. On the other hand, in the case of large enterprise projects, where there is a significant opportunity during the life of the project for management to influence the expected value of the project cash flows, a more realistic solution would use a diffusion analysis with multiple steps. In this case, management reviews quarterly and even weekly, and risk events will impact the project with a random periodicity. In conclusion, the frequency that management reviews the investment factors, such as customer demand and the status of the competition, indicates the number of diffusion steps during WaS period.

----------------------------Figure 3 ---------------------------

So far we have looked at a single growth RO, now we will extend our methodology to multioptions analysis. In Figure 4 we present the lattice model assuming an n-stage (one-step) binomial (diffusion) process. Each step represents a growth investment opportunity with a specific inception, waiting and operation period (only the waiting periods are shown in Figure 4). The value for each opportunity is given by equation 3. We work on compound options analysis similar to Angelou and Economides (2006[a]), Benaroch (2002), and Panayi and Trigeorgis (1998) work. However, it is the first time in the literature where a multioption analysis has been done under exogenous competition modeling, assuming a high number of competitors in the market sharing a couple of ROs.

----------------------------Figure 4 ---------------------------

C. *Option based approach to control market and competition risk*

Next, we present an approach that helps to address the questions: *What is the amount of flexibility embedded in an ICT business activity? How can we control competition and market risks so as to configure the business activity in a way to maximize Net Present Value (NPV)?* We treat overall business activity with option-based analysis under competition threat.

Our approach involves 6 main steps that must be repeated over time. Next, we explain these steps and illustrate them in the context of a real life broadband technology investment.

1. Define the content of the overall ICT business activity and the business modules (stages) that it is composed from. State the investment goals, requirements and assumptions (technological, organizational, economic, etc.) and then identify risks presence in the overall business activity.
2. Recognize the life cycle of each module (stage) of the investment opportunity and identify the various periods as described before for the various business alternatives.

3. Recognize and describe options embedded in the overall business activity and mapped to specific business modules. Recognize the nature of options in each strategy deployment alternative. An investment opportunity can embed shadow options, which usually can be converted into ROs upon making a prerequisite investment.
4. Define the competitive characteristics that each investment opportunity, treated as growth option, experiences. This requires market analysis for competitive status verification.
5. Evaluate investment-structuring alternatives for the life-cycle periods, to find the strategy that maximizes investment value. Starting from the end and going backwards we estimate the option values at each investment stage for the various business alternatives so as to exercise the options. We adopt compound option analysis (Angelou and Economides, 2006[b,c]). Finally, estimate the overall ENPV value, which includes all the embedded options in the selected deployment strategy.
6. Perform ROs update analysis. The previous steps help to best deploy a business activity under the information set available initially, but as time passes they must be re-applied in case some risks get resolved or new risks surface.

A REAL LIFE CASE STUDY

The ICT investor under investigation is Egnatia Odos S.A. (EO). EO was created in September 1995 and its aim is the management, design, construction, operation, and maintenance of the Greek 680 km Egnatia Motorway (EM). The transportation network of EO can be used for the installation of an optical network backbone infrastructure. In this case study the commercial opportunities this network represents will be analysed. EO has to decide if and how to proceed in the implementation of this business opportunity. The business opportunties available to EO, for the commercial usage of the Egnatia motorway through the deployment of broadband infrastructure and services, are investigated analytically by Iatropoulos et al. (2004) (Figure 5).

----------------------------Figure 5 ---------------------------

In the following we briefly present the available business models for EO.

- 1st business level: 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, Vivodi).
- 2nd business level: EO decides to install optical dark fibers with the intention of later exploring their commercial potential [Iatropoulos et al., 2004].
- 3rd business level: EO decides to light the optical fibers. This means that customers are able to buy wavelengths.
- 4th business level: EO enters the network services provision market, like Fast Internet and VPN.
- 5th business level: EO, further to the role of Network Access Provider, undertakes the role of Application Service Provider providing content and application services through the optical fiber network.

Iatroupoulos et al. (2004) examine the second business level activity and apply ROs analysis to estimate the optimum deployment strategy for dark fiber installation along the EO motorway. In this section we examine the business activity of implementing the third and fourth business levels and expand on previous work adopting compound options analysis under threat from competition. Our target is to define optimum deployment strategy for these business levels.

Firstly, EO decides to enter the broadband networks market by installing optical dark fibers along the "Egnatia Odos" motorway, with the intention of later exploring their commercial potential. Secondly, EO goes a step ahead and decides to light the optical fibers. This means that customers are able to buy wavelengths. Hiring wavelengths requires the installation, operational management and maintenance of active equipment. Thirdly, the company examines the possibility of entering the market of network services provision, like Fast Internet and VPN. We also consider this opportunity as a real growth option, which is based on both the initial infrastructure project as well as the first growth option to light the fibers. We consider the second and third stage as growth ROs. The options values stemmed from EO's belief that it could resolve some of the uncertainties. Such uncertainties are: the demand for broadband services in the region of interest and the ability 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. EO may adopt the strategy to wait and learn more about the investment so as 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 in terms of expected revenues.

However waiting to learn more about business conditions, concerning growth investment opportunities, is not without cost. Actually, the specific investment opportunities are shared among competitors in the market and they may experience significant degradation by first movers (competitors) entry into the market. Our analysis focuses on two investment performance indicators, (1) the NPV and (2) the overall ENPV of the overall investment opportunity under threat from competition.

For the aforementioned investment opportunities Iatropoulos et al. (2005) provide an analysis of the market demand for the EO case study. The target is to find the optimum deployment strategy for the overall business activity. We examine 9 different alternatives for EO to enter into the broadband market (Figure 6 in Appendix). The investment and competitive parameters are given in Table 1 in the Appendix. The numbers are fictitious, however the content and business characteristics of the specific case study are real and they are the results of discussion between the authors and EO ICT management. Our target is to present how our methodology is implemented. Guided by the relevant literature on broadband networks investment analysis (e.g. P-901), we will consider three different values of uncertainty, 20%, 40%, and 60% to express the range of potential revenues which are strongly related to broadband services demand.

Business modules revenue may also experience dependencies between each other. Actually, they may experience positive or negative dependencies (synergies). An investment opportunity treated as prerequisite of a future growth option may influence negatively or positively the future growth option whether it is or is not commercially exploited. For example, in the case of providing DF, the overall value of dark fiber revenues will be lower. This happens because the customer’s basis will be smaller, as bandwidth service providers will be excluded in this case. The same applies for the WL and NS investment opportunities. Alternatively, providing infrastructure network facilities to EO competitors for the upper business levels may contribute to an increase in market demand, due to externality effects. In this example we consider the case where there are no dependencies between growth investment opportunities.

We apply the proposed methodology in the 9 business alternatives to estimate the NPV (for zero uncertainty and without waiting policy) and the ENPV (real options analysis) values for each of them. The results are presented in Figure 7.

----------------------------Figure 7 ---------------------------

The results can be summarized as follows: Alternative 4 (invest now without waiting and so NPV=ENPV) indicates the higher business value for relatively low revenue uncertainty, while for σ_V=60% Alternative 9 presents the higher value. The longer WaS period may indicate higher option values for the specific values of the competitive parameters presented here, despite the threat from competitors to eliminate part or whole of the investment value. In general, it is a matter of compensating between the uncertainty control assured by ROs thinking and the competitive threat caused by the incoming competitors during Inception, WaS and the operation period for EO.

We also study the effect of key competitive parameters uncertainty about the option value for positive, zero and negative correlation (ρ) between revenue and c_w, λ_w for Alternative 9 (Figure 8).

----------------------------Figure 8 ---------------------------

The conclusion is that the higher amount of uncertainty for competitive parameters, for both WaS and the operation period indicates higher option values for the EO which further indicates a longer WaS period. This is the core idea of the ROs analysis. The higher amount of uncertainty existing during the WaS period indicates higher option value since more uncertainty will be resolved. However, for correlation value between competitive parameters and investment revenues close to 1 the ENPV is smaller than NPV indicating less need for WaS strategy.

Conclusion and Future Research

This paper contributes to the literature on the application of ROs theory to telecommunication investments. The main contributions of this work are the following.

- It is the first time that compound ROs have been analyzed in the telecommunication business field taking into account competitive threats that can eliminate their value.

- Due to a high number of competitors in the telecommunication field we adopt exogenous competition modeling and build on the assumptions in existing literature by considering that competitors arrival rate and impact from each entry into the market follow a joint-diffusion process with business revenues.

In particular, the paper presents a methodology that helps to use real operating options to find the optimum deployment strategy for telecommunication investments in a way that increases the value of these business activities. The paper also illustrates an example of how the methodology is applied in practice. The results of our methodology prove that ROs analysis may enhance performance of ICT business activities. We consider one time step joint-diffusion process. Multiple time steps result in increased granularity and so to increased accuracy in the results. Though the complexity of the model is increasing dramatically we capture more efficiently the additional dimension of new competition..

In this work we will focus on the ICT business field and especially on broadband technology investments. Applying the proposed methodology to solving investment problems under competitive conditions in specific technology areas (e.g. ERP systems and E-learning systems) would be another promising extension of this study. It can be also applied in any other field that requires modeling of competitive threat against the benefits of waiting before investing so as to receive more information about the specific opportunity. Such a case is a Research and Development Investment. In addition, decision-making for any technology infrastructure investment that can supports future opportunities, treated as real options under competitive threat, can adopt our analysis.

A limitation of our model can be in the way we estimate the up and down coefficients in the joint-diffusion process for the competitive parameters. We adopt the neutral risk probabilities for competitive parameters in a similar way to the overall market value V. These assumptions may be an issue of criticism that requires further discussion for their validation. However, our intention is to show how the uncertainty in competitive parameters influences the value of a future investment opportunity being treated as RO. In our analysis we consider only growth options and the subject of the investigation is the business level and entry time that the firm should adopt to increase its utility. The combination of operating with growth options, while increasing the complexity of the methodology, makes it more efficient. In this case we also examine the optimum deployment strategy for each business model (growth option). In addition, it would be possible to build a computer-based support system that can automatically screen out inferior investment-structuring alternatives by identifying tradeoffs based on the characteristics of the options involved (e.g. competition level).

Furthermore, someone could adopt endogenous competition modeling assuming that each one of the competitors in the market experiences a different level of the competitive parameters. In this case endogenous competition modeling requires the integration of ROs with Game Theory.

Finally, a holistic approach, by integrating tangible and intangible factors, for evaluating ICT business activities based on complex infrastructure investments may be necessary. For example, Roper-Lowe & Sharp (1990) use an Analytic Hierarchy Process model for the selection of a computer operating system. They mixed tangible and intangible factors in a benefits' hierarchy in order to prioritize three scenarios for a British Airways operating system upgrade.

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Appendix A

---------------------------Figure 6 --------------------------

In any of the strategies we consider that EO starts with the immediate investment of DF installation along the motorway. In alternative 1 EO lights the DF providing WL services immediately, while in alternatives 2 and 3 adopts a WaS period of 1 year and 2 years respectively. In alternative 4 the immediate implementation of the aforementioned stages including the NS provision is considered, while from alternatives 5 to 9 different implementation times for WL and NS services provision are examined.

---------------------------Table 1 --------------------------

Revenue uncertainty is taken from the literature from similar case studies Elnegaard & Stordahl (2002). We assume zero correlation between V and competitive parameters. Actually, in case of correlation 1, competitive parameters have linear relationships with V, however, as mentioned before a smaller correlation value can be applied in real life cases under competitors' asymmetries such us investment cost, initial infrastructure ownership, and other physical resources availability. In particular, EO has a competitive advantage over the rest of its competitors due to the availability of physical resources along the motorway. In addition, we model uncertainty for the one-time cost at expiration date assuming that it is ~~stochastic~~ too with σ_{x1}=30% and σ_{x2}=20%. Waiting can give a decision maker more information about costs. Costs can change through the introduction of new technologies, changes in the regulatory environment, new partnership possibilities, or the availability of grants to offset some of the development costs. However, sometimes it is not waiting but investing that reveals information about costs. For instance, a negative correlation value between investment revenue and cost indicates the inability to control the cost of the development project associating with lower revenues after the project/phase is completed. Finally, the annual risk-free interest rate is r_f=4%, while the discounted factor for the revenues is r=8%.

Figures

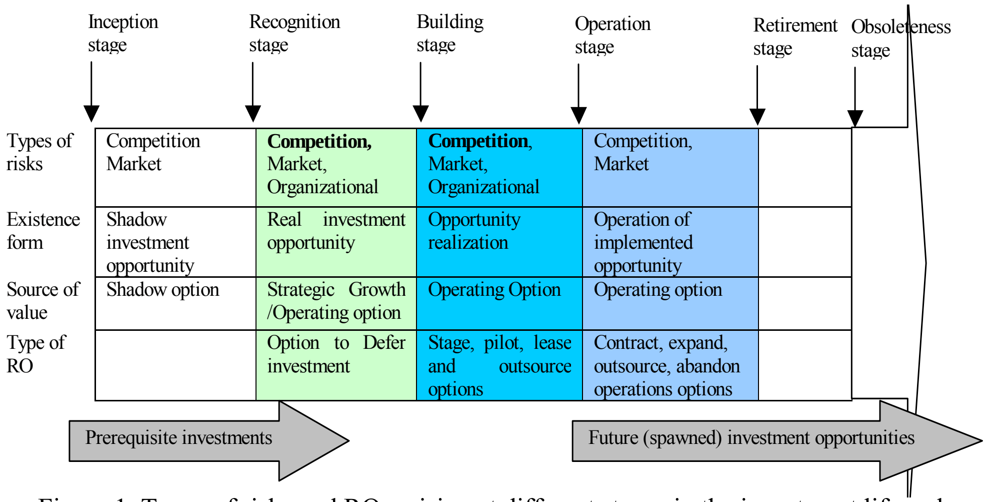

Figure 1. Types of risks and ROs arising at different stages in the investment lifecycle

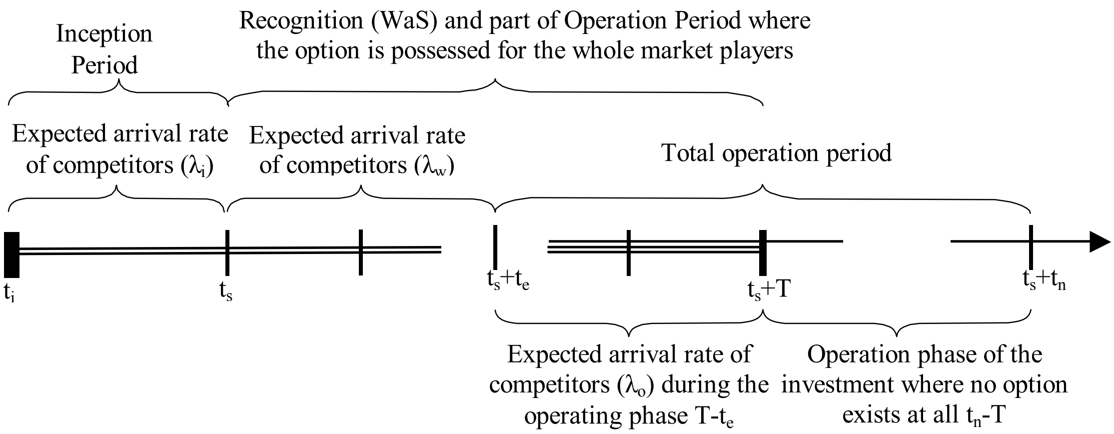

Figure 2. Inception, waiting (recognition) and operation periods competition modeling for a single RO

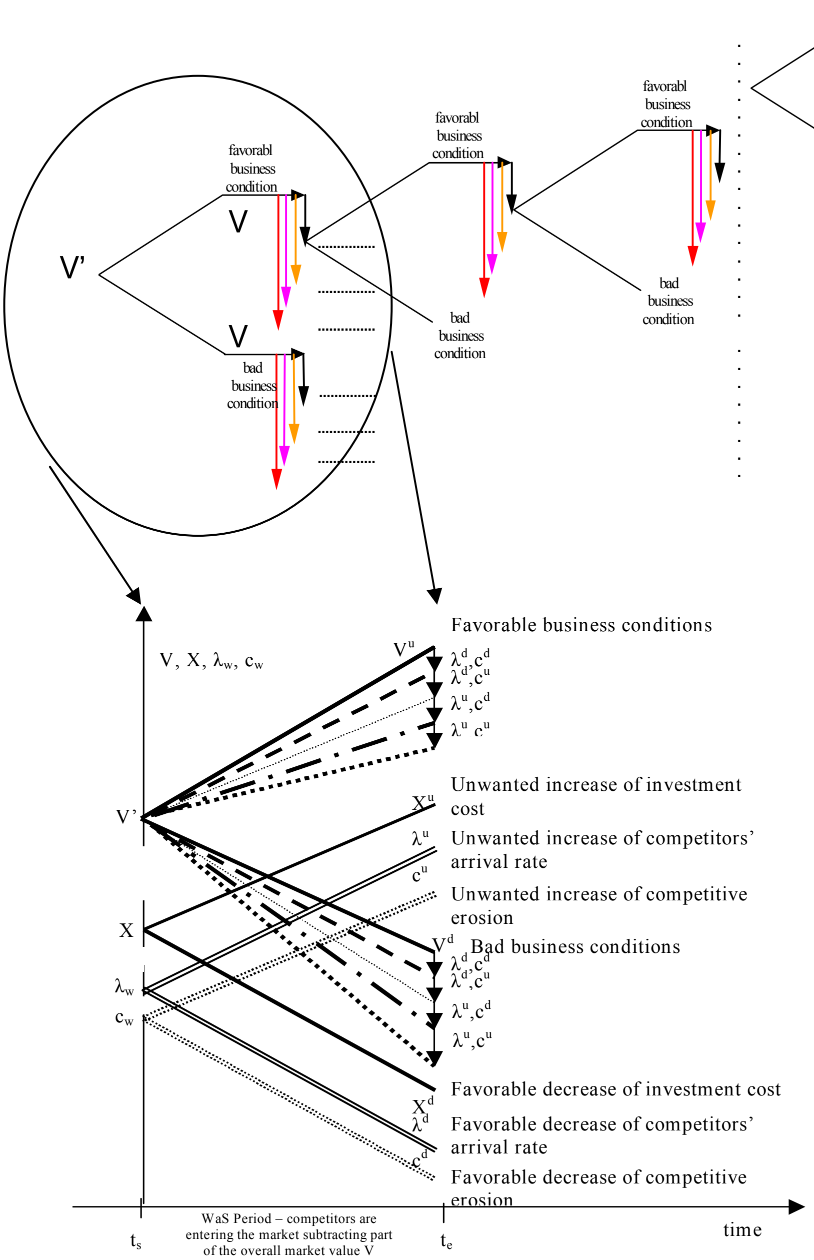

Figure 3. Investment Revenue and cost, competitors arrival rate λ_w and competitive erosion c_w joint diffusion process during WaS period, one time step ($V' = V - I_{ci} - I_{co}$)

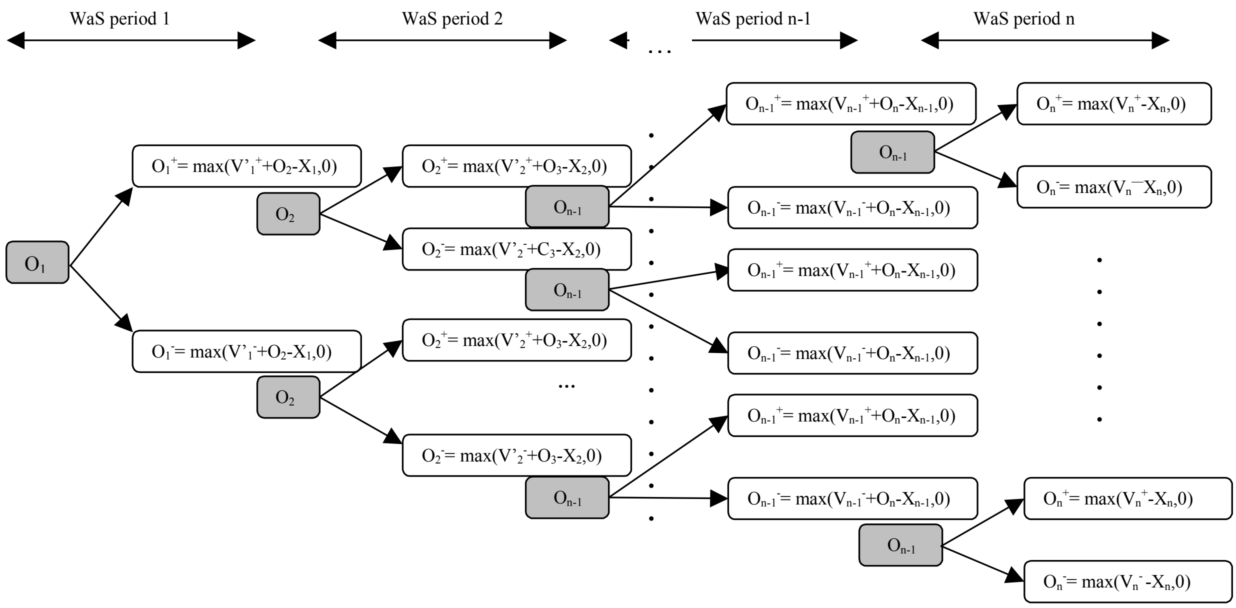

Figure 4. Compound Growth Options presentation

Overall investment opportunity value and the ROs payoff diagram in the n-stage deployment strategy (one-step)

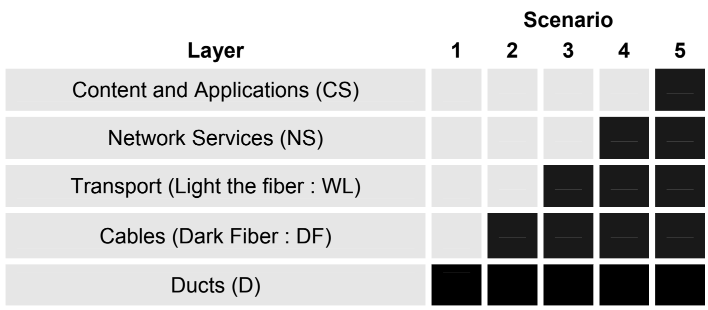

Figure 5. Business models for Egnatia Odos S.A. (Iatropoulos et al., 2004)

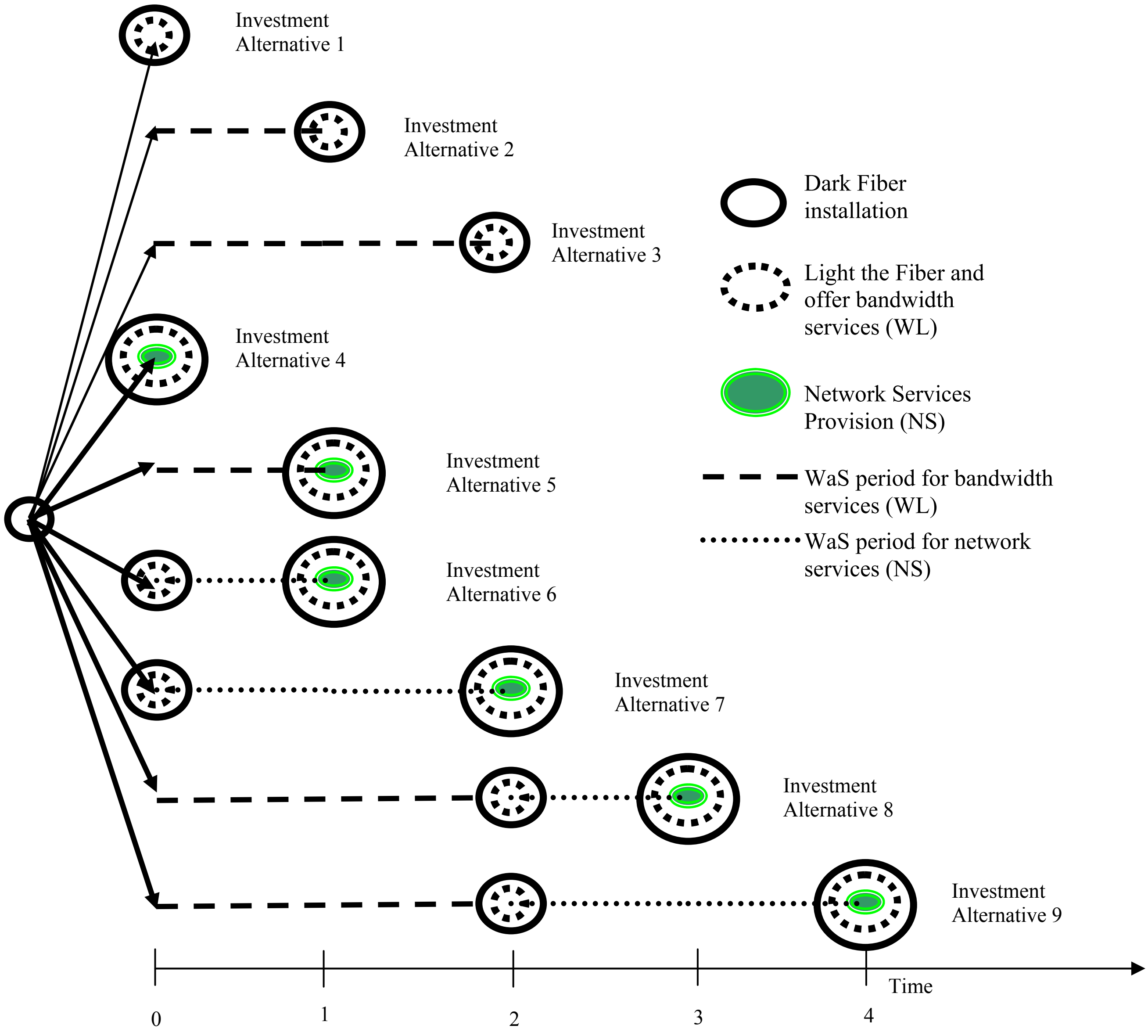

Figure 6. Alternative business deployment strategies for Egnatia Odos S.A.

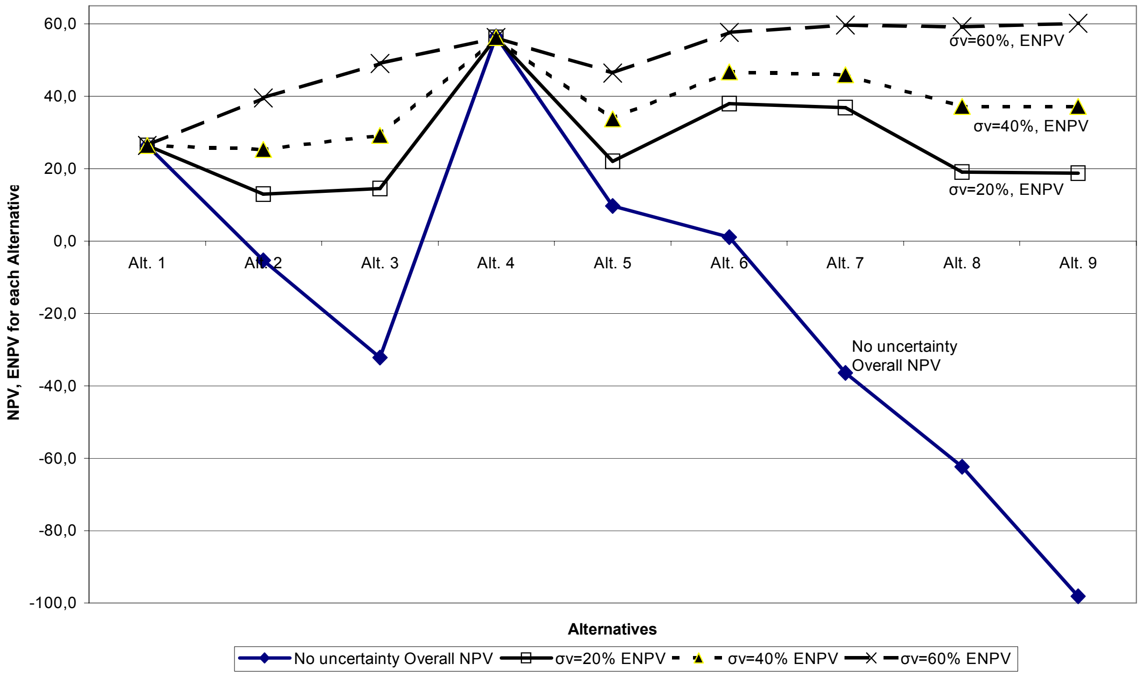

Figure 7. Values of business alternatives (Alt.)
σv=0%, 20%, 40%, 60%

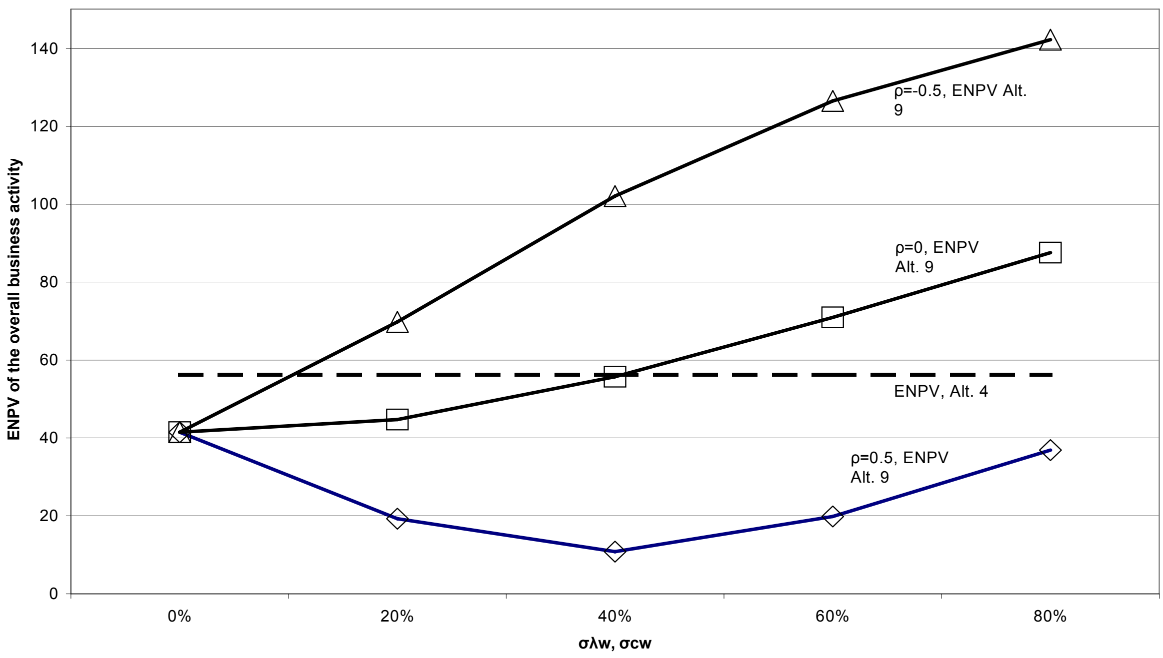

Figure 8. The effect of competitive erosion and competitors arrival rate uncertainty on option value for various values of correlation ρ between competition parameters and investment revenues V for Alt. 9.

Tables

Table 1. Investment and competition parameters

Parameters Value	**DF**	**WL**	**NS**
X (present value, immediate investment)	200	150	140
V (present value, immediate investment)	200	250	220
λ_i	-	-	1
c_i	-	-	0.07
λ_w	-	2	2
c_w	-	0.1	0.2
λ_o	1	1	1
c_o	0.1	0.05	0,05
$\sigma_{\lambda w}$	-	50%	50%
σ_{cw}	-	50%	30%
σ_X	-	30%	20%
σ_V	-	20%, **40%,** 60%	20%, **40%,** 60%
Revenue loss per year during inception period	-	-	8%
Revenue loss per year during waiting period	-	8%	8%
T maximum entry time from now	2	3	5
Risk free r_f	4%		
Revenues discount factor r	8%		
Correlation between V and competition parameters is zero			
Correlation between V and X is –0.5			
The analysis horizon is 15 years			
We assume that one-time investment cost increases with a growth rate equal to risk free interest rate			

Captions for Figures and Tables

Figure 1. Types of risks and ROs arising at different stages in the investment lifecycle

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