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A compound real option and AHP methodology for evaluating ICT business alternatives

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Abstract

After the liberalization of information and communication technology (ICT) markets many potential providers have appeared. Thus, business complexity, for ICT decision makers, has increased. In this paper, we focus on the problem of selecting the optimal business evolution path for ICT, focusing on the broadband technology (BT) field. Traditional quantitative cost–benefits analysis, such as net present value (NPV), is by no means sufficient for capturing the complexity of the problem in its entire. Researchers suggest the real options (ROs) for valuating ICT investments. However, RO models are strictly quantitative and very often ICT investments may also contain qualitative factors, which cannot be quantified in monetary terms. In addition, ROs analysis itself brings to the "surface" some factors that can be more efficiently treated qualitatively. We combine the ROs and analytic hierarchy process (AHP) into a common decision analysis framework providing an integrated multicriteria model, called ROAHP, for prioritizing ICT business alternatives. The proposed model is applied to a real life BT business case, showing how it can be formulated and solved.

Keywords: Real options; Decision analysis; Information and communication technologies; Investments analysis; Broadband technology; Analytic hierarchy process; Multicriteria decision making

1. Introduction

The valuation of information and communication technology (ICT) is a challenging task because it is characterized by high-level uncertainty and rapidly changing business conditions. This task is further exacerbated when we consider ICT infrastructure investments. ICT infrastructure is a collection of technologies, people, expertise, and processes. The technology component includes platform technologies, network and telecommunication technologies, key data and core data-processing applications (Duncan, 1995). The people and expertise component includes software analysts, architects and other employees responsible for the infrastructure

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design and support. Finally, the process component includes processes for architecture standardization and infrastructure change reviews. Evaluating such investments requires the modeling of the aforementioned factors in a multicriteria analysis basis.

After the liberalization of the ICT markets, the related business activities are not possessed exclusively by a single firm but rather are shared by many competitors. The main challenge for a potential provider (investor) is to roll out its business activity at the right time and the right scale or layer. The time and layer depend on ICT services penetration, network infrastructure cost, area characteristics, applications offered, expected tariff evolution, customers' willingness to pay, demand forecasts, evolution of expected market shares, and investor's technical skills.

Although the traditional cost–benefit analysis expressed in money terms such as investment cost, revenues, and net present value (NPV) are significant factors to be taken into account in the analysis process, it is by no means sufficient for capturing the complexity of the problem in its entire. Actually, it does not properly account for the flexibility inherented in most ICT investment decisions. For example, an ICT infrastructure project may have a negative NPV when evaluated on a stand-alone basis, but may also provide the option to launch future value-added services if business conditions are favorable. Real options (RO) analysis presents an alternative method since it takes into account the managerial flexibility of responding to a change or new situation in business conditions (Trigeorgis, 1996). However, ROs models are strictly quantitative, while ICT investments experience tangible and intangible factors and the latter can be mainly treated by qualitative analysis. In addition, ROs analysis itself brings to the "surface" a number of factors that cannot be quantified, at least easily, by existing ROs models and methodologies.

Hence, we consider that a holistic methodology should be developed in order to assist executives and decision makers in formulating problem parameters, understanding their interactions, estimating their contribution to the overall business value and so valuating effectively new ICT business activities.

We focus on the interface between ROs and AHP and the need for their integration. In addition, we discuss limitations of existing ROs models and their need for qualitative analysis. We integrate ROs thinking and AHP providing a multicriteria analysis methodology. It takes into account financial tangible and intangible factors and quantifies managerial flexibility in business's deployment strategy. We call this new model ROA-HP, which integrates ROs and AHP into a common decision analysis framework.

1.1. Problem background

We consider an ICT business activity, which contains N future business opportunities (BO). We consider that each BO_n is based on BO_{n-1}. We start from an initial infrastructure investment that supports these BOs. We treat these BOs as growth ROs. Our aim is to estimate the optimum layer, time, and evolution path to deploy the overall business activity. In order to achieve this we examine the various alternatives of its deployment strategy (Fig. 5a in Appendix A). We define as deployment strategy the time and the mode adopted for implementing the N BOs (e.g. to implement them in steps/phases or at once). The main challenge is to estimate the value of the initial ICT infrastructure, which embeds future BOs. These BOs (options) can be implemented (exercised) if and when the management decides that business conditions are favorable. The quantification of this managerial flexibility is achieved by using ROs. Another challenge is to combine tangible and intangible factors given by the ROs application to the ICT business field. For example, future BOs, which are based on initial ICT infrastructure projects, may be interdependent on each other (i.e. cross-investment synergies exist). Current growth options analysis based on compound options does not consider this issue (Taudes et al., 2000). Bardhan et al. (2004) examined project dependencies for prioritizing a portfolio of ICT projects. We extend this approach by modeling qualitatively the various cross-organizational synergies between future BOs that are treated as ROs. Qualitative modeling and thinking may be more flexible and easily adopted by senior managers when examining the various deployment alternatives of the same business activity. In addition, we examine these synergies in a multicriteria decision analysis framework using AHP.

Our analysis mainly focuses on the broadband technology (BT) business field. However, it can be easily extended to other ICT fields. We adopt a similar to Benaroch (2002) analysis focusing however on growth options, while he focused mainly on operating options. In addition, we extend his framework by combining tangible and intangible factors for finding the optimum combination of growth options to be implemented.

Them, we apply our proposed methodology to a real life business case associated with "Egnatia Odos S.A." strategic decision to deploy optical fibre along the Greek national motorway "Egnatia Odos".

The paper is organized as follows. In Section 2, we discuss about the BT infrastructure value and the available business models, which it can support. We also review the ROs thinking in the ICT field. In Section 3, we integrate ROs and AHP into a common decision analysis framework providing a new model called ROAHP. In Section 4, we apply the proposed models in a real life BT case. Finally, in Section 5, we conclude and suggest future research paths.

2. Broadband infrastructure as a source of value and option thinking

A key capability of ICT infrastructure is flexibility (Kulatilaka and Marks, 1988), the ability to support hardware, software, and networking technologies across a portfolio of systems capabilities, and to extend functionalities and capacities. BT infrastructure includes the resources that constitute a foundation for future business opportunities. The resources include physical resources, business rights to proceed in such a business field, as well as people expertise. In particular, after the ICT markets liberalization many organizations own a number of physical resources (e.g. power electricity networks, water management networks, and transportation networks) that can "host" BT (e.g. optical fibers). So, new business opportunities are appearing for these organizations that can either act alone, as new broadband services providers, or form alliances with existing telecommunication operators.

Iatropoulos et al. (2004) examined the business models in BT, which are available to a new potential provider (Fig. 1). Starting from the bottom to the top, the first business layer (BL) is the right (license) to deploy broadband business activity. The next BL is the physical mean upon which the network will be built. Examples include ducts to host dark fiber (DF) equipment or power electricity wires. Second is the implementation and commercial exploitation of telecommunication physical field such as dark fiber (DF) installation.

The third BL is the provision of bandwidth services. This requires the installation, operation, management and maintenance of active equipment. Bandwidth services provision mainly focuses on Internet service providers (ISP) or single companies/customers (i.e. ADSL, Ethernet to the Home/Office). The fourth BL is the network services provision, like fast Internet and virtual private networks (VPN). In this case the potential operator undertakes the role of network access provider (NAP). The fifth BL is content and application services provision. Here, the potential operator further to the role of the NAP undertakes the role of the application service provider (ASP) and content service provider (CSP) too. Services examples include videoconferences, e-learning, tele-working and video/audio on demand. In summary, with an appropriate broadband infrastructure, a firm can "build" and "boost" its BT business activity by developing new products or services in a competitive market. In this sense, broadband infrastructure investment (e.g. DF installation) creates growth options, which can be appropriately evaluated with ROs. In the following, we briefly present the ROs perspective and review its applicability to the ICT field.

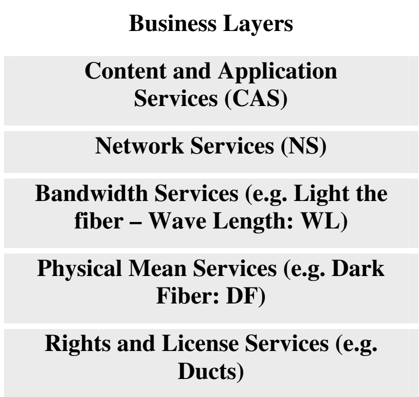


Fig. 1. Business models architecture for the broadband business field (Iatropoulos et al., 2004).

2.1. The ROs perspective

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 Siemens at 100€ per share on January 2010). ROs approach is 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. An investment embeds a RO when it offers to the management the opportunity to take some future action (such as abandoning, deferring or expanding the project) in response to events occurring within the firm and its business environment (Trigeorgis, 1996). For a general overview of ROs, Trigeorgis (1996) provided an in-depth review and examples on different ROs. For more practical issues the reader is referred to Mun (2002).

ROs have been applied to several ICT problems: ISDN investment valuation (Dos Santos, 1991), quantifying the benefits for switching from SAP R/2 to SAP R/3 (Taudes et al., 2000), upgrade from asymmetric digital subscriber loop (ADSL) to very high data rate subscriber loop (VDSL) valuation (Elnegaard and Stordahl, 2002; Elnegaard, 2002; Kalhagen and Elnegaard, 2002; EURESCOM, 2000), ICT investment opportunities uncertainty analysis (Schwartz and Zozaya-Gorostiza, 2003), capacity upgrading of base network (d'Halluin et al., 2002, in press), spectrum licensing and 3G investments (Basili and Fontini, 2003; Harmantzis and Tanguturi, 2004), optical fiber investment valuation (Iatropoulos et al., 2004). Angelou and Economides (2005) presented a comprehensive literature review of the ROs applications to real life ICT investments evaluation.

2.2. ROs applicability aspects in the ICT business field

Previous research of applying ROs to the ICT filed can be classified into three categories. The first category incorporates options thinking in cost–benefit analysis for ICT investment evaluation. Single or compound options were estimated and the target was either to estimate investments value or the optimum time to invest (Benaroch and Kauffman, 1999, 2000). Competition modeling can be considered as an extension of this category (Zhu and Weyant, 2003; Angelou and Economides, 2006, forthcoming). The second category involves portfolio management (Bardhan et al., 2004). ROs are used for valuing and prioritizing a portfolio of ICT projects, which are characterized by interdependencies, and sequencing constraints. The third category uses ROs for risk management and optimum ICT deployment strategy selection (Benaroch, 2002; Kumar, 2002).

The work in this paper mainly leverages the second and third research categories combining quantitative and quantitative analysis.

2.3. Real options limitations and the need for considering a qualitative perspective

Several conceptual and practical issues emerge when one tries to apply options theory in ICT business practice as it is proposed in the current literature. It is accepted that all ROs models provide approximate valuations of ROs values (Amram and Kulatilaka, 1999). Even the so-called accurate ROs models, such as the Black–Scholes formula, require some assumptions whose validity is still under criticism in the field of ICT investments (Tallon et al., 2002). Particularly, while the ROs are widely proposed for evaluating ICT investments, it is still accepted that the ROs applicability is limited by the fact that ICT investments assets are not traded. The non-tradability of ICT assets cannot reveal the investor's risk attitudes, in order to estimate the correct discount factor of ICT investments. The theoretical foundation of the ROs and their relevance to ICT investments has been discussed and applied in practice by Benaroch and Kauffman (1999, 2000) as far as the real asset non-tradability issue and risk-neutrality of the investor are concerned. However, its limitation is still under discussion.

In addition, to accurately estimate the parameters of a statistical distribution of outcomes and mainly volatility depends on the ability of senior managers. Dai et al. (2005) stated that many managers do not really have a "gut feel" for the estimation of the volatility though they understand its technical definition as a statistic. Hence, the estimation of revenues and cost volatility, which are used as input parameters in the typical ICT options values, can be a very difficult task (Taudes et al., 2000).

Also, the existing ROs models cannot support, in parallel, many sources of uncertainties. In practice, no more than two or three sources of uncertainties, which usually are revenue and cost, can be modeled by existing ROs models (Trigeorgis, 1996). However, ICT investments experience a variety of risks coming from competition, technology, firm, customers demand, and environmental issues. In a detailed ROs analysis the aforementioned issues should be modeled as specific parameters that follow stochastic processes.

From another perspective, someone can consider that the various sources of uncertainties contribute to the overall volatility of investment revenue and cost, and hence they are efficiently modeled. However, the estimation of contribution of various risk factors to the overall uncertainty (volatility) level (technology, competition, demand uncertainties, etc.) may not be possible. For example, the uncertainty of customers demand may be quantified by estimating its contribution to the overall investment volatility, while the contribution of the technology and firm's capability uncertainties may not. By adopting qualitative analysis, we can model some of the uncertainties "clearness" inherented in the investment opportunity that cannot be quantitatively estimated and included into the overall volatility. Benaroch (2002) provided a method for estimating the overall investment uncertainty (volatility) which can be broken down into its components (e.g. customer demand uncertainty, competition uncertainty, and technology uncertainty). However, the estimation of each component of the uncertainty may not be possible. We extend this thinking by considering that some of the overall uncertainties' components may be more efficiently treated in a qualitative way. On the other hand, the sources of uncertainties that can be quantified and included in the estimation of the overall investment volatility can be integrated into the typical ROs models.

An important barrier to the successful implementation is a general inability to reliably estimate cash flows that are enabled by ICT investments. Existing models for option valuation assume a certain distribution of the resulting cash flows, based on an efficient market. However, this is only rarely the case in the context of investments in the ICT business filed which is known for its uncertain, and unpredictable business conditions. It has been further recognized that finance-oriented option valuation models are too complex for managerial decision-making practice, when real life business conditions are taken into account. Especially, after the ICT markets liberalization, the required competition modeling has increased the complexity of existing options models. Options theory in its present state does provide a conceptual decision framework to evaluate the pro and con of ICT investments but in many cases it cannot be considered as a fully operation tool for management (Renkema, 1999).

Overall, these issues suggest that even quantified ROs analysis could produce only approximate valuations, which in some cases can cause serious mistakes in ICT investment decisions (Benaroch et al., 2006). For these reasons, we consider that quantitative ROs analysis can be enhanced by integrating it with other criteria treated mainly in a qualitative way. We introduce the AHP methodology and construct a specific multicriteria decision analysis model. This new model, ROAHP, integrates ROs and AHP into a common decision making framework.

3. ICT business evaluation

3.1. The need for a holistic approach

During the last two decades, there has been a growing amount of interest and research in the area of decision support systems (DSS) as vehicles for supporting managers in their semi-structured or unstructured activities of decision-making (Eom et al., 1998). However, the proposed investment evaluation methodologies typically focus on a single out many factors that should be assessed. These factors can be classified as financial, commercial-operational, strategic, and technical. Financial factors may contain product and service pricing, investment costs, and NPV. Commercial factors may include structure of ICT provider, organization and stuffing, internal and external competition. Strategic factors may contain strategic choices, innovative services provision and alliances. Finally, technical factors may contain technology choices and network architectures. In this work, we consider almost all of these factors and integrate multicriteria analysis with option thinking.

Some of the aforementioned aspects are covered by the ROs analysis, while others have an inherently qualitative nature and therefore a holistic investment evaluation process is required. We use the term "holistic evaluation" to express the integration of both quantitative and qualitative factors in order to capture the complexity of the business activity and the diverse requirements of the investment shareholders, sponsors, and users (including the funding bodies, the business users, and the single customers).

So far in the literature, the ROs models concern quantitative factors analysis for both benefits and costs. However, very often an ICT project owns a number of qualitative factors that should be taken into account in parallel with the quantitative ones. Managerial flexibility, which is expressed by the ROs, may apply to both quantitative and qualitative factors. However, the known ROs models take into account only the tangible factors. We enhance the nested ROs model under competition modeling (Angelou and Economides, 2006) by adopting the AHP methodology and construct a multicriteria model. One of the key factors behind AHP's choice is the value that AHP places on decision makers' opinions and the crucial role these opinions play in the decision-making process. Additionally, AHP is capable of integrating both qualitative and quantitative criteria into the decision-making process. Finally, through the pair wise comparison process, AHP decomposes large, complex decisions and allows the decision maker to focus their attention on each criterion. We call the proposed business prioritization model, ROAHP. Next, we provide a brief literature review of AHP applications to ICT business valuation. Afterwards, we introduce the proposed ROAHP model.

3.2. A brief AHP presentation and literature review

AHP is a multicriteria decision analysis technique. It aims at choosing from a number of alternatives based on how well these alternatives rate against a chosen set of qualitative as well as quantitative criteria (Saaty and Vargas, 1994; Schniederjans et al., 2005). Using AHP, it is possible to structure the decision problem into a hierarchy that reflects the values, goals, objectives, and desires of the decision-makers. Thus, AHP fits into the strategic investments problems and the framework of this study. The main advantage of the AHP approach is that different criteria with different measures can be easily transformed into a single utility measure. As input, AHP uses the judgments of the decision makers about the alternatives, evaluation criteria, relationships between the criteria (importance), and the relationships between the alternatives (preference). In the evaluation process, subjective values, personal knowledge, and objective information can be linked together. As an output, AHP provides the goal hierarchy, the priorities of alternatives and their sensitivities. Examples of applying AHP to ICT problems include the following: allocation of a budget for maintaining and enhancing the security of an organization's information system (Bodin et al., 2005), comparison of information technology investment alternatives (Hallikainen et al., 2002), selection of a vendor for a telecommunications system (Tam and Tummala, 2001), selection of a multimedia authoring system (Lai et al., 1999), measuring the relative importance of Intranet functions for a virtual organization (Kim, 1998).

4. The proposed model and methodology

In this section, we present a methodology that helps to address the questions: *What is the amount of flexibility embedded in an ICT business activity? How can we configure a specific ICT business activity in a way to maximize firm's utility that contains both tangible and intangible factors?*

The proposed model contains six perspectives: strategic intangible factors (SIF), tactical and operation intangible factors (TOIF), risk mitigation intangible factors (RMIF), financial tangible factors (FTF), ROs intangible factors (ROIF), and technical factors (TF) (Fig. 2). These perspectives are related to both internal and external business environment. Internal environment factors are strategic direction, capabilities and constraints, while external factors are business markets, competitors' response and technology markets.

4.1. Strategic intangible factors (SIF)

The strategic perspective is related to the selection of the optimum BL taking into account corporate strategy issues (Fig. 1), which are mainly based on qualitative analysis. Corporate strategy needs to be linked to the objectives of the business. The essential nature of this tie-up is twofold. Firstly, it provides the basis for establishing a clear strategic direction for the business, and demonstrates both the strategic awareness and strategic

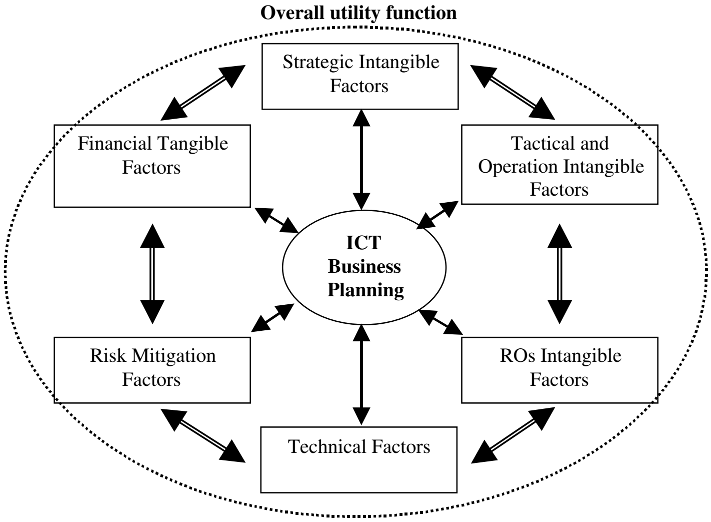


Fig. 2. The proposed model – six perspectives.

willingness, which are essential to corporate success. Secondly, it defines the boundaries and marks the parameters against which the various inputs can be measured and consistently established, thus providing the hallmarks of a coherent corporate plan. For each company, the objectives will be different in nature and emphasis will reflect the nature of the economy, markets, opportunity and preferences of those involved. Typical measures of strategic perspective for a potential ICT provider include the following:

- Shareholders and senior Management Commitment and funding handling (SMC).
- Strategy entry intensity in the ICT market (SEI).
- Structure complexity of the new ICT provider-need for alliances (SCA).

These factors are related to the selection of the optimum BL. The potential provider should answer to the question: "at what BL should we be involved according to our goal, constraints and strategy?"

Shareholders and senior management may not be fully committed to the investment providing full management support, and especially funding. Also, alliances with other competitors in the field may be required, depending on the BL that the potential ICT provider will decide to be involved. The higher the BT BL is, the higher the specific knowledge and expertise is required for the business development and operation.

The next factors are mainly focused on the estimation of the optimum deployment strategies-alternatives.

4.2. Tactical and operation intangible factors (TOIF)

Here, factors related to the tactical and operational perspectives are identified. These factors should be BO specific, and are requirements that must be fulfilled by isolating detailed tasks, processes and resources, in order to ensure medium/short-term tactical and operational success. If these factors are not considered, they will become an obstacle to corporate progress, and may ultimately result in a loss of business, and failure in the achievement of the specific business deliverables (Gunasekaran et al., 2001).

Regarding the BT business field, we consider the following TOIF measures:

- Internal resources-expertise availability (IREA).
- Competition advantage – innovative ICT services provision (CAIS).
- Internal competition – cannibalization of future investments – securing investment benefits (ICSI).

The firm can gain competitive advantage by implementing the project, which can be translated to an increase of the market share. In addition, by investing and exploiting a specific BO, another existing or future BO may be influenced negatively. Analytically, an investment opportunity treated as prerequisite of a future growth option may influence negatively or positively the future growth option if it is or it is not commercially exploited. In this sense, a new business activity may cannibalize existing business opportunities. For example, when a firm decides to install dark fiber (DF) (Fig. 1) looking afterwards for its commercial exploitation without providing bandwidth services, the overall value of revenues may be higher compared to the case of providing also bandwidth services. Actually, the overall value of DF revenues may be lower because the customer's basis in the second case will be smaller as bandwidth services providers will be excluded. The same applies for the wave length (WL) and network services (NS) BOs. We model qualitatively the performance influence of each investment opportunity when a following investment opportunity is implemented.

4.3. Financial tangible factors (FTF)

The financial perspective evaluates how a firm is meeting goals though financial measures. For financial valuation we may adopt traditional accounting techniques such as NPV, return on investment (ROI), internal rate of return (IRR), and one time investment costs (IC). In this work, we apply ROs to estimate the expanded NPV (ENPV) value for each deployment scenario. We adopt a compound ROs model under exogenous competition modeling provided by Angelou and Economides (2006, forthcoming). They considered that the competitors' arrivals rates, the competitive erosions during the waiting phase for the ROs to invest and investments' revenues follow a joint-diffusion process. As the number of players is increasing, the exogenous competition modeling should take place, since market conditions converge to perfect competition. In this case, a competitor's entry into the market will only cause a degradation of the overall ICT investment opportunity "pie", while the rest of the competitors will not react to this entry by changing their business strategy. Here, we extend that idea by integrating tangible and intangible criteria.

4.4. Risk mitigation intangible factors (FMIF)

Option thinking can support the control of different sources of risks present at the various stages of the investment life-cycle (Benaroch, 2002; Bräutigam and Esche, 2003). The lifecycle of an investment consists of six stages: inception, recognition, building, operation, retirement, and obsoleteness. During the inception stage, the BO exists as an implicit opportunity for the firm that can be facilitated by a prerequisite investment. We treat this BO as a shadow option. During the recognition stage, 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. During the operation stage, the investment produces direct and measurable payoffs. During the retirement stage, 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. Finally, when these assets and capabilities no longer can be reused, the investment reaches the obsoleteness stage. We focus on the inception and the recognition stages.

ICT investments experience a number of risks, which are coming from the internal and external environment of the firm (Benaroch, 2002; Bräutigam and Esche, 2003). The uncertainty control or "clearness", achieved by the ROs, is quantified by the volatility of the stochastic parameters such as investment revenues V and one time investment cost X (σ_v, σ_x). However, the overall uncertainty of an investment opportunity cannot, at least easily, be quantified. Qualitative modelling would help in this.

This uncertainty clearness, treated in qualitative way, may concern:

- Business complexity uncertainty (BC).
- Firm's financial exposure capability to afford business (FEC).
- Regulatory and environmental issues uncertainty clearness (RE).

Another factor that would be taken into account is technology uncertainty (e.g. new technologies which would be immature).

4.5. ROs intangible factors (ROIF)

The ROs analysis itself brings to the "surface" a number of factors that cannot be quantified, at least easily, by existing ROs models and methodologies. Fichman et al. (2005) called them potential pitfalls of option thinking for risk management and investment evaluation. We integrate some of them in our multicriteria decision analysis framework, in order to increase its efficiency and improve the decision making process.

Particularly, not all investments can be divided into stages. Sometimes, a firm should consider the investment as a whole entity. Such a case is when external funds must be raised or when a co-investment from other parties is required. Another issue is that stakeholders may prefer all at once funding in order to obtain maximum control of the investment and have so more time to get a troubled investment back on track before facing a next track of justification. We take care of this possibility by considering the intangible factor "capability-interest of staging the investment" (CSI).

In addition, by deferring the firm may loose some investments' benefits. The cost of delay in ROs literature was modeled as a divided yield (Trigeorgis, 1996). Instead, we propose the qualitative modeling of this factor. Although the main focus of the ICT investments' literature is on quantitative competition modeling (Zhu and Weyant, 2003), we consider that qualitative modeling is more practical and flexible, especially in cases of multi-options analysis where the complexity of the models increases dramatically. We name the intangible option factor "option cost of delay" (OCD).

In ROs literature, the investment opportunities that are known in advance, based on initial infrastructure investments, are treated as growth options. Compound option models were utilized to estimate their values. However in reality, ICT growth investment opportunities can be hardly defined during the decision phase (Benaroch, 2002). For this reason, we model qualitatively the existence of growth investment opportunities, which are based on clearly defined BOs of a firm's business activity and cannot be defined quantitatively in advance. Concerning growth options, the main challenge is the difficulty of estimating their values (due to ambiguity of future cash flows) and uncertainty about the appropriate value for option model parameters. We name this intangible option factor "no clarified growth options" (NCO). In addition, creating a growth option usually involves making the ICT platform more generic and modular for obtaining higher flexibility, experiencing however higher cost. We model this issue as intangible factor named "cost of business flexibility-modularity" (CBF).

So, we introduce the following ROIFs into ROAHP:

- Capability-interest of staging the investment (CSI).
- Option cost of delay (OCD).
- No clarified growth options (NCO).
- Cost of business flexibility-modularity (CBF).

4.6. Technical factors (TF)

The TF perspective focuses on identifying the optimal equilibrium between technology performance, reliability and other technical matters for alternative technical investment options. Examples of this perspective include the following: backbone network technology (BNT), access network technology (ANT) (e.g. ADSL, VDSL, and FTTO), and network topology (NT). We do not focus more on this perspective. The interested reader is referred to Yoon et al. (2005) and Ims (1998).

In the following, we propose an AHP-based structure in order to combine all the aforementioned factors in a single utility function.

4.7. ROAHP methodology

ROAHP methodology integrates all the above-mentioned factors into a single decision analysis structure, we have the ROAHP methodology (Fig. 6). The management of a business would follow ROAHP methodology to decide about the BL involvement, and the deployment strategy. AHP is used for both decisions.

In structure A, AHP decides about the layer at which the business should be involved. In structure B, AHP decides about the optimum way to proceed in the implementation of each of the BL.

ROAHP consists of three levels. In level 1, we consider the overall number of BOs, which can be implemented at once or in phases. Each implementation strategy defines an alternative to be examined compared to the others. In level 2, we have the options that embedded in each of the deployment strategy alternatives. A BO embeds an option when a deferral period before investing is adopted. In level 3, we consider all factors (criteria) affecting the investment. Using AHP, we make pair-wise comparisons among the BOs alternatives for every factor (criterion). The final result at the top is the overall business utility, which is composed of the aforementioned perspectives of our model.

4.7.1. Running the AHP multicriteria structure

First, we compare the business scenarios (alternatives) with respect to the SIFs for selecting the BL involvement. We perform pair-wise comparisons for all BLs and estimate overall value of SIFs perspective.

Then, we compare for each BO each alternative that contains it, with respect to TOIFs, RMIFs, ROIFs and TFs. We perform pair-wise comparisons for each BO for all the alternatives. Analytically, we start from the last business opportunity N (BO_N), which is supported partially or fully by previous BO_n ($n = 1,\ldots,N-1$). We perform pair-wise comparisons for the last BO_N concerning all the available deployment alternatives and assign relative values for each of the TOIFs, RMIFs, ROIFs, and TFs.

Going backwards, we perform pair-wise comparisons for the BO_{N-1}. In order to estimate the overall score of BO_{N-1} for each criterion, we also add the score of the BO_N that is based on the BO_{N-1}. However, it is required to define the importance of each criterion (factor) in relationship with the other criteria of the same BO as well as in relationship with the criterion itself in a different BO. For example, the criterion of NCO in our model, may be more important for earlier implementation of BO_n comparing to a later one, since with earlier implementation future value added services will be easier recognizable.

The proposed model for intangible factors adopts a similar approach to compound ROs as the score of each factor of BO_n is added to the score of the same criterion for BO_{n-1} if the later supports the former.

We continue up to BO_1 and estimate the overall score of each criterion for each alternative. In Fig. 5b and c (Appendix A), we present two versions of the proposed model for the estimation of the overall utility value for each of the business alternative examined at $t = t_1$ (=0).

For the estimation of ENPV value we adopt the compound ROs model under exogenous competition modelling by Angelou and Economides (2006).

The notations used in the proposed model are given in Table 1 in Appendix D.

4.7.2. Summary

Our methodology involves five main steps that help to optimally configure an ICT business activity.

1. Define the overall ICT business activity and the BOs that is composed from. State the business goals, requirements and assumptions (technological, organizational, economic, etc.) and then identify risks presence in the overall business activity.
2. Recognize the life cycle periods of each BO for each business alternative. Recognize the nature of options in each strategy deployment alternative. Define the competition characteristics of each investment opportunity, which is treated as growth option. This requires market analysis for competition status verification.
3. Recognize the overall tangible and intangible factors to be taken into account in the proposed model.
4. Evaluate investment-structuring alternatives applying ROAHP model to find the strategy that maximizes business value.
5. Perform sensitivity analysis in order to understand the contribution of each factor in the overall business utility function.

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 that some risks get resolved or new information surface.

5. 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 of the design, construction, operation, maintenance, and exploitation of the Greek 680 kilometers long Egnatia Motorway. Optical fibers are considered to be installed along the Egnatia Motorway. Thus an optical network backbone would be created. This case will analyze the commercial exploitation of this network. EO has to decide if and how to proceed in the implementation of this business activity. The business choices of EO for the commercial exploitation of Egnatia Motorway through the deployment of broadband infrastructure and services are investigated analytically by Iatropoulos et al. (2004) (Fig. 3).

The first scenario is related to the ducts layer. EO – owner of the ducts along Egnatia Motorway – decides at a specific point in time to rent its ducts to a telecom operator (e.g. OTE, Vodafone, and Vivodi). In this scenario, EO is not involved in any business activity related to the provision of infrastructure or broadband services directly, but EO receives an agreed fee (e.g. a fixed monthly rent or a variable amount based on the revenue created by the use of the ducts). By adopting this scenario EO will not own any growth investment opportunity regarding the network services (NS) provision in the future.

The second scenario is related to the cables layer. EO decides to install optical dark fibers looking afterwards for their commercial exploitation.

The third scenario is related to the transport layer. EO decides to light the optical fibres. This means that the customers are able to buy wavelengths (CANARIE, 2007). Hiring wavelengths requires the installation, operation, management and maintenance of active equipment.

The fourth scenario is related to the network services. EO not only lights up the optical fibers but also enters into the market of network services provision (e.g. Fast Internet and VPN). So, EO may become a network access provider.

Finally, the fifth scenario is related to the content and application services. In addition to offering NS, offers CAS. So, EO may become an application service provider (ASP).

Iatropoulos et al. (2004) provided a market demand analysis for EO. In order to select the appropriate BL, the following customers' characteristics are important

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

In general, customers interested in using dark fiber include those who possess (or are capable of doing) the technical skills to "light" the dark fibre. This segment includes the universities, the educational network operators (e.g. GRNet, GUNet, and SEEREN), Internet service providers (ISPs), ASPs (e.g. OTENET), and telecom operators (e.g. OTE, Vivodi, MedNautilus, and Forthnet). Customers without technical expertise like health institutions, post offices, regional authorities, etc,. will mostly be willing to use the network service rather than managing fiber optic equipment. The same applies to most customers of the private sector like

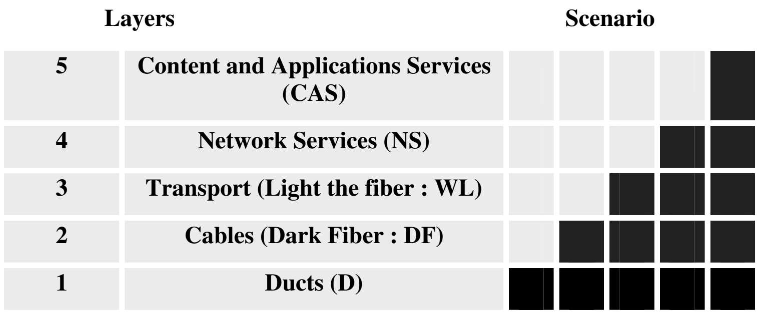


Fig. 3. Business layers for Egnatia Odos S.A. (Iatropoulos et al., 2004).

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 (e.g. 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 European Union funding to build their own metropolitan area networks (MANs) have been improved. This development creates a potentially large customer base in the DF sector.

5.1. EO's strategic business goal

The strategic goal of EO is to enter into the telecommunication market. To fulfil this goal EO is examining the exploitation of competitive advantage of its physical resources. Possibilities to be examined include employing internal project and operation management, or partnership for the development and commercial exploitation of its business opportunities. Iatropoulos et al. (2004) examined the second BL activity and applied ROs analysis for estimating the optimum time to install DF along Egnatia Motorway. In this work, we examine the business activity of implementing the third and fourth BLs. Our aim is to find the optimum deployment strategy for the EO's business activity.

We consider that EO owns a number of options to be exercised when market conditions are favourable in terms of customers' demand and competition intensity in the geographical areas of interest. First, EO decides to enter the market of broadband networks installing optical DFs along the Egnatia Motorway, looking afterwards for their commercial exploitation. DF installation is considered as the initial infrastructure project. Second, EO goes a step ahead and decides to light the optical fibers. This means that the customers are able to buy wavelengths. Hiring wavelengths requires the installation, operation management and maintenance of active equipment. We consider this stage as the first option to growth. Third, the company examines the possibility of entering the market of network services (NS) provision selling Fast Internet and VPN. We also consider this opportunity as a growth real option, which is based on both the initial infrastructure project as well as the first growth option to light the fibers. The options values stemmed from EO's expectation 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 an appropriate business partnership may be examined. EO may adopt the strategy to wait and learn more about the business activity, 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. However, waiting to learn more about business conditions is not without cost. Actually, the specific BOs are shared among competitors into the market and may experience significant degradation by first movers (competitors). As mentioned before, we do not focus on the estimation of the overall ENPV of the overall business activity under competition threat.

EO examines 11 different alternatives to enter into the broadband market (Fig. 7 in Appendix D). The numbers are fictitious in order to protect EO business activity. However, the content and business characteristics of the specific case study are real and are results of extensive discussions between the authors and EO's ICT management. Next, we will apply ROAHP to this case.

Guided by the related literature on broadband networks investment analysis (e.g. P-901), we consider three different values of uncertainty (20%, 40%, and 60%) regarding potential revenues, which are strongly related to broadband services demand.

5.2. Application of the ROAHP model

First, applying AHP, the pair-wise comparison matrices for the alternatives are derived and the relative performance measures are computed for all factors. Comparisons concern the optimum BL selection with respect to SIFs perspective and the optimum deployment strategy selection for BOs with respect to the rest of factors of the ROAHP model. We use the nine-point scale (Saaty and Vargas, 1994) adapted to our case. We judge each one of the 11 alternative scenarios and the two BLs using the following scale: Extremely preferable (E), very strongly preferable (VS), strongly preferable (S), moderate preferable (M) and equally preferable (E). We also include the intermediate values between these scores.

The criteria taken into account in this case study indicate either benefits or costs. In practice it means that for benefits factors more preferable is the alternative that provides higher benefit value compared to another one. On the opposite, for costs factors more preferable is the scenario that provides smaller cost value compared to another one

SIFs

- SMC and SCA indicate cost.
- SEI indicate benefit.

TOIFs

- IREA indicate cost.
- CAIS indicate benefit.
- ICSI indicate cost.

RMIFs

- All sub criteria indicate benefits.

ROIFs

- CSI indicate benefit (in our analysis, however, depending on the shareholders interest it may indicate cost).
- OCD indicate cost.
- NCO indicate benefits.
- CBF indicate cost.

By using the Expert Choice (Expert Choice, 1995) and making judgments according to the aforementioned nine-point scale we derive the pair wise comparison matrixes. Particularly, the pair-wise comparisons were performed by the authors. Since it is sometimes difficult to find technical people who can compare options, it is necessary for the analysts to learn in detail about each option and do the scoring themselves. They took into account various discussions between the authors and the ICT management of the company as well as the work of Iatropoulos et al. (2004) where all the available business opportunities were discussed. Finally, the company has published in the press its possible future business activities in the specific business field.

In the specific case, we achieved consistency ratio level lower that 0.10 in order to be acceptable (Saaty and Vargas, 1994). Since FTFs, here ENPV, are by definition measurable in quantitative units we normalize them in order to maintain parity among factors included in the evaluation of AHP. EO's ICT management and the authors performed the scoring, since the aim of this case study is for explaining the ROAHP methodology. In a comprehensive judgment, the group of decision makers should also involve business and market analysts in the BT filed as well as EO's senior management and shareholders. Also, the final result would be more accurate if technical factors were also taken into account. So, BT technical experts would also participate.

First, we performed paired comparisons for all BLs alternatives according to the principles of the AHP with respect to all criteria defined for SIFs. The prioritization results are given in Fig. 4a. As seen, business layer 1 – BO ducts (BL1-D) has the first priority to be implemented considering the specific importance of the criteria. For a different importance of the criteria, BL4-DF/WL/NS is the best solution (Fig. 4b).

Afterwards, in order to select the business deployment strategy, we performed all paired comparisons for alternatives 3–11 with respect to all criteria defined in the ROAHP model. We applied the group c of expressions in Appendix A, for the estimation of the overall utility function concerning SIFs, FTFs (ENPV), TOIFs, RMIFs, ROIFs. In Tables 2 and 3 of Appendix E, we present the overall values for each

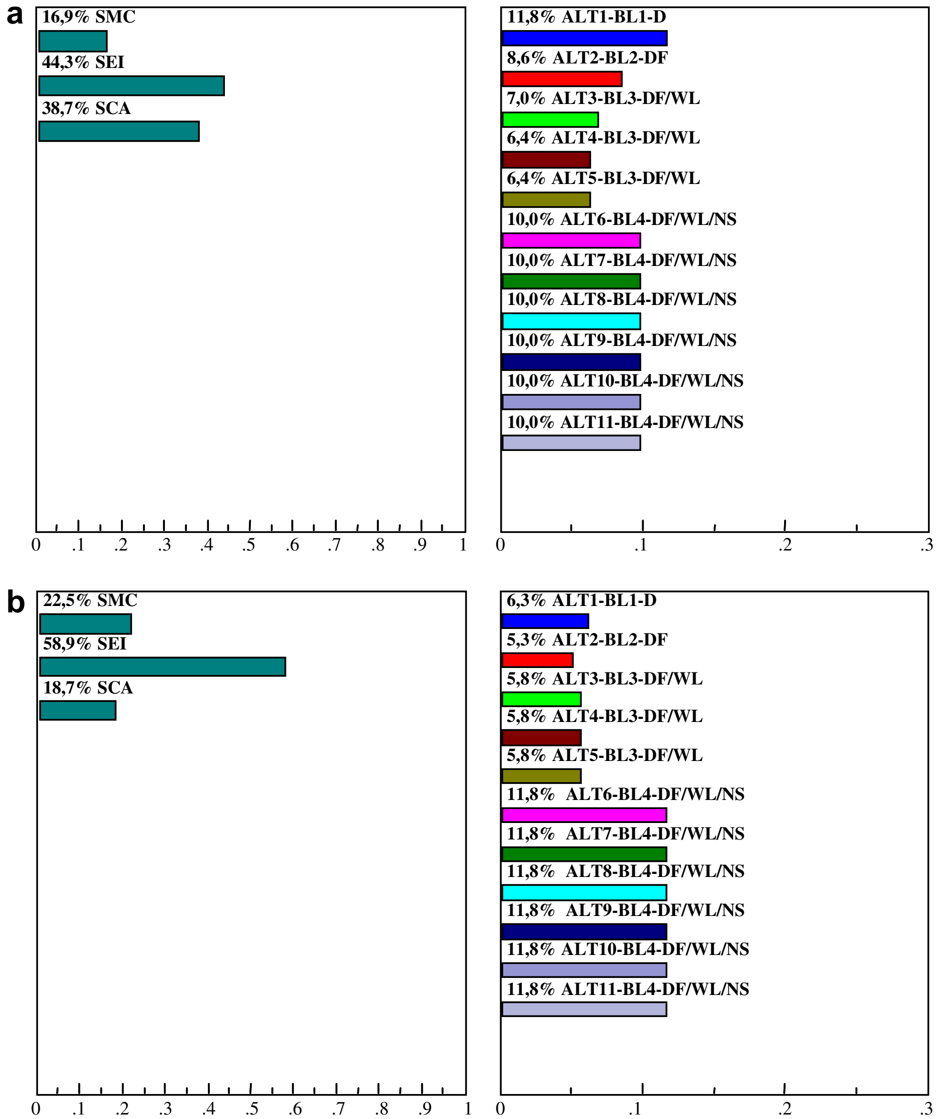


Fig. 4. Business layer prioritization performed with Expert Choice tool.

business deployment alternative of the five perspectives taken into account in our case study. Finally, the prioritization results are given in Table 3. We can see that scenario six appears as the most favorable configuration for business deployment for various values of weighting factors W_{SIF}, W_{OFTF}, W_{OTOIF}, W_{OROIF}, W_{ORMIF}. The input data are quite subjective, especially the intangible ones. Performing sensitivity analysis we can study how sensitive the priorities of the alternatives are to the changes of the input data, i.e. the importance of the criteria. As it can be seen, Alt. 6 appears as the most favorable scenario, while Alts. 11, 10, 7 experience changes in the priorities for different values of the aforementioned weighting factors.

6. Conclusions and future research

We consider that a holistic approach is necessary to evaluate ICT business activities based on complex infrastructure investments.

In this work we provide a decision analysis framework for prioritizing different deployment strategies of ICT business activities focusing on the BT field. In our analysis, we take into account financial tangible and intangible factors and quantify managerial flexibility in the business implementation strategy. Our analysis is based on six perspectives (Fig. 2). We analyze the various deployment alternatives focusing on strategic, non-financial enterprise goals and incorporate these considerations with the financial, tangible goals using a multi-option model. Finally, we apply our model to a specific BT business case showing how it can be formulated and solved.

Analytically, our main contributions are the following:

- We combine ROs and AHP proposing a new model, called ROAHP. Previous ROs models employed only a quantitative factors analysis for both benefits and costs. However, very often an ICT project also owns a number of qualitative factors that should be taken into account in parallel with the quantitative ones.
- We discuss the need for integrating ROs and qualitative analysis. There is criticism in ROs literature about existing ROs models and their applicability to real life cases. Our multicriteria model supports decision makers in adopting ROs modeling relaxing the issues that may prevent ROs applicability. Limitation of ROs applicability may concern practical issues (management perspective on investment's deployment strategy) but also ROs basic assumptions.
- By modeling and integrating ROs quantitative estimation with qualitative perspective factors we enhance decision-making. ROs propose to wait before investment, to proceed in steps for obtaining flexibility in ICT business activity. However, all this thinking may be different from the management's perspective for specific investment and overall business strategy. We integrated both perspectives in a multicriteria model in order to achieve a balance between ROs philosophy and other practical managerial issues.

We take into account a relatively small number of intangible factors. In a future work, we shall include into the ROAHP model more detailed intangible factors. Also, in real life cases, further analysis is required for business alternatives ranking. In particular, the decision makers should perform extended sensitivity analysis for estimating the amount of influence of each priority as well as the weights factors before adopting the final solution of ranking.

Finally, we can consider endogenous competition modeling combining game theory and ROs in a multicriteria analysis perspective. We are planning to extend our work and take into account competitive interactions among firms in the ICT investment field.

Appendix A

For the estimation of the optimum BL, we perform AHP and estimate the detailed priority value for each BL of all criteria of SIFs perspective.

For the estimation of optimum deployment strategy we perform AHP and estimate for BO_N the detailed priority value of each criterion (factor) in each alternative. Afterwards, we perform the same for BO_{N-1}, up to BO_1, while at the end we estimate the overall value of each specific criterion (factor). Hence, the overall business utility (OBU) adopting group b of expressions is given by

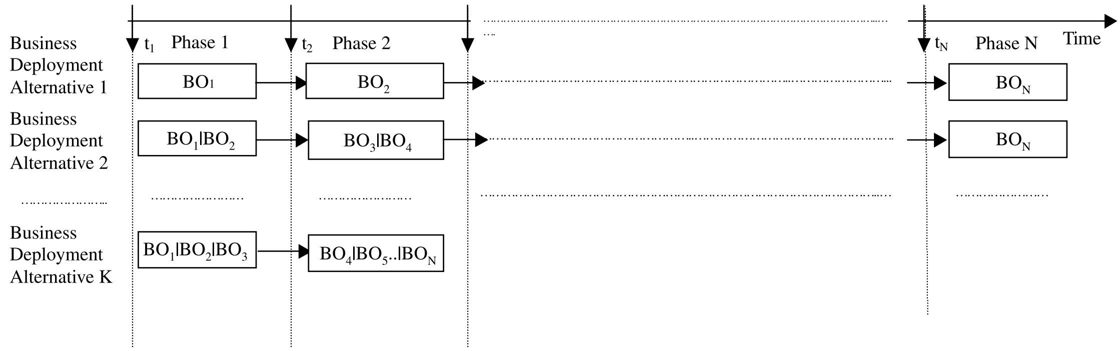
$$\begin{aligned}\mathrm{OBU}_k = {} & w_{\mathrm{OSIFS}} w_{\mathrm{SIFS}_{i_0}} \mathrm{OSIF}'_{i_0 l(k)} + w_{\mathrm{OFTF}} w_{\mathrm{FTF}_{i_1}} \mathrm{OFTF}'_{i_1 k} + w_{\mathrm{OTOIF}} w_{\mathrm{TOIF}_{i_2}} \mathrm{OTOIF}'_{i_2 k} \\ & + w_{\mathrm{ORMIF}} w_{\mathrm{RMIF}_{i_3}} \mathrm{ORMIF}'_{i_3 k} + w_{\mathrm{OROIF}} w_{\mathrm{ROIF}_{i_4}} \mathrm{OROIF}'_{i_4 k} + w_{\mathrm{OTF}} w_{\mathrm{TF}_{i_5}} \mathrm{OTF}'_{i_5 k} \qquad \text{(A-c)}\end{aligned}$$

Alternatively we can perform AHP and estimate the overall values, for BO_N, of the ROIFs, RMIFs, TOIFs, and TFs in each alternative. Afterwards, we perform the same for BO_{N-1}, up to BO_1. In this case the OBU is estimated by the group c of expressions and it is given by

$$\begin{aligned}\mathrm{OBU}_k = {} & w_{\mathrm{OSIFS}} \mathrm{OSIF}'_{l(k)} + w_{\mathrm{OFTF}} \mathrm{OFTF}'_k + w_{\mathrm{OTOIF}} \mathrm{OTOIF}'_k + w_{\mathrm{ORMIF}} \mathrm{ORMIF}'_k + w_{\mathrm{OROIF}} \mathrm{OROIF}'_k \\ & + w_{\mathrm{OTF}} \mathrm{OTF}'_k \qquad \text{(A-b)}\end{aligned}$$

See Fig. 5a–c.

a



b

$$OV_{k1}=\max(V_{k1}-X_{k1}+OV_{k2},0)$$
$$ENPV_{k1}= V_{k1}-X_{k1+}OV_{k2} \quad (1.1)$$
$$OTOIF'_{i1,k}= w_{i2,k1}TOIF_{i2,k1}+TOIF'_{i2,k2} \quad (2.1)$$
$$ORMIF'_{i3,k} = w_{i3,k1}RMIF_{i3,k1}+RMIF'_{i3,k2} \quad (3.1)$$
$$OROIF'_{i4,k}= w_{i4,k1}ROIF_{i4,k1}+ROIF'_{i4,k2} \quad (4.1)$$
$$TF'_{i5,k}= w_{i5,k1}TF_{i5,k1}+TF'_{i5,k2} \quad (5.1)$$

$$OV_{k2}=\max(V_{k2}-X_{k2}+OV_{k3},0) \quad (1.2)$$
$$TOIF'_{i2,k2}= w_{i2,k2}TOIF_{i2,k2}+TOIF'_{i2,k3} \quad (2.2)$$
$$RMIF'_{i3,k2}= w_{i3,k2}RMIF_{i3,k2}+RMIF'_{i3,k3} \quad (3.2)$$
$$ROIF'_{i4,k2}= w_{i4,k2}ROIF_{i4,k2}+ROIF'_{i4,k3} \quad (4.2)$$
$$TF'_{i5,k2}= w_{i5,k2}TF_{i5,k2}+TF'_{i5,k3} \quad (5.2)$$

$$OV_{kN-1}=\max(V_{kN-1}-X_{kN-1}+OV_{kN},0) \quad (1.N-1)$$
$$TOIF'_{i2,kN-1}= w_{i2,kN-1}TOIF_{i2,kN-1}+TOIF'_{i2,kN} \quad (2.N-1)$$
$$RMIF'_{i3,kN-1}=w_{i3,kN-1}RMIF_{i3,kN-1}+RMIF'_{i3,kN} \quad (3.N-1)$$
$$ROIF'_{i4,kN-1}= w_{i4,kN-1}ROIF_{i4,kN-1}+ROIF'_{i4,kN} \quad (4.N-1)$$
$$TF'_{i5,kN-1}= w_{i5,kN-1}TF_{i5,kN-1}+TF'_{i5,kN} \quad (5.N-1)$$

$$OV_{kN}=\max(V_{kN}-X_{kN},0) \quad (1.N)$$
$$TOIF'i_{2,kN}= w_{i2,kN}TOIF_{i2,kN} \quad (2.N)$$
$$RMIF'_{i3,kN}=w_{i3,kN}RMFI_{i3,kN} \quad (3.N)$$
$$ROIF'_{i4,kN}= w_{i4,kN}ROIF_{i4,kN} \quad (4.N)$$
$$TF'_{i5,kN}= w_{i5,kN}TF_{i5,kN} \quad (5.N)$$

c

$$OTOIF'_{k}= w_{OTOIF,k1}OTOIF_{k1}+OTOIF'_{k2} \quad (2.1)$$
$$ORMIF'_{k}= w_{ORMIF,k1}ORMIF_{k1}+ORMIF'_{k2} \quad (3.1)$$
$$OROIF'_{k}= w_{OROIF,k1}OROIF_{k1}+OROIF'_{k2} \quad (4.1)$$
$$OTF'_{k}= w_{OTF,k1}OTF_{k1}+OTF'_{k2} \quad (5.1)$$

$$OTOIF'_{k2}= w_{OTOIF,k2}OTOIF_{k2}+OTOIF'_{k3} \quad (2.2)$$
$$ORMIF'_{k2}= w_{ORMIF,k2}ORMIF_{k2}+ORMIF'_{k3} \quad (3.2)$$
$$OROIF'_{k2}= w_{OROIF,k2}OROIF_{k2}+OROIF'_{k3} \quad (4.2)$$
$$OTF'_{k2}= w_{OTF,k2}OTF_{k2}+OTF'_{k3} \quad (5.2)$$

$$OTOIF'_{kN-1}= w_{OTOIF,kN-1}OTOIF_{kN-1}+OTOIF'_{kN} \quad (2.N-1)$$
$$ORMIF'_{kN-1}=w_{ORMIF,kN-1}ORMIF_{kN-1}+ORMIF'_{kN} \quad (3.N-1)$$
$$OROIR'_{kN-1}= w_{OROIF,kN-1}OROIF_{kN-1}+OROIF'_{kN} \quad (4.N-1)$$
$$OTF'_{kN-1}= w_{OTF,kN-1}OTF_{kN-1}+OTF'_{kN} \quad (5.N-1)$$

$$OTOIF'_{kN}= w_{OTOIF,kN}OTOIF_{kN} \quad (2.N)$$
$$ORMIF'_{kN}=w_{ORMIF,kN}ORMFI_{kN} \quad (3.N)$$
$$OROIF'_{kN}= w_{OROIF,kN}OROIF_{kN} \quad (4.N)$$
$$OTF'_{kN}= w_{OTF,kN}OTF_{kN} \quad (5.N)$$

Fig. 5. (a) ICT business alternatives deployed in up to N business opportunities and respective N phases. (b) The proposed compound model for multicriteria intangible factors, version a. (c) The proposed compound model for multicriteria intangible factors, version b (used in the real life case study).

Appendix B

See Fig. 6.

Appendix C

See Table 1.

Appendix D

In business alternative (alt.) 1 EO examines the possibility to rent its physical resources without being involved with any ICT business activities. In alt. 2, we consider that EO makes the investment of installing DF along the motorway. In alt. 3, EO lights the DF providing WL services immediately, while in alts 4 and 5 EO waits a deferral period of 1 year and 2 years, respectively. In alt. 6, EO immediately implements the aforementioned stages including the NS provision. For alternatives 7 to 11, EO considers different implementation times for WL and NS services provision.

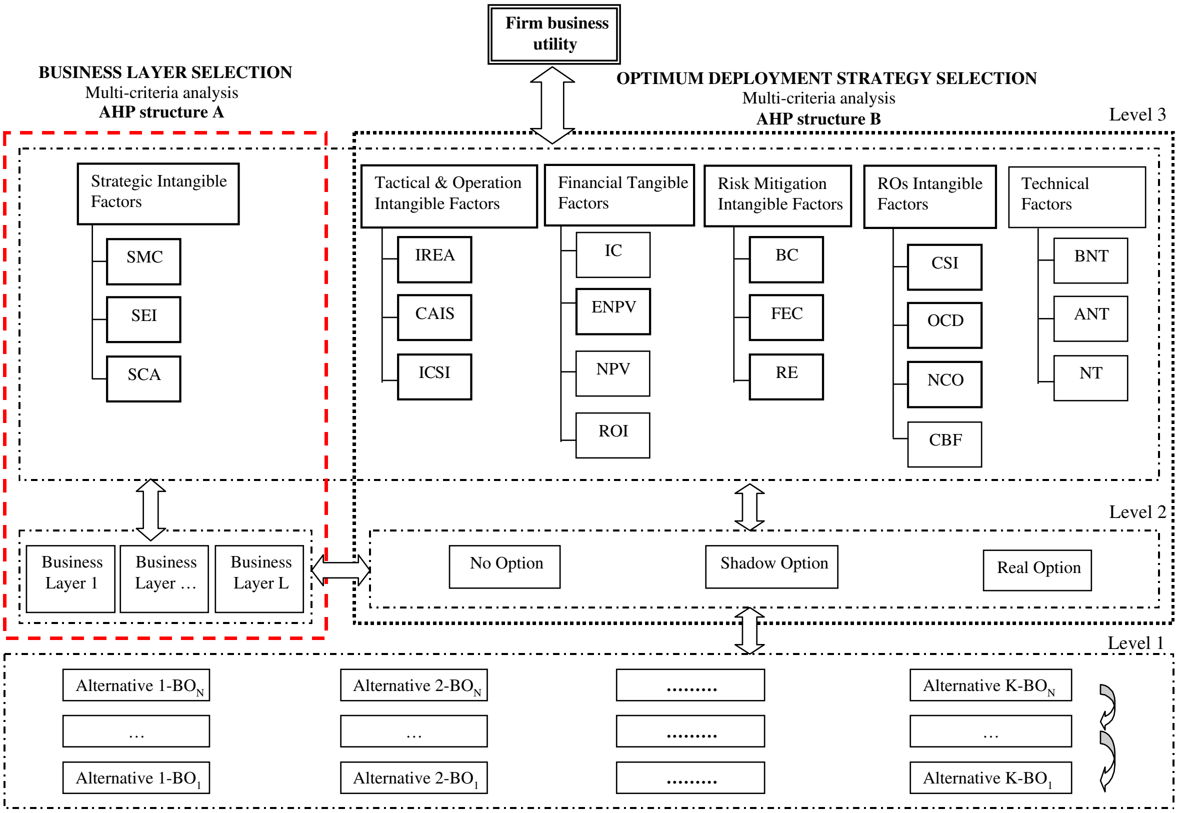


Fig. 6. ROAHP model structure.

Table 1
Notations used in our model

Notation	Definition
OBU_k	
BOn	Business opportunity n ($n = 1,2,3,\ldots,N$). We treat BO_1 as initial infrastructure project
N	The total number of business opportunities (BO)
K	The total number of business deployment scenarios/alternatives
V_{kn}	Revenues of BO_n at alternative k ($k = 1,\ldots,K$)
X_{kn}	Investment cost of BO_n at alternative k
OV_{kn}	Option value of BO_n at alternative k
$ENPV_{k1}$	ENPV of BO, which is treated as infrastructure project, at business alternative k that includes compound options
OBU_k	Overall business utility for alternative/scenario k
Business layer selection	
$SIF_{i0,l(k)}$	The score of the SIF_{i0} at business layer (BL_l) of alternative l ($l = 1,\ldots,L$) for the SIF i_0 ($i_0 = 1,\ldots,I_0$). Each deployment alternative k takes a value according to BL that belongs
L	Total number of business layers, which are available to the potential new ICT provider to be adopted
I_0	Total number of factors included in this category
$OSIF'_{i0,l(k)}$	Overall score of the SIF category at BL_l for criterion i_0. Each deployment alternative k takes a value for criterion i_0 according to BL that belongs
$OSIF'_{l(k)}$	Overall score of SIF category of alternative k that belongs to BL_l ($l = 1,\ldots,L$). (Each deployment alternative k takes a value according to BL that belongs)
W_{OSIF}	The weight of importance of SIFs category with respect to rest of categories

(*continued on next page*)

Table 1 (*continued*)

Notation	Definition
Business deployment strategy selection	
Group (b) of expressions	
FTF_{i1kn}	The score of the BO_n at alternative k for the FTF i_1 ($i_1 = 1,\ldots,I_1$)
FTF'_{i1kn}	Weighted score of the BO_n at alternative k for the FTF i_1 (in our case OV_{kn})
I_1	Total number of factors included in this category (in our case $I_1 = 1$)
$w_{i1,n}$	The weight of importance of i_1 criterion for BO_n
$\mathrm{OFTF}'_{i1,k}$	Overall (compound) score of the FTF_{i1} at alternative k, ENPV_k
TOIF_{i2kn}	The score of the BO_n at alternative k for the TOIF i_2 ($i_2 = 1,\ldots,I_2$)
TOIF'_{i2kn}	Weighted score of the BO_n at alternative k for the TOIF i_2
I_2	Total number of factors included in this category (in our case 3)
$w_{i2,n}$	The weight of importance of i_2 criterion for BO_n
$\mathrm{OTOIF}'_{i2,k}$	Overall (compound) score of TOIF_{i2} at alternative k
RMIF_{i3kn}	The score of the BO_n at alternative k for the RMIF i_3 ($i_3 = 1,\ldots,I_3$)
RMIF'_{i3kn}	Weighted score of the BO_n at alternative k for the RMIF i_3
I_3	Total number of factors included in this category (here 3)
$w_{i3,n}$	The weight of importance of i_3 criterion for BO_n
$\mathrm{ORMIF}'_{i3,k}$	Overall (compound) score of RMIF_{i3} at alternative k
ROIF_{i4kn}	The score of the BO_n at alternative k for the ROIF i_4 ($i_4 = 1,\ldots,I_4$)
ROIF'_{i4kn}	Weighted score of the BO_n at alternative k for the ROIF i_4
I_4	Total number of factors included in this category
$w_{i4,n}$	The weight of importance of i_4 criterion for BO_n
$\mathrm{OROIF}'_{i4,k}$	Overall (compound) score of ROIF_{i4} at alternative k
TF_{i5kn}	The score of the BO_n at alternative k ($n = 1,\ldots,N$ and $k = 1,\ldots,K$) for the TF i_5 ($i_5 = 1,\ldots,I_5$)
TF'_{i5kn}	Weighted score of the BO_n at alternative k for the TF i_5
I_5	Total number of factors included in this category
$w_{i5,n}$	The weight of importance of i_5 criterion for BO_n
$\mathrm{OTF}_{i5,k}$	Overall (compound) score of TF_{i5} at alternative k
Group (c) of expressions	
OFTF_{kn}	Overall score of FTF category of BO_n at alternative k
$W_{\mathrm{OFTF},n}$	The weight of importance of FTFs category of BO_n with respect to other BOs of FTF category
OFTF'_{kn}	Weighted overall score of FTFs category of BO_n at alternative k
OFTF'_{k}	Overall (compound) score of FTFs category at alternative k
OTOIF_{kn}	Overall score of TOIFs category of BO_n at alternative k
$w_{\mathrm{OTOIF},n}$	The weight of importance of TOIFs category of BO_n with respect to other BOs of TOIF category.
OTOIF'_{kn}	Weighted overall score of TOIFs category of BO_n at alternative k
OTOIF'_{k}	Overall (compound) score of TOIFs category at alternative k
ORMIF_{kn}	Overall score of RMIFs category of BO_n at alternative k
$w_{\mathrm{ORMIF},n}$	The weight of importance of RMIFs category of BO_n with respect to other BOs of RMIF category
ORMIF'_{kn}	Weighted overall score of RMIFs category of BO_n at alternative k
ORMIF'_{k}	Overall (compound) score of RMIFs category at alternative k
OROIF_{kn}	Overall score of ROIFs category of BO_n at alternative k
$w_{\mathrm{OROIF},n}$	The weight of importance of ROIFs category of BO_n with respect to other BOs of ROIF category
OROIF'_{kn}	Weighted overall score of ROIFs category of BO_n at alternative k
OROIF'_{k}	Overall (compound) score of RMIFs category at alternative k
OTF_{kn}	Overall score of TFs category of BO_n at alternative k
$w_{\mathrm{OTF},n}$	The weight of importance of TFs category of BO_n with respect to other BOs of TF category
OTF'_{kn}	Weighted overall score of TFs category of BO_n at alternative k
OTF'_{k}	Overall (compound) score of TFs category at alternative k
W_{OFTF}	The weight of importance of FTFs category with respect to rest of categories
W_{OTOIF}	The weight of importance of TOIFs category with respect to rest of categories
W_{ORMIF}	The weight of importance of RMIFs category with respect to rest of categories
W_{OROIF}	The weight of importance of ROFs category with respect to rest of categories
W_{OTF}	The weight of importance of TFs category with respect to rest of categories

The target for EO's management is to select the optimum BL to be involved as well as the optimum time and mode to implement business activity.

See Fig. 7.

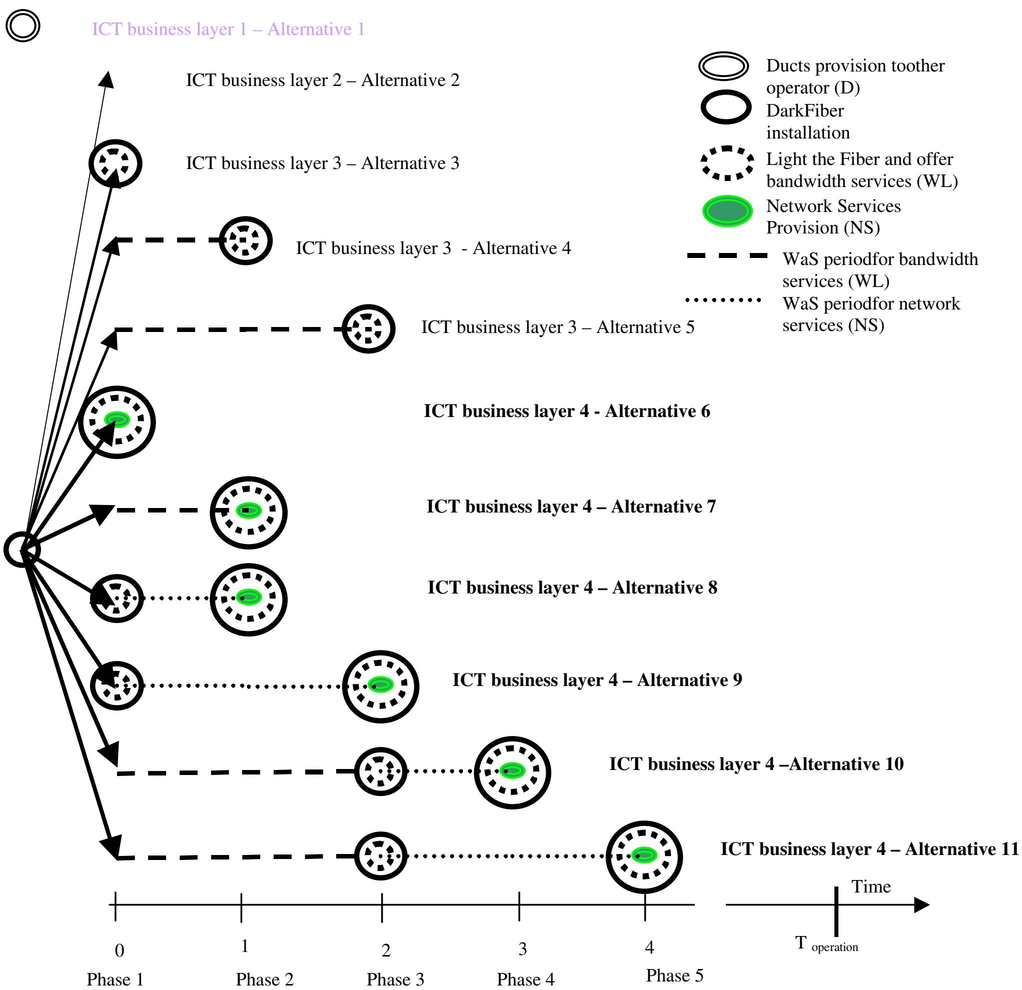


Fig. 7. Alternative business deployment strategies for Egnatia Odos S.A.

Appendix E

See Table 2 and 3.

Table 2
Alternatives prioritisation for each perspective of analysis applying AHP with Expert Choice

Scenario	Total	FTF (ENPV)			Scenario	WRMIF	0.2	0.3	0.5
		$\sigma v = 20\%$	$\sigma v = 40\%$	$\sigma v = 60\%$		Total D	DF	WL	NS
SIF					*RMIF*				
					Alt.1				
					Alt.2				
Alt.3	0.116	0.11	0.08	0.06	Alt.3	0.04	0.11	0.06	
Alt.4	0.116	0.05	0.08	0.09	Alt.4	0.06	0.11	0.12	
Alt.5	0.116	0.06	0.09	0.11	Alt.5	0.08	0.11	0.18	
Alt.6	0.109	0.23	0.17	0.12	Alt.6	0.07	0.11	0.06	0.06
Alt.7	0.109	0.09	0.10	0.10	Alt.7	0.10	0.11	0.11	0.09
Alt.8	0.109	0.16	0.14	0.13	Alt.8	0.08	0.11	0.05	0.09

(*continued on next page*)

Table 2 (*continued*)

Scenario	Total	FTF (ENPV)			Scenario	WRMIF	0.2	0.3	0.5
		$\sigma v = 20\%$	$\sigma v = 40\%$	$\sigma v = 60\%$		Total D	DF	WL	NS
Alt.9	0.109	0.15	0.14	0.13	Alt.9	0.12	0.11	0.05	0.16
Alt.10	0.109	0.08	0.11	0.13	Alt.10	0.19	0.11	0.19	0.22
Alt.11	0.109	0.08	0.11	0.13	Alt.11	0.27	0.11	0.19	0.38
	WTOIF	0.2	0.3	0.5		WROIF	0.2	0.3	0.5
	Total D	DF	WL	NS		Total D	DF	WL	NS
TOIF					*R0IF*				
Alt.1					Alt.1				
Alt.2					Alt.2				
Alt.3	0.058	0.15	0.09		Alt.3	0.07	0.11	0.17	
Alt.4	0.040	0.10	0.07		Alt.4	0.05	0.11	0.08	
Alt.5	0.041	0.08	0.08		Alt.5	0.04	0.11	0.05	
Alt.6	0.213	0.13	0.14	0.29	Alt.6	0.28	0.11	0.19	0.41
Alt.7	0.128	0.1	0.11	0.15	Alt.7	0.14	0.11	0.11	0.18
Alt.8	0.169	0.14	0.14	0.2	Alt.8	0.16	0.11	0.16	0.18
Alt.9	0.131	0.14	0.14	0.13	Alt.9	0.13	0.11	0.15	0.12
Alt.10	0.101	0.08	0.11	0.10	Alt.10	0.07	0.11	0.05	0.07
Alt.11	0.119	0.08	0.11	0.14	Alt.11	0.06	0.11	0.05	0.05
WSIF	0.3								
WOFTF	0.2								
WOTOIF	0.3								
WORMIF	0.1								
WOROIF	0.1								

Table 3
Alternatives prioritization according to overall business utility as well as ENPV

	$\sigma v = 20\%$	$\sigma v = 40\%$	$\sigma v = 60\%$				ENPV				
							$\sigma v = 20\%$	$\sigma v = 40\%$	$\sigma v = 60\%$		
Alt.6	0.184	0.172	0.163	WSIF	0.3	Alt.6	56.23	56.23	56.23		
Alt.8	0.138	0.134	0.132	WOFTF	0.2	Alt.8	37.95	46.72	57.7		
Alt.9	0.126	0.124	0.123	WOTOIF	0.2	Alt.9	36.84	45.96	59.75		
Alt.7	0.115	0.117	0.117	WORMIF	0.1	Alt.10	19	37.15	59.25		
Alt.11	0.110	0.117	0.121	WROIF	0.2	Alt.11	18.77	37.13	60.23		
Alt.10	0.102	0.108	0.112			Alt.7	22.04	33.74	46.4		
Alt.3	0.087	0.081	0.077			Alt.5	14.46	29.18	49.06		
Alt.5	0.070	0.075	0.079			Alt.3	26.3	26.3	26.3		
Alt.4	0.068	0.073	0.075			Alt.4	12.93	25.38	39.55		
Alt.6	0.177	0.165	0.156	WSIF	0.3	Alt.6	0.196	0.177	0.165	WSIF	0.2
Alt.8	0.139	0.135	0.133	WOFTF	0.2	Alt.8	0.142	0.137	0.134	WOFTF	0.3
Alt.9	0.127	0.124	0.123	WOTOIF	0.3	Alt.9	0.131	0.126	0.125	WOTOIF	0.2
Alt.11	0.112	0.123	0.127	WORMIF	0.1	Alt.11	0.107	0.117	0.124	WORMIF	0.1
Alt.7	0.113	0.115	0.115	WROIF	0.1	Alt.7	0.113	0.116	0.117	WROIF	0.2
Alt.10	0.104	0.11	0.115			Alt.10	0.098	0.108	0.114		
Alt.3	0.085	0.079	0.075			Alt.3	0.086	0.077	0.071		
Alt.5	0.070	0.075	0.079			Alt.5	0.064	0.072	0.079		
Alt.4	0.067	0.072	0.074			Alt.4	0.062	0.069	0.072		

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