INVESTMENT ANALYSIS IN R&D AIR TRAFFIC MANAGEMENT USING DECISION ANALYSIS TECHNIQUES; STANDARD PRACTICES IN EUROPEAN PROJECTS

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***Abstract*— R&D managers throughout the world are continually faced with a series of decisions as to; how to select the most appropriate projects from several competing proposals; how best to evaluate a project during its execution?; how best to make use of available knowledge about the project to forecast a project failure and initiate its early closure to prevent further drain of resources?. Due to their inherent complexity and uncertainty, R&D projects are not easily amenable for performance measurement. As R&D is companies´ key investment into their futures it is important to be able to measure R&D process through all its stages. This paper explains the techniques that will help Decision Makers to do that and to increase the insight in the decision. In R&D ATM the use of the European Model for Air Traffic Management Strategic Investment Analysis and promptly the use of the Cooperative Approach for Air Traffic Services Business Case within the European Operational Concept Validation Methodology have highlighted the need to include Decision Analysis techniques in the analysis. These are Economic Modeling, Decision Trees, Influence Diagrams, Sensitivity and Probabilistic Analysis and multi criteria analysis, all of them help the analyst to understand the key uncertainties of a project, to concentrate in the critical variables that affect the decision, to understand the risk associated to the project and to minimize the cost of performing the analysis.**

Keywords- Investment, Probabilistic, Risk, Uncertainty, Sensitivity, Valuation, Cost Benefit Analysis, Business Case, EMOSIA, CAATSII

I. INTRODUCTION

As R&D is companies´ key investment into their futures it is important to be able to measure R&D process through all its stages. This paper intends to establish the basic techniques that will help stakeholders to assess the overall R&D process in a consistent way.

Whereas we wish to see R&D as an investment into our companies´ futures, in fact it is often seen as a cost. Demonstrating the value of this investment requires convincing evidence of short and long term business impact, based on credible data.

The difficulty is that this business impact is usually indirect and hard to quantify. R&D creates and pulls together new technologies and ideas, and thereby contributes new and better products, processes, and services. It acts as an integrator of knowledge and technology, combining scouting, negotiating, and management skills. Impact relates as much to the unnoticed elimination of inappropriate paths as to the parameters of the individual technologies and products that emerge. The time lag between investing in people, capabilities and knowledge, and obtaining tangible results is often considerable.

Too often, at the completion of a project, management may realize that the market no longer exists, or the technology is obsolete, or the original purpose no longer fit the current business strategy.

There is, by definition, an in-built tension between running today's business well and preparing for an uncertain future, but it is important to point out that future is the scenario where the value is created. The R&D process itself is viewed as an information conversion process in which the organization attempts to move from uncertainty in technology and requirements to the certainty of an introduction product.

And there is an inherent non-diversifiable risk associated with the use of technologies whose technical readiness is not fully developed, or whose degree of integration is still incomplete. Projects show a technological risk profile that will be mapped using the TRL (Technology Readiness Level) status of the different technologies involved. Managing the project risk profile can lead tangible benefits: establish ad-hoc discount rates, prioritize investment within the project, help make the appropriate go / no-go / hold decisions and provide both a project baseline and an indicator as to the degree of readiness achievement.

The term economic value creation has a specific meaning; it refers to the task of determining the monetary worth of an asset, object or entity. Economic assessment seeks to answer a fundamental question: "What is it worth?"

Determining the inherent value of a share of common stock, a traditional valuation problem, is difficult, but valuing technology is even tougher. Technology may exist as intellectual capital and not even be visible on the corporate balance sheet; it may be embedded in physical assets that are valued on the basis of historic cost and do not reflect technology's wealth-creating potential.

There is a growing recognition that the worth of a business cannot be determined without recognizing the value of its technology. At the same time, the people who develop technology are increasingly aware that they must estimate the future value of their output if they are to acquire the resources needed to turn proposals into programs. As per managers, value-based management leads to effective decision making. Focus on value also ensures a clear and common vocabulary for corporate communications.

To face with problems of decision, R&D managers are to select the most appropriate technology projects from several competing proposals, and evaluate projects during its execution with any sources of documentation and according to established processed, guidelines and best practices.

The Decision Analysis techniques described in this paper will increase the insight in the valuation of the technology. These techniques are Economic Modelling, Decision Trees, Influence Diagrams, Sensitivity and Probabilistic Analysis and Multi Criteria Analysis; all of them help the analyst to understand the key uncertainties of a project, to concentrate in the critical variables that affect the decision, to understand the risk associated to the project and to minimize the cost of performing the analysis.

In R&D ATM the use of the European Model for Air Traffic Management Strategic Investment Analysis (EMOSIA) and promptly the use of the Cooperative Approach for Air Traffic Services (CAATS) Business Case within the European Operational Concept Validation Methodology (E-OCVM) have highlighted the need to include Decision Analysis techniques in the analysis.

II. DECISION ANALYSIS

Decision Making is a complex thing in life. True decision making occurs not when you already know exactly what to do, but when you do not know what to do. When you have a balance conflicting values, sort through complex situations, and deal with uncertainty, you have reached the point of true decision making. This paper explains some tools of decision analysis.

Decision Analysis functions [1] at four different levels are 1) a philosophy, 2) a decision framework, 3) a decision-making process, and 4) a decision-making methodology.

1. As a philosophy, decision analysis describes a rational, consistent way to make decisions. It provides decision-makers with two basics, invaluable insights: the first insight is that uncertainty is a consequence of our incomplete knowledge of the world; the second basic insight is that there is a distinction between good decisions and good outcomes.

2. As a framework for decision making, decision analysis provides concepts and language to help the decision maker.

3. As a decision making process, decision analysis provides a step by step procedure that has proved practical in tackling even the most complex problems in an efficient and orderly way.

4. As a methodology, decision analysis provides a number of specific tools that are sometimes indispensable in a analysing a decision problem. It is a common mistake to confuse decision analysis with constructing and manipulating influence diagrams and decision trees. The real contribution and challenge of decision analysis occur at the much more general level of defining the problem and identifying the true decision points and alternatives. Nonetheless, obtaining a full understanding of the philosophy and framework of decision analysis requires some familiarity with the tools.

III. UNCERTAINTY

"If a man will begin with certainties, he shall end in doubts; but if he will be content to begin with doubts, he shall end in certainties". (Sir Francis Bacon)

Whenever possible the assessment of costs and benefits will rely on quantitative data analyses using existing data and/or tools such as simulation models. Expert judgement on benefits and costs will be used when these data are not available or to fill gaps in knowledge.

However, most data about things to happen in the future is uncertain by definition. The treatment of these uncertainties conveys that:

- Uncertainty is a consequence of our incomplete knowledge of the world
- To deal with uncertainty we use ranges and probabilities
- Probability is the quantitative language for communication about uncertainty

The assessment of costs and benefits will include consistent information about its uncertainty (and confidence). For example, if the assessment is entirely based on judgement by one expert, the level of confidence is lower than if the assessment is backed by relevant fast simulation analyses. If the assessment has already reached a level of detail where probability distributions are used, confidence intervals will have to be provided.

Modelling the uncertainty in the cost and benefit outcomes can be done following a simple procedure. In order to characterize uncertain variables [2] for a deterministic sensitivity analysis, experts will be asked to assign three point ranges to the uncertainties as follows:

- Lower bound: there is only a 10% chance the actual outcome would be lower
- Base case: there is a 50/50 chance that the actual outcome would be higher or lower
- Higher bound: there is only a 10% chance the actual outcome would be higher

The expert judgement on the ranges for these uncertainties will be revisited (following the iterative nature of the overall process) in order to provide further detail and make it more precise. Often, the resulting probability distribution in this phase does not correspond to the distribution that would be obtained by simply using the quick range information provided in the first iteration.

Uncertainty variables should be included relating to:

- Time
- Costs
- Benefits units and drivers

Some sources of uncertainty identified in ATM [3] are:

- Lack of understanding about market risks
- Incomplete specifications
- Poorly defined technology
- Optimism regarding projects
- Under-estimating technical solution complexity
- Inexperienced team, resulting in cost overruns and late schedule
- Poor management practices
- Unreliable funding
- Obsolescence and cost of re-design
- Cost to implement and train staff in new processes

Consequences of Not Assessing Uncertainty:

- Point estimates often lead to unwelcome surprises
- Insufficient funds and management attention are provided for risk abatement
- Insufficient funds and management attention are given to opportunity capture
- Project may be improperly managed
- Cost overrun
- Schedule delay
- Unimaginative solutions, not ‘best of industry’
- Projects and contracts may be improperly bid

IV. DECISION TREES

It is a type of tree-diagram used in determining the optimum course of action, in situations having several possible alternatives with uncertain outcomes. The resulting chart or diagram (which looks like a cluster of tree branches) displays the structure of a particular decision, and the interrelationships and interplay between different alternatives, decisions, and possible outcomes [4] i.e. it represents all the different combinations of events that can occur and their probabilities.

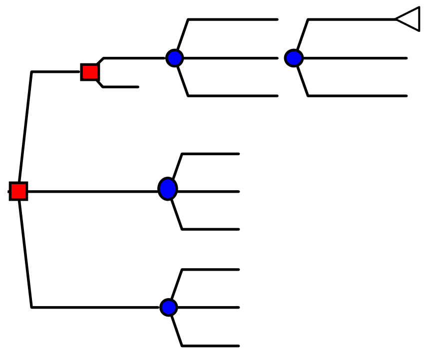

Figure 1 Decision Tree Example

A decision Tree consists of 3 types of nodes:

- Decision nodes - commonly represented by squares
- Chance nodes - represented by circles
- End nodes - represented by triangles

Decision trees in ATM are used generally in Investment Analysis, Operation planning, Conflict resolution [5], human Factors issues and Safety analysis.

V. Influence Diagrams

An influence diagram is a graphical representation that shows all the variables that impact the value of a project. Influence diagrams are composed of a number of graphical elements or shapes known as nodes. In ATM influence diagrams highlight the relationships between elements as cost/revenue structure of airlines [6]. Each of the four types of nodes represents a specific type of information as shown in the example of figure 1.

There are four types of nodes:

- Value – contains instructions for how to calculate the value of the project in various stages
- Deterministic – expresses constant values or equations combining other variables
- Uncertainty – expresses a lack of knowledge concerning the distribution of the variable
- Decisions – include the quantities with one or more possible outcomes which can be manually controlled

Each influence diagram highlights:

- The inputs required for the analysis versus the functions used to calculate cost and benefit and to describe the timing of the costs and benefits
- The uncertainties and where they fit in to the analysis model
- The inter-relationships between all the variables (inputs and calculations based on inputs)

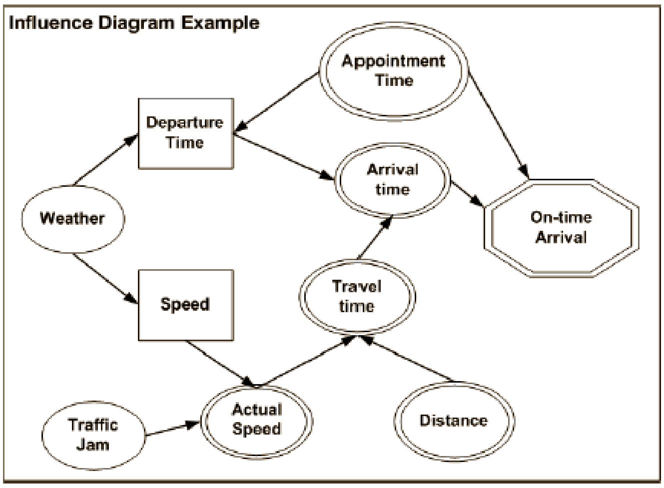

Figure 1 Influence diagram Example

Influence diagrams provide:

- A deterministic evaluation of the project by identifying the most critical variables and displaying them in a Tornado diagram
- A probabilistic evaluation of the project by assessing probability distributions of the critical uncertainties

VI. Sensitivity Analysis

Sensitivity analysis examines the sensitivity of the project's economic performance, its cots and benefits, to the variation of individual parameters in order to identify the most critical issues and the degree of their impact.

The most significant parameters to be considered in the conduct of a sensitivity analysis will vary from project case to project case and cannot be brought in advance.

The results of a sensitivity analysis are usually presented graphically. Tornado Graphs are the standard tool for this purpose.

A Tornado Graph compares the results of multiple analyses. The X-axis is drawn in the units of the expected value (typically NPV), and then for each variable (listed on the Y-axis), a bar is drawn between the extreme values of the expected value calculated from the lower and upper bound values. See the following picture for an illustration. The variable with the greatest range is plotted on the top of the graph, and the remaining variables proceed down the Y-axis with decreasing range. The longest bar in the graph is associated with the variable that has the largest potential impact on expected value, and thus needs careful attention.

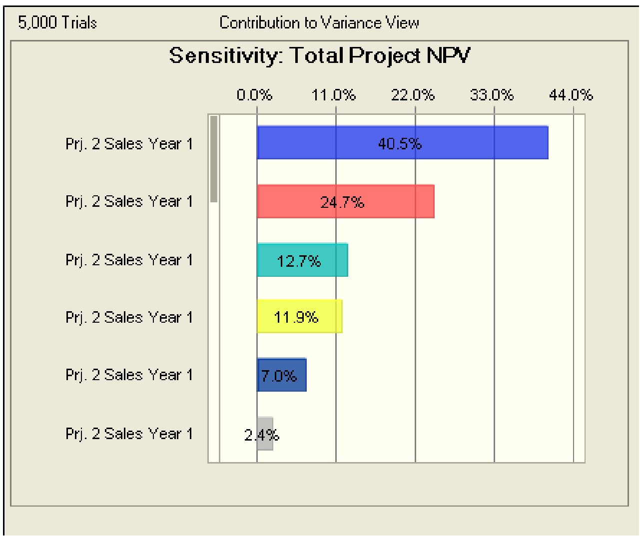

Figure 2 Tornado diagram Example

The Tornado graph brings attention to the variables that require further attention. In most real projects, the Pareto rule will happen, as 20% of the variables will typically account for 80% of possible expected value excursion.

VII. PROBABILISTIC ANALYSIS

Probabilities represent our state of knowledge. They are a statement of how likely we think an event is to occur.

Probabilistic Risk analysis provides the probability distributions of output magnitudes. The decision-maker can then have a complete picture of all the possible outcomes.

These probability distributions can then be used to perform different assessments:

- Determine a correct range for the results
- Identify probability of occurrence for each possible outcome

As a result, it is easy to get an overview of the risks involved and a feeling for how they should be addressed.

The uncertainties of the model have to be carefully assessed in order to get the results as reliable as they can be.

The following picture shows a typical probabilistic distribution (87.53% of positive NPV):

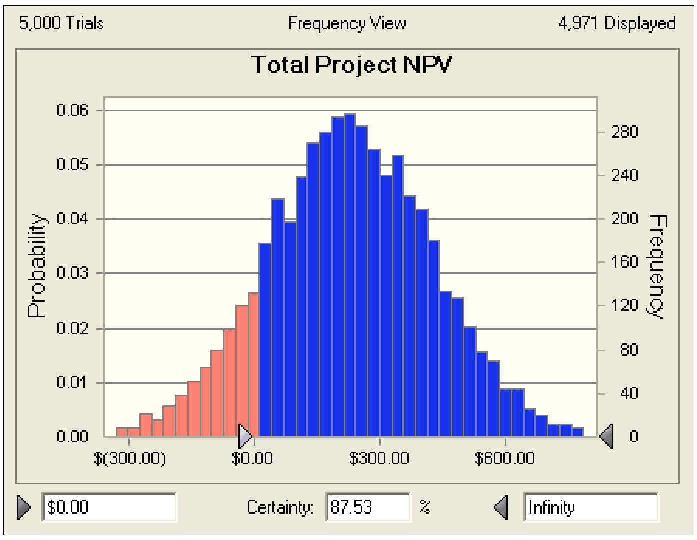

Figure 3 Probabilistic diagram

VIII. MULTI-CRITERIA ANALYSIS

The multi criteria analysis (MCA) [7] techniques support comparison of different alternatives on the basis of a set of criteria.

Multi Criteria Analysis (MCA) is a new approach for complex systems like the ones in ATM. MCA can handle all concurrent goals (e.g. cost, performance, vulnerability and complexity) in a much more efficient and holistic manner, and these can remain in their own native figure of merit. It is a much more efficient methodology since it yields results that are closer to the optimal, and allows experts to make contributions within their domain of knowledge, without having to strive with the specifics of other domains or the general methodology.

The recent developments in ATM put more emphasis on the use of MCA techniques for performing Business Cases, which seems sensible considering the value of MCA for impact assessments in addition to the Cost Benefit Analysis (CBA).

IX. METHODOLOGIES FOR ATM

A. *EMOSIA*

In 2003, the European Organisation for the Safety of Air Navigation (EUROCONTROL) and Boeing Air Traffic Management signed a contract to develop models to support the economic evaluation of Air Traffic Management investments. Air Traffic Management, with help from decision consultants from Boeing Commercial Airplanes (BCA) and the Boeing Research & Technology Europe (BRTE) in Madrid, worked with EUROCONTROL and stakeholders to meet the following objectives:

- To develop methods and support tools for the economic evaluation of all lifecycle phases of the ATM improvements and
- To develop a collaborative process for economic evaluations that ensures stakeholder ownership of the results.

The result of this cooperation in solving the challenges facing the air traffic system has been the EMOSIA Cost Benefit Analysis [8]. It is analytical tool developed together with the European ATM/CNS community that provides a common approach for Cost-Benefit Analyses of European ATM investments. Models were built using Influence Diagrams which were designed to determine where and how it is the best to invest resources in a project.

EMOSIA models were developed in collaborative process and emphasise the importance of stakeholder segmentation as ATM projects require investment by different groups, and costs and benefits can be differently distributed among: service providers, airlines, airports, and military and general aviation.

- Focus segments for which economic evaluations will be conducted (i.e., airspace users and air navigation service providers (ANSPs)).
- Contributing segments that are considered to have complete coverage of costs and benefits (e.g., regulatory authorities, organisations that coordinate and plan programs, R&D organisations) and/or segments that can contribute information to estimate costs and benefits (e.g., equipment manufacturing industries).

EMOSIA illustrated in the Figure 4 below is a platform for making informed decisions on ATM/CNS investments and ensures that all involved parties speak the same language when deciding. The overall aim is to guarantee that the decisions are the best possible taking into account all stakeholders' perspectives. Among various factors influencing decisions on strategic investments, it is important to understand uncertainties and their significance.

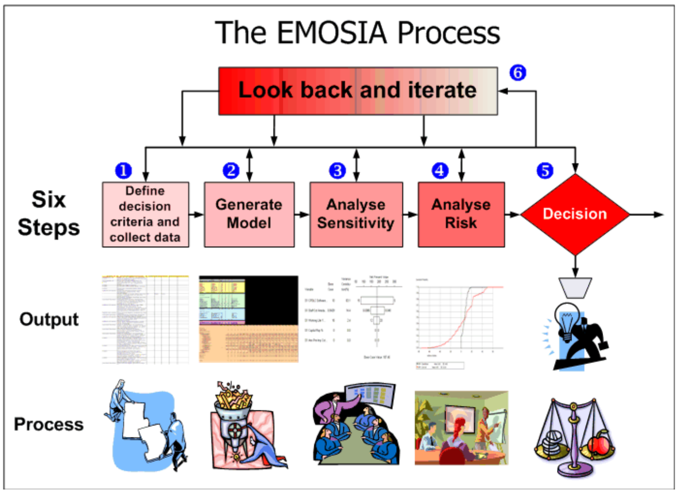

Figure 4 EMOSIA Process

EMOSIA uses standard tools along with six steps iterative process (i.e., ID, spreadsheets, sensitivity analysis graph (Tornado diagram) and risk analysis graph (i.e., cumulative probability curve).

B. THE CAATS BUSINESS CASE

The Cooperative Approach to Air Traffic Services I and II (CAATSI and CAATSII) were Sixth Framework Programme projects funded by the European Commission. The work conducted was to manage, consolidate and disseminate the knowledge gathered in European ATM-related projects. One of the main outcomes of the project were good practice manuals and typical guidelines material called "cases" in the area of Business and has been integrated in the E-OCVM [9]. The aim is to provide a coordinated approach to avoid overlapping and gaps in R&D projects and to achieve a paradigm shift in European ATM-related projects, especially FP6th projects. The CAATS Business Case intents to propose the most appropriate solutions in investment analysis and Decision Making for the Single European Sky Air Traffic Management Research (SESAR) program [10].

1) The E-OCVM

CAATS I project team identified as the best validation methodology given its applicability to the project lifecycle phases. In this framework, the stakeholders cooperate to follow the progress of the ATM Operational Concept (OC). An OC is a potential solution for a problem identified in the ATM system. The development of an ATM OC has a lifecycle in which the concept undergoes a maturity process evolution. The E-OCVM focuses on describing the type of information that should be expected from the validation process and how this information should be structured to ensure that stakeholders could access and understand it. The objective of CAATS II coordination action team focused on four areas namely safety, human factors, business and environment. On the basis of the good practices identified for these areas, the intention has been to develop 'cases' that can be integrated in the E-OCVM. Figure 5 below represents the Business Case as the focal point of the performance assessment within the E-OCVM Lifecycle phases.

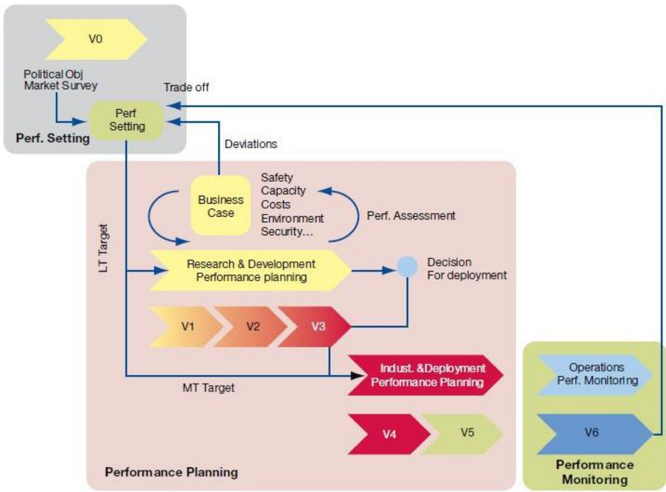

Figure 5 The Business Case and the performance assessment

The E-OCVM is the framework where each of the considered disciplines to be validated should be integrated. The result should be an integrated set of "cases" with the complete picture of advantages and barriers for the further development of the concept to be presented to the stakeholders and decision makers. As part of validation process, the contribution that each element of the plan will have on performance will be verified. Potential deviations from planned performance are detected and predicted as early as possible. Information regarding such raising deviations is made available to the group of experts dealing with performance in order to initiate a trade off across the difference performance areas. Performance Assessment results (e.g., Safety, Environment) together with the expected benefits is consolidated into a Business Case by a 'Business Case Group' where all stakeholder groups are represented. In the next point of this paper an overview of the Business Case is presented.

2) The Business Case Methodology overview

The Business Case is a support tool to the Decision Makers for the assessment of investment decisions. In particular, Business Case is gaining an increasing importance within ATM, given that it will involve large expenditure, to be realized by many states in order to materialize new OC and provide new infrastructure. The CAATSII team has developed a comprehensive Business Case approach which specifically targets the needs of ATM Stakeholders. The Guidance Material for a Typical Business Case aims to explain the role of the Business Case in ATM context and to provide a guide for building a Business Case [11]. This document is also supported by the Good Practices [12] document which provides recommendations for developing a Business Case and sources of references. All together, these documents will make the development of a Business Case a no-pain task with a very fast learning curve and consistent outputs. The Guidelines and Good Practices documents seek to address the types of problems associated with the analysis of ATM, like:

- the many different stakeholders affected by changes and the complexity
- the lack of consensus in the way in which to approach qualitative benefits
- Need for a standardization process for a Business Case approach
- the considerable effort and cost associated with full, detailed analysis of major changes to the aviation system

The Business Case goes beyond a Cost-Benefit Analysis (CBA), which is understood here as the assessment of costs and benefits translated in monetary terms. It helps to prepare the required evidence for stakeholders by assessing potential impacts from a multi-criteria perspective (e.g., typically safety, environment, human factor), including synergies and trade-offs (e.g., use of Multi Criteria Decision Analysis techniques) [13]. The assessment can range from qualitative to quantitative impact whenever possible.

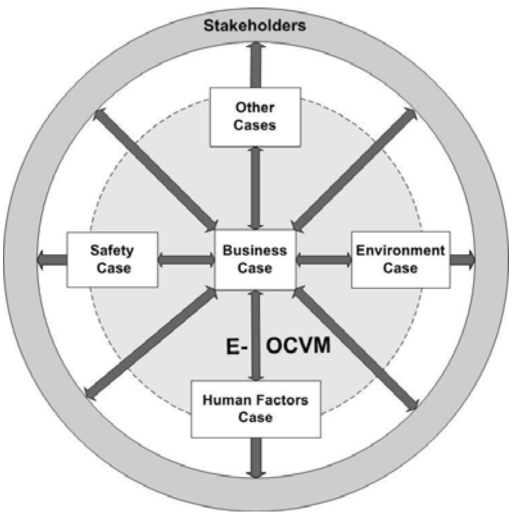

Figure 6 - The Business Case Multi perspectives

The guidelines are intended to provide a generic framework in four Key Steps 1) Scope and Framing, 2) Define Option/ Alternatives 3) Analysis and 4) Follow up that can be applied for conducting different Business Cases, and do not describe in detail how to assess any particular project. First, Business Case provides support techniques to assist decision-makers, recognizing that there are always benefits which cannot be economically valued; Second, Business Case can be applied at all stages of a project/program Lifecycle and has value in planning the timing and direction of a project, rather than simply deciding whether or not to implement a project/program; Lastly, Business Cases can be applied at different stages of a program, ranging from scoping studies to highly detailed analyses. The stages are sequential and the results of each stage can be reviewed before deciding if further work is required.

X. CONCLUSIONS

The Decision Analysis techniques described in this paper will increase the insight in the valuation of technology. It will help the analyst to understand the key uncertainties of a project, to concentrate in the critical variables that affect a decision, to understand the risk associated to a project and to minimize the cost of performing an analysis.

As a methodology, decision analysis provides a number of specific tools that are sometimes indispensable in analysing a decision problem. It is important to understand that we need to deal with uncertainty. Uncertainty is a consequence of our incomplete knowledge of the world.

The tools depicted are:

Decision Tree: it represents all the different combinations of events that can occur and their probabilities.

Influence diagram: a graphical representation that shows all the variables that impact the value of a project.

Sensitivity Analysis: Sensitivity analysis examines the sensitivity of the project's economic performance, its cots and benefits, to the variation of individual parameters in order to identify the most critical issues and the degree of their impact.

Probabilistic Analysis: Probabilistic Risk analysis provides the probability distributions of output magnitudes. The decision-maker can then have a complete picture of all the possible outcomes.

Also, we emphasize that in R&D ATM EMOSIA and promptly the use of the CAATS Business Case within the E-OCVM have highlighted the need to include Decision Analysis techniques in the analysis.

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