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A Decision Support System for Investment Evaluation in Information Systems / Information Technology in Public Administration Organisations

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1 Introduction

In a permanently changing world, everyone needs to take quick decisions. This is also true for the Portuguese public administration, where managers need to take fast and complex decisions regarding investments in new information systems or technologies.

The human factor is the most important of our society, but computer programs, databases, networks, telecommunication networks, fax machines, mobile phones, and other technological innovations at both organisational and individual levels, as well as scientific findings are continuously transforming the way organisations operate.

This transformation is taking place through several elements, such as the usage of information as a production-oriented resource and, from an organisational standpoint; both public and private institutions are experiencing an increase in the use of a variety of information technologies. Nowadays, it is nearly impossible for an organisation to operate without the use of one or more information technologies. Therefore, technology plays an important role in the way we communicate, work, play, and do business.

Today, almost all organisations, and the Portuguese public administration is no exception, need to invest financial resources in new technologies or information systems. However, the public administration usually has financial restrictions, so, some investments in technology are too costly for the financial possibilities of the Portuguese public organisations. Apart from the reduced budgets there are also other difficulties, such as the need for providing better service with reduced staff; constraints of legal and regulatory, contractual, personnel and institutional nature; sometimes public organisations are forced to render services to citizens entitled by law to receive this services. Besides these difficulties, there are also technological problems that managers fail to identify, such as the importance of the investment in backup robot technology to avoid information losses. There are other problems that public organisation managers must pay attention, such as the information system security, technological park maintenance, and so on. As investments in new technologies or information systems are essential nowadays, it is extremely important to help public administration decision makers in their IS/IT investment decisions.

The managers could use Decision Support System (DSS) to back their process of decision on IS/IT investment projects. However, such systems incorporate multiple variables and conditions on the process-oriented aspects of decision-making, and investment projects usually have multiple and mutually conflicting objectives, such as political interests or society pressing, making it important to evaluate all available alternatives and to determine preferable strategies, which better suit a sustainable investment project. In order to evaluate the different alternatives for a decision, taking into account several criteria, there are multi-criteria analysis methods, such as Analytical Hierarchy Process (AHP), which have been used to deal with benefit and cost analysis by government agencies for resource allocation (Chiou et al., 2005). This multi-criteria decision-making method provides a logical and scientific basis to decision-making in which pairwise comparisons of components are made according to a common goal or criteria (Harker, 1988, op. cit. Philips-Wren, 2004). According to Huang et al. (2004) "AHP provides a flexible and easily understandable way of analyzing project risks. It is a multi-criteria decision-making methodology that allows subjective as well as objective factors to be considered in project risk analysis".

Thus, we could use the AHP method as a complement of the DSS tool. This method is recommended in this research to provide increased value when supporting decisions on IS/IT investment projects, since it allows handling both tangible (quantitative and qualitative) and intangible factors that influence the IS/IT investment decisions, as well as the financial analysis techniques included within the DSS.

This document is organized as follows:

- The first chapter presents the introduction of the research question and the hypothesis for this thesis;
- The second chapter includes literature review on decision support systems;
- The third chapter introduces the MAIS – Metodologia de avaliação de investimentos, Serrano et al (2004). It is an evaluation investments methodology based on the strategic alignment, benefits management, risk analysis and financial analysis method for investments analysis;
- The fourth chapter introduces the AHP - Analytical Hierarchy Process as well as a newly developed enhancement for the AHP inconsistency problems;
- The fifth chapter discusses how to use the AHP for evaluating investment decisions;
- The sixth chapter presents the DSS model (MAIS+AHP), which could be used by the Portuguese public administration for evaluating IS/IT investments;
- The seventh chapter, discusses the convenience of this study for the Portuguese public administration;

- The eighth chapter presents a summary and this study's contribution for the literature;
- And finally the overall conclusion of the study.

1.1 Research question and hypothesis

The previous section presents some of the problems and difficulties, that Portuguese public administration managers face when they intend to invest in IS/IT projects, such as the financial restrictions, the reduced staff and the legal and regulatory constraints. The attempt of finding an answer for the resolution of these problems leads us to the research question for this study, which involves the contribution of decision support systems to the IS/IT investments' decision:

- What may be done to help Public Administration Managers regarding IS/IT investment decisions?

In order to comprehend the various issues related to the investment decisions involving information systems technologies in the Portuguese public administration, this study addresses the following areas:

- The needs for investment in IS/IT;
- Decision Support systems to help decision makers with IS/IT investment decisions;
- Analysis tools that may help taking investment decisions involving IS/IT;
- The model framework for evaluating IS/IT investments.

The research question leads to the research hypothesis:

- A Decision Support System (DSS) may help managers of the Public Administration to take better decisions regarding investments in IS/IT.

1.2 Problem statement

The problems facing public administration chief officers in their efforts to make choices in IS/IT investments are extensive and various. For example, there is no customized model to these organisations' specific issues and needs to be followed or consulted when evaluating an investment. As far as this problem is concerned, one question arises: Why is a model for decision support regarding IS/IT investments so important?

A model for decision support regarding IS/IT investments is important because it may be used to assess business initiatives as a vehicle for experimentation, often in analyzing IS/IT proposals and estimating their likely effects. The proposals producing the best financial and technical results, according to the model, should be the choices (acquisitions) of the organisation. Therefore, the decision support based on the simulation of IS/IT proposals has the objective of helping managers to get the best IS/IT investment for the organisation.

Obviously, each organisation is subtly different, even from others in the same field, and no model can completely address all the issues each individual organisation faces. However, what a model may provide is a framework designed to address the issues and needs of a particular process, which are related across organisations in comparable circumstances (Kraemer et al., 1987).

In our research, we did not find a model that included a complete investment analysis tool for evaluating investments on IS/IT for the Portuguese public administration. Such tool would involve financial, quantitative and qualitative analysis, and could help managers deciding the best investment planning.

Nowadays, the investment in technology cannot be postponed and Public Administration has reached a stage, where the use of information technology has become widespread and is an essential component for daily operations and, in the future, all innovative processes will require the usage of technological instruments.

Investment decisions are complex processes due to the vast amount of information about technology in the market, most of them performing the same thing. The wide range of hardware and software makes the search for the best information system or technology a quite difficult selection (high level of risk involved). IS/IT investment evaluation involves a complexity of quantitative and qualitative measures[1] regarding properly balanced, financial and technical issues which influence the choice.

In conclusion, a decision support system model for IS/IT investment might help managers responsible for selecting the correct IS/IT investments project for their organisations.

1.3 Purpose of study

The technological environment has suffered a rapid evolution and is permanently changing. For example, in the last fifteen years, organisations have started with stand-alone computers, but quickly evolved to network models: LAN networks, WAN networks, World Wide Web and the Virtual Private Networks, among others. This diversity, together with the several market vendors, each one with their own system's specificity, does not help the choices of public organisations managers, when they intend to invest in IS/IT projects. Thus, the acquisition process faced by the decision makers is a sequence of tasks that needs to be

[1] The quantitative and qualitative measures are discussed in Chapter 3.

constantly updated due to the rapidly changing nature of both the technologies and the organisational processes. In the process of selecting the best IS/IT investment projects, besides the technological swift changes, most organisations have the following problems:

- The cost of the emergent technology is usually beyond their financial possibilities;
- The previous technologies become easily affordable, but they are so varied that it is difficult to select the best alternative;
- Most of the time, public organisation managers have a lack of technical knowledge.

This work intends to propose the design of a Decision Support System (DSS) to help public organisation chief officers dealing with decisions, regarding the evaluation of IS/IT investment projects, such as the acquisition of new Computer Networks, Computer Server, Databases or to invest in a new Enterprise Resource Planning (ERP). Such DSS is designed to maximize the benefits associated with the investment; foster the investment's alignment with the strategy of the organisation and help managers taking investment decisions considering the following factors:

- Financial requirements of current projects;
- Factors influencing the benefits materialization of each project (Time, Quality and Cost);
- Priority of investments.

This dissertation focuses on Portuguese public administration and on the myriad of issues that managers or decision makers face regarding IS/IT investments. Most of these managers experience significant difficulties in dealing with the acceptable costs and appropriate selection of technologies for their organisations. They also face the uncertainty regarding how organisations will operate in the future and the direction to take has become increasingly important. At this moment, we are at a crossroad regarding information technologies – so many needs, so many choices and limited funds.

Based on what has previously been stated and on other elements, such as political issues, some of the public services are placed on the Internet by government orders. We believe that most Portuguese public organisations must pay greater attention to the acquisition of IS/IT, and in relation to that, it is recommended to evaluate the need to develop a DSS to help decision makers on investment decisions in IS/IT projects.

This work is innovative, since our research found no study evaluating the need for a DSS to help managers in Portuguese public organisations, for tasks such as identifying the best IS/IT investment, evaluating the impact of IS/IT investments, managing IS/IT investments or increasing knowledge and skills. That is why we think it is an important topic since it serves many different functions and it is essential to establish appropriate and effective approaches or methodologies regarding the management of information systems and the use of decision support systems in organisations. Therefore, it is important to study the concept of Management Information Systems (MIS) and Decision Support Systems (DSS).

The MIS focuses on the automation of business activities, especially those of a clerical nature, attempting to provide approaches to deal with the ever- changing problems and situations surrounding all aspects of the information's management (McFarlan and McKenny, 1983).

According to Applegate et al. (1996), the DSS is an Interactive computer-based system that intends to help decision makers using data and models to identify and solve problems and make decisions. The system must aid a decision maker to solve un-programmed, unstructured (or semi-structured) problems. According to Power (2000), DSSs help managers or decision makers in using and manipulating data, applying checklists and heuristics, and building and using mathematical models. The DSS may also be useful in the development of the organisations strategic planning. However, the concept of DSS will be detailed in the chapter 2.

In order to design and develop a decision support system for helping decision makers in selecting IS/IT investments projects, it is necessary to combine decision analysis with traditional investment evaluation approaches. According to Matheson (1968, op. cit. Poh, 2000) decision analysis seeks to apply logical mathematical modelling and structuring of the decision situation, computational implementation of the model and finally, quantitative evaluation and the comparison of the alternative courses of action.

1.4 Topic relevance

The current literature concerning the usage of decision support systems for the acquisition or investment in information technologies, within the Portuguese public sector, is rather vague. Most of the literature focuses on the selection of specific technologies, such as Workflow systems. Therefore, the intention of this work is:

- to provide ground for future studies into the problems surrounding the IS/IT investment in Portuguese public administration.

- to recommend a design for a decision support system based on the following tools:
    - MAIS - Investments Valuation Methodology proposed in 2004 by António Serrano, University of Évora and a team of IIMF - Instituto de Informática from the Ministry of Finance;

  This methodology is an evaluation process supported by an investment evaluation tool, which allows the assessment IS/TI projects investments in towards the strategic alignment, financial viability and risk.

    - AHP – Analytical Hierarchy Process to help evaluating the investments in IS/IT specifically within public administration.

  AHP is a decision method proposed by Saaty (1980); this method provides a mathematically rigorous application and proven process for prioritization and decision-making. By reducing complex decision to a series of pairwise comparisons and then synthesizing the results, decision-makers reach the best decision based on a clear rationale.

- to propose improvements to the AHP model.
- to recommend material to foster:
    - a discussion on Decision Support Systems, which is often glossed over by the organisations' managers;
    - a discussion of management and organisational issues that are directly linked to investments in IS/IT and Public Administration needs.

In the area of benefit management for IS/IT investments, a significant part of the research conducted prior to this study focused on public sector systems and was based on the benefits management proposed by Ward and Murray (2000).

1.5 Public Administration's needs and the challenge of managing IS/IT investments

According to Nijland (2001) "Senior management as well as information systems professionals recognise IS/IT evaluation as one of the important and unresolved concerns in information management (e.g. Farbey et al. 1993, Grembergen and Bloemen 1997)". We feel that IS/IT investments have organisational impacts which are difficult to quantify, and the evaluation of IS/IT investment involves the inherent difficulties of estimating future situations and envisaging possible benefits at some point in the future. Due to difficulty in measuring the intangible benefits, it is also hard to associate perceived benefits directly to the specific IS/IT investment projects.

One of the challenges faced by decision makers is the need to put into practice IS/IT project risk assessment and control the uncertainty of investment results in IS/IT projects. The public organisations managers must think about the benefits of IS/IT investment, as a way of improving quality, avoiding excessive costs and reducing risks, besides bearing in mind the idea that the investment will only be worthwhile if the new IS/IT technological infrastructure is exploited in an effective manner. But such things are hard to quantify and the benefits of an IS/IT investment could depend on the secondary effects that occur due to changes generated by the investment, for example:

- Public services like DGCI[2] could increase the number of users (secondary benefit) by investing in a new and emergent technology (Web

[2] DGCI – Direcção Geral de Contribuições e Impostos

development Services), providing better services (on-line IRS or VAT refunds) for the population (primary benefit).

As well as in the example above the information system improvements for better quality services and the evaluation of investment benefits in IS/IT projects depend most of all on the user's acceptance. The evaluation of IS/IT investment projects is intrinsically subjective, namely based on individual judgements (including political considerations). However, IS/IT investment must be financially justifiable on the grounds of efficiency gains and the evaluation of IS/IT investments should be more focused on effectiveness.

According to Fitzgerald (1998), the objective of effective Investment projects is not only to reduce costs of performing existing tasks, but also to adopt procedures in order to better achieve the desired results. Organisations have to think on how to perform better services for citizens to achieve their desired results. Therefore, the justification for IS/IT investment projects must be based on effectiveness criteria, such as increased functionality, service quality, enhanced public services for the benefit of society, and so on. However, information systems investment projects in public organisations are not likely to have a clear definition for success and failure, and investment goals change over time due to evolving user requirements, which makes IS/IT evaluation and the comparison between prior expectations and eventual outcome difficult, Keen and Scott Morton (1978).

In order to address the problems related to IS/IT evaluation, numerous methods and techniques have been developed to help managing and controlling IT costs and benefits. Most of the IS/IT evaluation literature is devoted to the evaluation of IS/IT investments, mainly discussing different methods to address the intangible benefits of the investments using various criteria for evaluation (Nijland, 2001).

According to the same author, traditional appraisal techniques, such as Cost Benefit Analysis, Payback time and Return on Investment, which do not account specifically for IS/IT characteristics, are still dominant in IS/IT evaluation.

It is clear that managers need to use these techniques for a financial approach in evaluating investments, but they also need a more complete tool, such as a decision support system with financial and also non-financial techniques, which supports them in evaluating overall investments decision objectives.

In the next chapter, we will use a literature review to make a brief history of the DSS evolution. We will digest DSS features (in which we intend to describe the structure of DSS, specifying its elementary components, including the functional capabilities requested by a DSS) and abilities to formulate a definition of the DSS work, which will be the base for the development of our study. These functional capabilities are the bases for the exploration of the wide variety of issues that influence the design of decision support systems for helping decision makers.

2 DSS Literature Review

DSS concept

The decision support systems mentioned in the previous chapter may assume different forms and can be used in different ways. According to Turban (1995) and Keen and Scott Morton (1978, op. cit. Shim et al, 2002), the concept of support system for decision involves:

- The theoretical studies on the decision making in organisations, elaborated in Carnegie Institute of Technology in late fifties and early sixties;
- The technical work in the area of interactive computation, elaborated by Massachusetts Institute of Technology during the 1960s.

There are some difficulties in defining the concept of a DSS, since it is impossible to create an exact definition that includes all the facets of a DSS Keen (1980, op. cit. Schroff, 1998). However Power (1997), claimed that the concept of decision support system remains useful, since it applies to several types of information systems that support the process of decision-making.

2.1 DSS brief history

Historical perspective

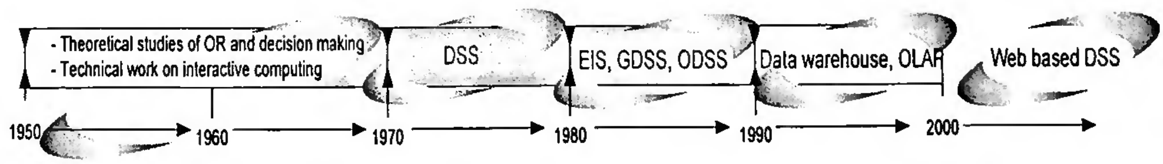
It is not clear that the DSS has appeared during the sixties, in fact, according to Haettenschwiler (1999, op. cit. Gachet, 2001) it is considered that the DSS became a research area in the seventies and continued more intensely during the eighties.

In the eighties and during the nineties, it became clearer that DSS belonged to an research environment with multidisciplinary bases, such as, research in the field of databases, studies in the interactivity of man-machine, simulation methods, software engineering, network telecommunications, artificial intelligence, and so on. The role of DSS and its future evolution is inextricably linked to (Keen, 1987; Shim et al., 2002 and Carlsson and Turban, 2002):

- The analysis of Information Systems (particularly with the development of new information technologies and communications, such as web-based technology and wireless networks);
- Operational Research and Artificial Intelligence;
- Organisational teams who create the necessary synergy for the accumulation of experience and knowledge.

These multidisciplinary bases and the constantly changing technology result in new types of DSSs. According to Gachet (2001) in mid and late of 1980s new types of DSS appeared, such as the Executive Information Systems (EIS), Group Decision Support Systems (GDSS) and Organizational Decision Support Systems (ODSS) see fig. 1.

Fig. 1. - A brief history of DSS



Source: based on Gachet (2001)

Thus DSS constitutes an evolutionary element of the IS and the point of convergence with the use of several emerging analysis techniques, namely from the Operational Research. These are complex systems often formed from several subsystems, such as various databases, OLAP systems or complex mathematical libraries.

The wide variety of DSS descriptions and features results in a variety of definitions.

At the early 1970s, DSS was described as a computer system that helped the decision process, (Little, 1970). In the middle of the same decade, the interactive computer systems appeared, aiding the more effective agents of decision, by using databases and model bases.

There are authors, such as Bonczek et al (1980) that defined a DSS as being a "computer system constituted by three components which interact: a communication system and two other components; one knowledge system in the domain of DSS and a sub-system of processing problems". The interactivity concept appeared and the human system interface got their own relevance. At the beginning of the eighties, the interactivity concept was already established in the DSS community. Besides beyond few exceptions, the user-friendly programs were produced at this time with the name DSS (Shim et al., 2002). It is also at this time, that disciplines such as OR (Operational Research) and Cognitive Psychology began to be included in the area of DSS. Also at the beginning of the 80's, authors such as Moore and Chang (1980) defined a DSS as an "extensive system, capable to support processes ad-hoc of analysis of data and modelling the problems, guided for the planning (of the future) and used in irregular intervals of time and non planning ". DSS is generally defined as an interactive information system that helps the decision makers to use the data and the models for the resolution of not well-structured, unstructured or semi-structured problems.

At the end of the eighties, the focus stands on the definition of DSS terms. Keen (1987); for example, preferred to define “support to the decision in detriment of “support system to the decision ". The same author provided a widely accepted definition bringing together three perspectives:

- Decision, which is related to analytic aspects of DSS and to the criteria to select actions.
- Support, which puts the focus on the perception and implementation by the way human beings act and by the way of helping them.
- System, which emphasizes directly technological characteristic with the project (design), architecture, hardware, and so on.

In 1990, several authors brought new concepts to the DSS area. For example, Klein and Leif (1995) defined DSS as a "computer program that supplies information of a certain application domain through analytical models of decision and databases access, with the purpose of supporting the agent of decision, in an effective way, and in the process of making the decision in complex and not well structured tasks (not scheduled)". This author focuses the DSS objective and brings the concepts of analytical models and databases for supporting the decision agents in complex and not well-structured tasks. There are also authors, such as Power (2000) who presents a complex but complete definition of Decision Support System, which is an “Interactive computer-based systems intended to help decision makers use data and models to identify and solve problems and make decisions. The system must aid a decision maker in solving un-programmed, unstructured (or semi structured) problems, the system must possess an interactive query facility, with a query language that is easy to learn and use” (cf. Bonczek, Holsapple and Whinston, 1980), or Shim et al (2002) who defines that DSS "are computer technology solutions that can be used to support complex decision making and problem solving".

Although this section presented an historical perspective of some DSS definitions, the next section presents the definition with the best fit to the present work.

2.2 DSS definition

Nowadays there is no formal agreement regarding the characteristics and capabilities of a DSS. In our opinion, such system is best used on the resolution of less structured problems or in problems which require the participation of people from different departments or organisation levels.

Generally, a well-designed DSS to help the decision makers on the resolution of the problems described above has to have the following features, based on the framework for development of DSS recommended by Sprague (1980):

- A support for all the decision process phases, i.e.: intelligence, project, choice and implementation;
- A support for a variety of styles and decision processes;
- A tool designed to improve the effectiveness of the decision making (accuracy, quality, opportunity) more than the efficiency (the cost of a certain decision making, including the computer processing time);
- Process control of decision agent: the DSS should have the objective of supplying support to the decision agent and not substituting him, the decision agent can refuse to accept the recommendations of the computer at any time along the process;

- Knowledge: most of the advanced DSS are equipped with a knowledge component, which allows the effective and efficient resolution of more complex problems.

We could say that the decision support system characteristics and concepts are quite vast and its definition depends on the author's research. For example, according to Druzdzel and Flynn (1999), the concept of DSS is extremely broad and its definition varies depending on the author's point of view.

A DSS definition has to be based on several aspects, such as the different historical perspectives of DSS definition, the concepts used, the characteristics and capacities of a DSS. Turban (1995) and Turban and Aronson (2001), introducing a group of concepts and characteristics for a more complete DSS definition, which is "it uses an interactive, flexible and adaptable computer-based information system, especially developed for supporting the solution of unstructured management problems for improving decision making. This system uses data, and supplies an easy-to-use interface, and allows for the decision-maker's own insights". We adopted this DSS definitions, because their DSS definition is totally compatible with the work developed in this project. Also, according to these authors "a DSS usually uses models and is built (often by end users) by an interactive and iterative process. It supports all phases of decision making and may include a knowledge base component". This last perspective expands the capacities of traditional DSSs, integrating knowledge bases. In addition, the same authors presented a group of characteristics and capacities that are considered relevant. Those characteristics are:

- DSS incorporates both data and models;

- They are designed to assist managers in their decision processes in semi-structured or unstructured tasks, to provide support at the several levels of the administration, from the government to the managers of the public administration;
- They support, rather than replace, managerial judgment, providing support to workgroups or individual agents of decision - many of the problems of the organisation involve groups of decision;

The objective of DSS is to improve the decisions' effectiveness, rather than the efficiency of decisions.

According to Kroenke (1989), a DSS is a computerized system and it is constituted by the components of these systems: hardware, data, programs, people and procedures. This author introduces the concept of DSS components, which is an important topic to create models, because these components allow the development of a conceptual design of the DSS that helps managers collecting or gathering information and models, to synthesize and to analyse the important data for decision-making. The DSS components are briefly described in the coming sub-sections.

2.3 DSS components

The study (definition, classification and construction) of a DSS is extended to its components, which are useful to design a conceptual model and to develop the DSS. According to Sprague and Watson (1996) the typological models, frameworks or conceptual models are fundamental to understand a new and complex DSS.

Sprague (1987) presents the components of DSS: the Data Base System Administration, the Model Base System Administration and the Dialogue Generation System Administration.

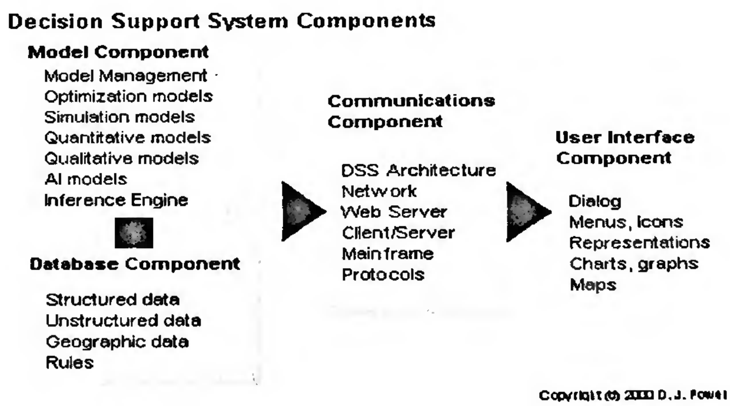
There are other authors, such as Turban (1995), who consider that a DSS is composed by:

- Data Administration (data bases and the tools for its administration);
- Administration Model, which is a software that includes several types of models, such as, administration, financial, statistical, and so on;
- Communication (dialogue system or interface);
- Knowledge Administration.

Another author, Power (2000) claims that DSSs have four components, (Fig. 2).

- Model component (the model bases and the analytic tools);
- Database component;
- Communication component (the architecture and the net of a DSS);
- User Interface component.

Fig. 2 - Decision Support System Components



However, there are more components. Hättenschwiler (1999, op. cit. Gachet, 2001) propose a new component, the knowledge-base management sub-system, based on artificial intelligence technology and emergent expert systems.
This study is intended to design a DSS with the following components: the database component for using and manipulating data on the database; the model component, which has the qualitative, quantitative and mathematical models, and the user interface component, which has the dialog menus.
Besides the DSS architecture, it is also important to classify the DSS taxonomies, which are briefly described in the following sections.

2.4 DSS taxonomies

As with the DSS definition, there is no all-embracing taxonomy for those systems either. Different authors propose different classifications. In 1980, Steven Alter proposed a taxonomy to classify the decision support systems. Such classification considers seven categories for the decision support systems:

- File drawer systems;
- Data analysis systems;
- Analysis information systems;
- Accounting and financial models;
- Representational models;
- Optimization models;
- Suggestion models.

At the conceptual level, Power (2001), based on Alter's (1980) classification, proposed a taxonomy with five generic types of DSS (see appendix I). According to Power, Alter's DSS category typology is still relevant for the discussion of some types of DSS. The first three types of DSS can be called data-oriented or data-driven models, the following three types can be called model-oriented or model-driven, and Alter's suggestion model can be called intelligent or Knowledge-driven DSS.

One of the generic types is the Model-Driven, which includes systems that use representation models, optimization models, accounting and financial models. This type of DSS emphasizes the access and the manipulation of models and together with statistical analysis tools uses data and parameters supplied by the decision makers, to help them analysing certain problems. These systems are usually non-intensive users of data.

This work is intended to present a Model-Driven DSS with strategic alignment, financial evaluation, and risk evaluation and multi-criteria analysis models for helping public organisations managers on the IS/IT investment projects evaluation.

2.5 Why use a DSS for IS/IT investment evaluation?

According to Hochstrasser (1992), management gives less attention to the "hidden or indirect costs surrounding IT, which can be up to four times greater than its direct IT costs component". In addition, Irani and Love (2001) have found that management tends to be myopic when considering IT investment decisions, mainly because it has no framework to evaluate their IT investments. That is why this work intends to propose a model driven DSS to be used by the Portuguese public administration, allowing the access and the manipulation of data (financial and non-financial) to support decision makers in their assessment of new information systems or technology investment projects.

We think that organisation's managers need to have a tool to help them in the evaluation of the investment process. According to the work of Lycett and Giaglis (2000), the process of evaluation of IS/IT investments is an important issue for organisations:

- First, organisations need to justify information system investments (because of the large sum of capital involved) and need to prioritise between heterogeneous investments proposals competing for scarce organisational resources (Strassman, 1985).
- Second, the evaluation helps to obtain the best cost / benefit ratio, in order to better deploy resources and to improve the organisational services at the lower cost possible, with the objective of rendering better services to the citizen;
- Third, evaluation provides a basic managerial feedback function and forms a fundamental component of the organisational learning process, (Smithson and Hirschheim, 1998);
- Fourth, evaluation provides benchmarks for what is to be achieved by the information system investment. According to Farbey et al. (1992) such benchmarks can later be used to provide a measure of the success of the implementation of development projects.

The following chapter will provide a literature review which addresses a variety of financial and non-financial techniques for evaluating information systems and technology investments, which is used to support the decision making on IS/IT project investments. This study is also based on the underlying investments and benefits of the investment issues in the field of Management Information Systems (MIS) and the usefulness of the DSS - Decision Support Systems, especially when part of this DSS is constituted by the AHP – Analytical Hierarchy Process.

3 Decision support for evaluation of IS/IT investments

Nowadays, managers take decisions on a daily basis and the reality they face is increasingly interlinked and complex. Considering the complexity of the organisational environment, the act of decision-making is the conclusion of a process, which generates two or more alternative ways for reaching a certain aim. The decision process complexity may result from lack of problem structure as well as from the excess of information to treat. This circumstance fostered the interest on the development of the Decision Support Systems. The objective of the DSS developers is to build a system, which provides support to management decisions. In DSS development, like in any other development of systems, the most important thing are the needs of the users. They are very important because DSSs have to incorporate organisation styles of management used by the decision-making administration (focus in the organisation as a helping decision system). According to Palma dos Reis (1999) the DSS seeks to help the decision makers in tasks, such as the organization of the information access and in organizing the analysis of the referred information. The same author refers that the decision makers should use a Decision Support System in order to develop slightly structured and complex decisions with major impact or a significant risk level for the organization.

In general, the decision makers should use the DSS to perform the slightly structured, complex and significant decisions, in order to construct the strategic planning for the organization and to help them performing their information analysis in issues, such as the evaluation of the investment on information systems and technology, which are strategic for the organisations.

The decision support systems bring a new approach and incorporate techniques to better evaluate the organisations strategic resource investments. Based on Earl (1987, op. cit. Powell, 1999), four reasons are suggested (adapted to public organisations) to use IS/IT as a strategic resource:

- Advantage in better public service choices;
- Improving productivity and performance in public services;
- Enabling new ways of managing and organizing public organisations;
- Developing new public services (business).

The DSS will always be used to help in strategic planning[3], which is an important subject for any organisation, regardless of its ultimate goals. According to McNamara (1999), strategic planning brings benefits to organisations, such as:

- Cleary defining the purpose of the organisation and establishing realistic goals and consistent objectives with that mission in a clear time frame within the organisation's capacity for implementation;
- More effective strategies for current and future operations;
- Clear and concise priorities for the usage of limited resources;
- Developing a sense of ownership of the plan;
- A high probability of improved decision making based on information learned from the process;
- Ensuring the organisation's resources most effective use by focusing them on key priorities;
- Improving management change and providing a base from which progress can be measured;

[3] The Strategic Planning provides a structure for understanding and addressing complex issues in a particular organisational context.

- A clearer picture of possible consequences;
- Overall increased performance of the organisation and bringing together everyone's best and most reasoned efforts that provide important value towards building a consensus about where an organisations is aiming.

In summary the DSS could be used in a process for evaluating of IS/IT investment by the Portuguese public organisations.

Authors like Andresen (2002) presented a list of IT investments evaluation methods, such as the Internal Rate of Return (IRR), the Net Present Value (NPV), the Return on Original Investments (ROOI), the Value Analysis (VA), the Critical Success Factors, Prototyping and so on. Some of them have been identified in the literature review and will be treated with further detail in the next section.

3.1 Critical aspects on investments analysis

In this section we will use the term "project" with the meaning of IS/IT investment project.

From what was said in the section above, we can conclude that one of the most important aspects for the organisation is the managers' capacity to take strategic choices and make decisions regarding investments.

In order to find an organisational method for supporting the strategic choices and decisions regarding IS/IT investments, we found the work of the Committee on Capital Planning and Information Technologies investment for USA Federal agencies between 1997 and 2000. According to this work, the processes of decision making regarding investments involve three stages:

- Search and select;

- Control;
- Evaluation.

Search and select

This is a process of searching for ideas and investment opportunities, by elaborating a plan and selecting the necessary information for the identification and evaluation of the best investment opportunity.

Control

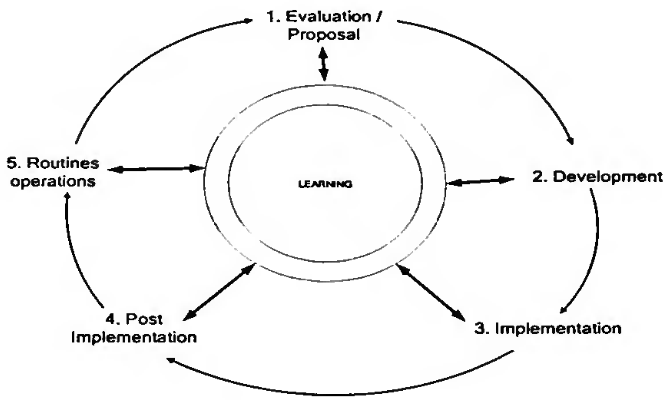
Involving the right people for future projects and documenting all actions and decisions. These processes ensure that the evaluation of investments is performed in a disciplined, well-managed and consistent way.

Evaluation

According to Willcocks and Lester (1999), organisations supported the notion of an evaluating learning cycle, with the evaluation at each stage feeding into the next to establish a learning spiral accross time. That is useful to control a specific project, but also for building organizational know-how on IS/IT and its management.

The evaluation cycle (Fig. 3) based on Willcocks and Lester (1996) is:

Fig. 3 - Investing in IS/IT: Evaluation cycle



Source: Adapted from Willcocks (1999)

According to Willcocks and Lester (1999) "Organisations need to shape the context in which effective evaluation practice can be conducted. Traditional techniques cannot be relied upon themselves to assess the types of technologies and how they are increasingly being applied in organisational settings. A range of modern techniques can be tailored and applied".

In order to improve their IS/IT cost/benefit management and to perform the IS/IT evaluation investments process properly, organisations display great interest in financial and non-financial evaluation methods.

According to Andresen (2002), a list of methods was combined and provided from several authors like Farbey,Land & Targget (1993), Remenyi, Money & Twite (1995), Renkema & Berghout (1997) and Powell (1999). The identified methods can be described through a large range of characteristics, from those with simple measures to those with complex ones. This list is outlined in the subsequent type of IT investments, type of impact, evaluation criteria, stage of IT evaluation, type of outcome, method difficulties, extent of involvement, cost of the method and scope of the method. Supported on these, the author identified three groups of methods that are based on the possible types of output.

- Financial methods – Methods that have a financial output.
  The decision related to the acceptance and rejection of IS/IT investments projects based on methods of economic-financial measures imply for the decision agent, that the investments are profitable.
- Quantitative methods – Methods that have an output with one or several non-financial and quantitative measures when evaluating the IT investment. Evaluation with financial and non-financial criteria.
- Qualitative methods – Methods for evaluating IT investments by providing qualitative output that, by definition, are non-quantitative.

Financial Methods

According to Lycett and Giaglis (2000) "the classic financial/accounting methods of investment evaluation are currently the most widely used methods for information system evaluation", and Andresen (2002) refers to the financial methods as the "Methods, that have an output of a financial character or which are expressing a financial condition, are categorised in this group. They assess the IT investments' financial value by analysing its cash in-and out-flow and may assign arbitrary monetary values to non-economically measurable costs and benefits."

According to Remer and Nieto (1995, op. cit. Godinho et al., 2004) the evaluation and project selection methods involve the calculation of economic-financial measures and can be classified within five classes of methods:

1) Equivalent worth

The equivalent worth methods examine the project cash flows and, through discounting or compounding, resolve them to one equivalent cash flow or to an equivalent series of cash flows.

According to Bacon (1992) the evaluation of cash flows is based on the time-value of money, using discount cash flow (DCF) techniques. The DCF techniques reduce all estimated cash outflows (costs) and inflows (benefits) associated with a given investment or project to the present.

2) Rate of return

The rate of return measures the rate at which the invested capital will grow if the project is pursued. The Internal Rate of Return (IRR) is the most widely used of these methods.

3) Ratio

These methods can be defined as the quotient between the present value of the returns and the present value of the investment. The Profitability Index (PI) is the most widely used ratio method. The PI is the quotient between the present value of the future cash flows generated by the project and the initial investment.

4) Payback

These methods include the payback period, which calculate how long it takes to recover the invested capital (is the number of years required for the accumulated project cash flows to equal the initial investment), and the discounted payback period, which is similar to payback period, except that it considers the discounted cash flows instead of the raw cash flows.

5) Accounting

These methods consider profitability from an accounting perspective. This class includes the return on original investment (ROOI) and the return on average investment (ROAI).

- The ROOI is the quotient between the average yearly accounting profit, which excludes depreciation, and the investment made in the project.
- The ROAI is the quotient between the average yearly accounting profit and the average book value (average value of the difference between investment and depreciation) during the project life.

The DSS incorporates the financial investment analyzing tools for supporting better and valuable decision process in IS/IT investments, for the improvement of internal-organisational services performance and for the best quality of public services. However, to make the financial analyzing tools work well, the organisations need to have quantitative data to treat. According to Godinho et al. (2004), financial methods cannot be used unless quantitative data about the investments costs and returns is available.

Some of the financial methods could be the update of the cash flows, which are designated as "actualization cash flows criteria". According to Serrano et al (2004) the main sophisticated cash flows criteria methods are:

- The Internal Rate of Profitability (IRP);
- The Net Present Value (NPV);
- The Profitability Index (PI);
- The Rate Benefit-Cost (RBC).

Some of the most representative characteristics of the financial methods IRP, NPV, ROI, CBA, Payback and ROM will be illustrated in the next paragraphs. In addition, some comparisons will be established among the several methods and some of the advantages and disadvantages will be mentioned, comparatively, or by themselves, according to the authors Remer and Nieto (1995) and Brealey and Myers (2000). We think that managers with the responsibility for accepting or rejecting the investment projects should be aware not only of the advantages, but also of the disadvantages in using anyone of these methods.

The Internal Rate of Profitability (IRP)

The most representative method of the rate profitability methods class is the internal rate of profitability (IRP). However, there are other variants of this method, such as the marginal rate profitability of the invested capital, the external rate of profitability and the profitability rate growth.

The internal rate of profitability is the actualization value rate, identical for all the periods, that makes the NPV equal to zero

$$IRP = \sum_{t=0}^{T} \frac{CF_t}{(1 + TIR)^t} = 0$$

t - Period in which the treasury flows are repeated;

T - n° of periods;

CF_t - treasury flows that happen in the period t;

IRP - internal rates of profitability.

The evaluation project based on the IRP assumes that the project will be accepted if its internal rate profitability is superior to the actualization rate of reference. This happens because it is supposed that, in these conditions, the NPV of the project is positive when that actualization reference rate is considered.

According to Meredith and Suresh (1986), the NPV methods approach is usually preferable for the decision agents compared to the IRP approach. There are several reasons that can be presented to justify such a preference:

- The NPV has the largest flexibility, because it allows the temporary structure of the actualization rates to be considered;
- The fact that, in the case of NPV, it is supposed that the generated flows are reinvested with the actualization rate value (the opportunity cost of capital) while, in the case of IRP, it is supposed that the same flows are reinvested with the values of their own IRP;
- The addictive property of NPV.

In spite of IRP presenting some relative disadvantages compared to NPV, this does not mean that the IRP method is not used. One of the most important reasons for its success, at the practical level, is the intuition, simplicity and easiness of assimilation of IRP by the decision agents. This advantage of IRP is more evident when we are dealing with a project with 2 periods.

According to Godinho et al. (2004) many authors, such as Brealey and Myers (2000), consider that, in most situations, the NPV the best economic profitability measure for investment projects.

The Net Present Value (NPV)

The methods for project evaluation based on the concept of Net Present Value are characterized fundamentally as converting the project's provisional treasury flows, related with its lifespan, with the objective of joining them in a single value expressed in the present. The transformation is made through an actualization rate and the period of time associated with each treasury flow. The NPV determines the project value based on its provisional treasury flows of investment and project exploration, transforming them into present values. It discounts all estimated cash flows for a project to present value, using a required rate of return, that is:

$$NPV = \sum_{t=0}^{T} \frac{CF_t}{(1+rt)^t}$$

t - Period after which the treasury flows are repeated;

T - n° of periods;

CFt - treasury flows that occur in the period t (by hypothesis, it is assumed from now on that the relative treasury flow to the period t occurs at the end of that period, to the exception of the period zero that occurs at the beginning of the period 1);

rt - rate of actualization relative to the period t (in the cases in which the temporary structure is not considered important, the actualization rate is independent of the period t).

The NPV method is also a variant of Discounted Cash Flow (DCF) Methods and according to Bacon (1992) in the evaluation class there are other DCF techniques for helping the IS/IT investments decision systems, such as the:

- Internal Rate of Return (IRR);

  It aims to find the discount rate that would equate the present value of estimated cash out-flows with the present value of inflows, i.e. the annual rate at which project is estimated to pay off. The value of the IRR is found by solving the following equation:

$$C_0 - B_0 = \sum_{i=0}^{T} \frac{B_i - C_i}{(1 + IRR)^i}$$

- Profitability Index Method (PIM).

  It provides comparative profitability among different investments by dividing the present value of future cash flows by a project's initial investment.

In practice most organisations use the Discount Cash Flow (DCF) methods to assess their IS/IT investments. Besides this method, there are others such as the Average or Accounting Rate of Return (ARR), the Payback Method (PBK) and the Budgetary Criteria.

However, according to Nijland (2001) "many researchers have criticized the discount cash flow (DCF) methods, which originate from accounting, as a means for IT evaluation". The same author refers that, from a practical point of view there are some difficulties such as: it is hard to quantify intangibles, it favours quick-return projects and there is a lack of consideration for typical characteristics of IS/IT projects. A critical theoretical perspective adds another critique, namely the inability of the methods to capture an independent reality. According to Knights and Murray (1994), these methods obscure the actual personal objectives pursued by decision-makers behind a rationalized myth and the overt organisational goals.

However, researchers such as, Symons and Walsham (1991) argue that these methods are not to be abandoned blindly, though they are a symbolic expression of belief in rational management. Still, according to Walsham (1999) there are two reservations to be made in using DCF methods as a ritual:

- First, they may become a device to suppress the least powerful in organisational terms;
- Second, DCF methods can be a major obstruction to innovative organisational change, because they tend to favour projects with quick financial results, rather than strategic opportunities.

In conclusion, DCF approaches are highly deficient in generating real understanding of the costs and benefits of a computer-based system and its human and organisational consequences. Therefore, these methods are not widely adopted in organisational practice. Also according to Serafeimidis and Smithson (1995), even the interpretive approach in IS/IT evaluation, recognizing the social aspects of evaluation and taking into account all views of the stakeholders, have in practice being abandonned.

However, according to Ballantine et al (1999), in spite of the existence of various approaches and techniques for IT investments evaluation, most organisations will still use simple accounting methods, such as, Return on Investments (ROI) or cost-benefits analysis (CBA), in order to decide whether to keep on with a certain IT project or not.

The Return On Investment (ROI)

The accounting profitability rate of the investment in one project is determined through the ratio between the liquid medium result of the project exploration along its useful lifespan and the investment, that is to say:

$$\text{ROI} = \frac{\dfrac{\sum_{t=1}^{T} RLE_t}{T}}{-I}$$

I - relative negative value to the investment;

t - Period in which the liquid result of exploration is repeated;

T - n° of periods;

RLEt - liquid result exploration in the period t.

This evaluation method presents the disadvantage of not considering the value of the money along the period of time. In face of this situation, Remer and Nieto (1995b) considers that it does not make sense to compare the value of this rate with the actualization rate (opportunity cost of the capital), to take an eventual decision of accepting, or not, a project. So the ROI should not be used isolated in the project selection evaluation. In addition, Brealey and Myers (2000) alerts for the dangers that the decision agents face when they use accountancy profitability rates in process evaluation and project selection, and refers that the accountant measures are vulnerable to outrages of accountability character and that, sometimes, can distort the relative value of the project profitability. This implies, for example, the possibility of accepting one bad project or rejecting a good one. Besides, he also criticizes the dependence that the accountant method has upon the accountability results, such as the possibility to set that certain expenses comes from exploration or investment. If expenses result from exploration, they are discounted in the respective year, while if they result from investment, they are amortized along several periods. This can bring direct consequences to the final value of the profitability rates obtained by the application of the ROI method.

The ROI, as well as the NPV or the IRR methods, is not suitable for evaluating investments that are expected to yield benefits that are primarily intangible, indirect or strategic in nature, Brown (1994, op. cit Lycett and Giaglis, 2000). However, there is a technique which attempts to overcome the problem of valuing intangibles, the Cost Benefits Analysis (CBA).

Cost Benefits Analysis (CBA) is another method for measuring technology investment. According to Prest and Turvey (1965, op. cit. Murphy and Simon, 2001) the CBA is often the method used in practice to compare the costs and benefits of all types of capital investment projects. Farbey,Land, and Targett (1992) and Bacon (1992) considered said that it is the most often used technique in calculating the economic value of IT projects.

The Cost Benefits Analysis (CBA)

According to Lycett and Giaglis (2000), "Cost Benefit Analysis (CBA) is a variant of DCF-based methods that attempts to control the problem of valuing intangibles. It does this by assigning a monetary value for each element contributing to the cost and benefits of an information system project, including intangibles".

It is generally accepted that all CBA approaches require assessments (estimates) of costs and benefits in future periods. These assessments should account for the relevant costs at each period of the project or system's life cycle. The CBA also includes the use of marginal versus average value analysis and sensitivity analysis should always be part of the process.

According to Murphy and Simon (2001) "the assessments of costs and benefits is at the heart of any CBA activity. Following the assessment of cost and benefits, one of a number of outcome measures is calculated. The most common measures include payback period, net present value and internal rate of return". The Net Present Value and the Internal Rate of Return were discussed before and payback is simply the earliest period in which the project's cost is recovered. By using this criterion, it is assumed that the best project will be the one with the shortest payback period.

CBA has been criticized by several authors, such as Keen (1975, op. cit. Murphy and Simon, 2001) who considered that the large majority of information systems' costs and benefits are difficult to measure. This is becoming increasingly true as the use of information systems moves from transactional towards strategic. In addition, according to Lycett and Giaglis (2000), "This method is necessarily based on surrogate measures for intangible costs and benefits, which may involve considerable controversy and debate".

According to Lincoln et al. (1990), the SESAME is a variant of CBA in which the payback of the information systems project is derived by computing what costs would have been if the same functionality had been delivered by non-computer-based methods.

However, according to Lycett and Giaglis (2000) Return On Management (ROM), proposed by Strassman (1990), provides another alternative, which seeks to provide an index of the contribution of Management Information System (MIS) to the organisation. In other words, this method has the most reliable contribution index of the Management Information System to the organisation. It expresses the outcome of the introduction of a new system, by the change to the value added by management generated from the introduction of a new system, which is the residual value after deducting the cost and value added by each resource, including capital, from total revenue, but excluding management and the cost of management.

Besides the financial methods, there are the quantitative methods. According to Andresen (2002), the methods categorised in the quantitative methods group "provide an output with one or several non-financial and quantitative measures when evaluating the IS/IT investment. This implies that the evaluation is completed by using, not only a financial criterion, but also non-financial criteria".

Quantitative Methods

The quantitative methods combine the measures into one single quantitative output, or each of the measures may be quantitatively expressed. Examples of these methods could be the Information Economics, Multi-Objective and Multi-Criteria Methods (MOMC) and Value Analysis.

Information Economics

This method proposed by Parker and Benson (1988), is an ex-ante evaluation approach and it is probably the most acclaimed IS/IT evaluation, on which IBM has also based its consultancy practices (Strassman, 1990). It encompasses the whole decision making process for intangible value and risk factors derived from a strategic IS/IT investment. These include a number of human and management factors that organisations ignore or neglect. In practice, the method is a variant on cost-benefits analysis, constructed to work with the particular uncertainties and intangibles found in IS/IT projects. According to Stewart and Mohamed (2003) this approach employs very detailed tools and techniques for assessing the desirability and priority of IS/IT projects. The major advantage of this approach is that it goes beyond traditional "business value" techniques introducing the concept of value and risk, and extends the normal cost-benefits by three processes.

- Primarily, the value linking, which looks for the consequential impact of a primary change spreading through different functions;
- Secondly, the process of value acceleration, which attempts to define the value of future systems, that are dependent on the introduction of the system in question. Hence the value of a primary system is seen to be enhanced if it is also seen as the platform on which later systems can be built;
- Thirdly, the process of job enrichment, which provides an evaluation of the additional value to the organisation of the enhanced skills and understanding, which its staff may gain from the use of IS/IT.

Multi-Objective, Multi-Criteria Methods (MOMC)

According to Farbey et al. (1999), these methods have their roots in Elster and Hylland (1986) Social Choice Theory and Multi-attribute Utility Theory. The advantage of these methods is the opportunity provided to explore the problem and the views and preferences of the people affected by the use of the method, and the fact that people explicitly recognize the existence of many points of view and more than one set of values in the decision to invest in IS/IT. The authors such as Chandler (1982) claim the MOMC Methods are an alternative to cost-benefit-analysis, which do not rely on monetary measurements of value. Instead, they work via an interactive procedure to establish preferences and utilities. The decision makers can appraise the relative value of different desired outcomes in terms of their preferences. For example, they have the capability of ranking goals by applying weights to individual preferences for each goal.

The MOMC approach permits an exploration of different viewpoints, i.e., it allows the evaluation of the project by one person or by a group of persons. This approach propose that the value of the project can be expressed or measure in terms other than money and is better used when there are a number of possible objectives to serve a number of different groups or persons in the organisation. The MOMC takes a traditional socio-technical stand paying attention to many points of view and raising issues: The process of evaluation, which should itself be socio-technical; the criteria for evaluation; the locus of control and the assumed value consensus.

Value Analysis

The VA is an exploratory technique, which tries to assess the incremental value of the outputs of a proposed system, principally its value to decision-making and decision-makers. The method is based on the notion that it is more important to concentrate on value (added) than on cost saved. Based on the authors Melone and Wharton (1984), this technique attempts to evaluate a wide range of benefits, including intangible benefits. It begins with an agreed estimate value of a proposed system (VA may use an iterative approach, such as the Delphi method, to provide answers). Then, a working model of how the system will work in practice (a prototype of the system in order to gain more experience in which decision makers might use the system) is constructed. The process is repeated until the proposed system delivers a variety of information, such as where it is expected to help managers to make better purchasing decision or improve their work satisfaction.

The advantages of this method are:

- The process establishes agreed values for intangibles outputs;
- The decision-makers are involved throughout building a confidence in the eventual result.

The VA method groups the benefits into homogenous categories, using statistical techniques to summarize the benefits in separate categories, and then determines a value for the benefit. The value can be expressed either as utility (calculation of utility scores by attaching utility weights to each category of the benefit), as well as in monetary terms.

In conclusion, the VA allows to test the sensitivity of the solution to different interpretations and valuations. VA is a sophisticated and costly technique, much of whose value stems from the insights gained from the exploratory nature of the process.

However, not every IS/IT project in the public sector equally lends itself to the quantification of benefits when evaluating the IS/IT investment. For example, some IS/IT development initiatives or activities are undertaken for political reasons, while others may be pure "act of faith" efforts, so strict ROI ground rules may be more difficult to establish. This is one of the reasons why the evaluation techniques, explained above, were unable to capture many of the qualitative and intangible benefits brought by investments in IS/IT. Strassman (1990), Farbey et al. (1993) and Ward and Murray (2000) said the most common causes of the difficulty to evaluate IS/IT investments are the following:

- The intangible nature of the benefits;
- The benefits of IT are felt in the long run;
- The 'real' benefits of IT are strategic and competitive advantages which are inherently difficult to quantify;
- The benefits of IT are indirect to business or society and therefore indistinguishable from many other confounding factors;
- Information Systems affect many aspects of the organisation (people, process, strategy, etc), the combined effect of them determines the outcome;
- The level of analysis at which our efforts are concentrated is out of focus, either too general or too narrow.

According to Farbey et al (1999), many IS/IT investments possibly carry more intangible benefit, which are critical to success, and strategic IS/IT investments are relatively new and organisations have not learned how to deal with them. However, the issue of valuing intangible benefits should not be an insuperable problem, since some evaluation techniques are specifically developed to deal with intangibility, such as Cost Benefit Analysis in financial methods and Value Analysis in Quantitative methods.

In conclusion, there is no doubt that evaluating IS/IT investments is problematic (Costs and benefits are harder to identify) and it is clear that the justification of IS/IT is difficult, yet several authors propose a multiplicity of evaluation methods or approaches described in the paragraphs above, each with their own characteristics and focus. The analysis of these methods shows differences at the detail level; at the process management involved, at the level and function of the people involved, and at the characteristics of the data required.

In the next section, we recommend the qualitative methods for evaluating IS/IT investments. These methods also address the intangible benefits based on qualitative data of the investments using various criteria of evaluation.

The qualitative methods

The last group of methods is categorised as evaluating IS/IT investments by providing qualitative output, which, by definition, are non-financial or quantitative. There are several methods of qualitative evaluation for IS/IT investments, such as the Critical Success Factors (CSF) or the Analytical Hierarchy Process (AHP).

- **Critical Success Factors**

The Critical Success Factors (CSF) method is based on the work of Rockart (1979). This method is implemented through a series of two to three interview sessions. In such sessions, top managers define their own current information needs in order to be able to determine the information they need to monitor their organisation's progress. Managers express their opinions about the factors that ensure the successful competitive performance of the organisation (key areas that are critical to the business success). Then, they rank the factors according to their significance and examine the role that IT, in general or a specific system can play in supporting the executive in dealing with the critical issues.

This method provides a focus on issues, such as the identification of critical success factors, which can help top management in:

- Determining where management attention should be directed;
- Developing measures for critical success factors;
- Determining the amount of information required and thus limiting gathering unnecessary data.

Another technique to help managers on the qualitative evaluation of IS/IT investments is the Analytical Hierarchy Process (AHP).

- **AHP – Analytical Hierarchy Process**

According to Power (2000), the AHP is "An approach to decision making that involves structuring multiple choice criteria into a hierarchy, assessing the relative importance of these criteria, comparing alternatives for each criterion, and determining an overall ranking of the alternatives". This tool helps in the resolution of multi-criteria problems by breaking down criteria and comparing them to each other. An overall weight of criteria is compared in order to achieve the best decision.

The use of AHP is intended to help public administration managers in multi-criteria appreciation of different features for IS/IT Investments.

This tool will be comprehensively discussed in chapter 4.

According to Khalifa et al. (1999) IS/IT evaluation can contribute to the success of the IS or IT system, when the proper method is applied to the appropriate organisational context. Based on financial and quantitative methods, this work's intent is to recommend an *ex ante* IS/IT investment appraisal or evaluation methodology for the Portuguese public administration.

3.2 Methodology for analyzing IS/IT investments

According to Serrano (2005) "the evaluation of IS/IT investments can be faced as a process, or a group of parallel processes, that can occur in a continuous way or at different moments, for finding and turning explicit the quantitative and qualitative organisational impacts of an IS/IT project". In order to achieve the qualitative and quantitative values of the IS/IT investment, the managers have to use appraisal techniques.

The use of traditional appraisal techniques to justify IS/IT investments has been on the spotlight on recent years. The reason for this growing interest in this subject is due to the large sums of money being spent on the adoption of information technologies, and the increasing need to justify the significant capital expenditures. However, the referred techniques have inconsistency problems and, according to Alter (1999), most of the executives are not comfortable with the available set of tools and appraisal techniques used to justify their IS/IT project investments. Nevertheless, according to Serrano (2005) the problem of employing such techniques to the IS/IT investments does not reside in its inconsistency, but in the incorrect use of the appraisal techniques. In order to avoid the incorrect use of the appraisal techniques in IS/IT investments by the Portuguese public administration managers, it is important to design and develop an investment evaluation model. The decision makers could use such model as part of the decision taking justification process. The referred model could also provide a group of measures that would make easier for the decision makers to control the investment evaluation of the project implementation. According to Renkema (1999, op. cit. Serrano, 2005), the investment evaluation process in IS/IT is extremely important for the organisation, due to the following reasons:

- It prevents the bad attribution of financial resources;
- It improves the business performance;
- It creates a shared vision of the investment and it takes advantage of the learning opportunities;
- It explores with profit the IT infrastructure.

The investment evaluation model holds a couple of objectives, such as informing about the benefits of the IS/IT investment and helping the Portuguese public administration managers in the evaluation of the IS/IT investment projects.

In order to evaluate the IS/IT investment project s, some authors, such as Wehrs (1999, op. cit. Murphy and Simon, 2001), differentiate between ex ante and ex post evaluation. In ex ante evaluation, the focus goes to the justification of the IS/IT investment before it is made, on the other hand, ex post evaluation purpose is to justify the costs that have occurred and to help predicting future IS/IT expenditures.

The recommended investment evaluation model is based on an ex ante evaluation analysis methodology for the IS/IT investment projects. Therefore, the objective of the IS/IT project evaluation is to put the focus on the investment decision rather than on the justification of costs already incurred. The ex-ante investment evaluation method is based on the MAIS – Metodologia de Avaliação de Investimentos proposed by António Serrano and a team of IIMF – Instituto de Informática do Ministério das Finanças in 2004 for the Portuguese Finance

Cabinet, Serrano et al (2004), and the AHP – Analytical Hierarchy Process proposed by Thomas Saaty approximately 25 years ago, Saaty (2001).

The referred methodology combined with the AHP is the basis for the Decision Support System (DSS) model to assess IS/IT project investments.

The DSS entails the analysis of five different features:

1. Strategic alignment;
2. Financial analysis;
3. Risk analysis;
4. Global analysis;
5. Qualitative multi-criteria analysis;

In the following sections, the evaluation investment methodology will be concisely focused, in each of the following features: strategic alignment; financial analysis; risk analysis and qualitative multi-criteria analysis.

The strategic alignment of the investment

Within the strategic evaluation module, it is intended to make an alignment of the investment project with the organisation objectives, such as:

- Determine the degree of project alignment with the strategic business objectives of the public organisations.
- Identify the benefits to be obtained from the project, which is based on the evaluation of investment return within the financial analysis scope.
- Identify the consequences of project failure, which is based on qualitative analysis features, in order to evaluate the strategic alignment and the benefits to get.

Financial analysis of the Investment

The main objective of this feature is to evaluate the financial viability of the IS/IT investment projects based on the following financial methods for evaluation of IS/IT project investments:

- Net Present Value (NPV);
- Internal Rate of Profitability (IRP);
- Period of Recovery of the Investment (Pay-Back);
- Return On Investment (ROI).

Risk Analysis of the investment

The risk evaluation and management is a process that should be maintained from the beginning until the end of the IS/IT investment project.

One of the risk analysis objectives is to reduce the risk impact consequences in the execution of the IS/IT investment. Another objective is identifying and evaluating the risk features that can put at risk the success of the project. This can be done through a group of concrete actions that detect and reduce or eliminate the potential risk.

In order to reduce or eliminate the risk of the investment, the managers have to implement pro-active actions, analyse the potential risk for the organisations, and answer a questionnaire, which is divided in four areas:

- Strategic or Organisation Risk - this intends to evaluate the risk grade in the capacity of the organisation in accepting the project and respective organisation impacts;
- Technological Risk - this intends to evaluate the degree of flaw risk or technology instability;

- Project Risk - this intends to evaluate the risk of deviations from what was initially foreseen or due to coordination problems in project administration;
- What is the Critical Success Factor (CSF) identified by the organisations? The CSF is the qualitative information for evaluating the coherence of the given answers in the three previous features.

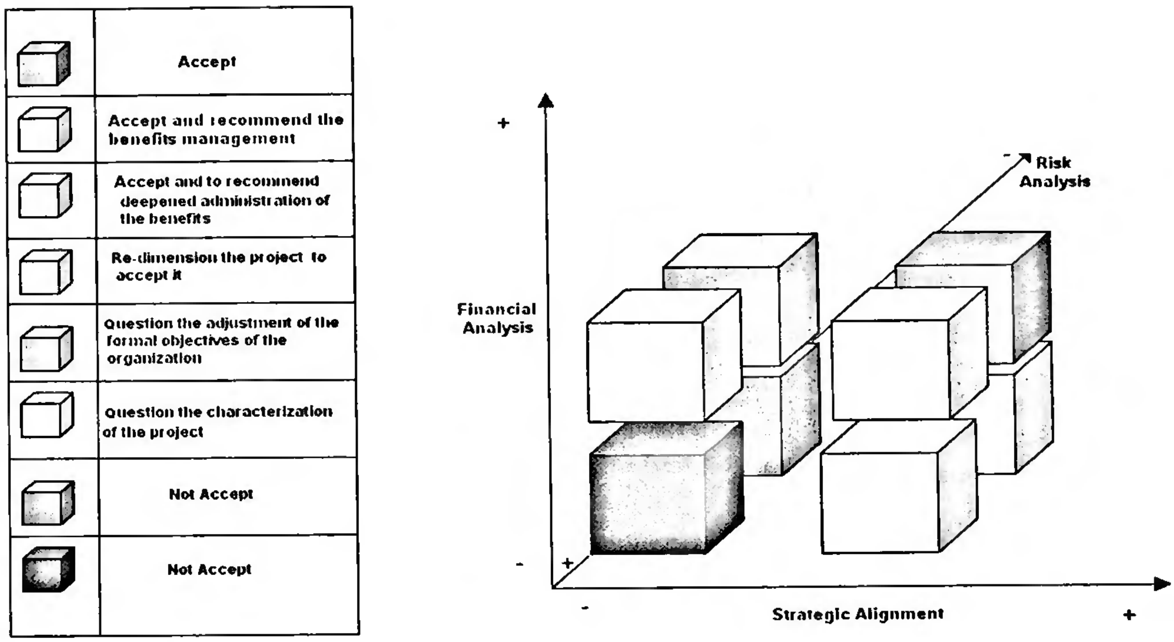
The first three features will be attributed values for each answer, depending on the chosen option and based on whether each feature is classified as low, medium or high risk.

The fourth feature, the CSF is the qualitative information to validate the coherence of the answers in the previous features.

Global analysis

The three features - the strategic, financial alignment and risk evaluations - provide a valid reading of the investment, although only partial. In order to guarantee a global and integrated reading, it is necessary to conjugate the results of the three features. The conjugation results of the referred features are made through a multidimensional analysis, which positions the projects in the Global Analysis Matrix cubes, represented in Fig. 4.

Fig. 4 - Global Analysis Matrix



Source: This graph is adapted from Metodologia de Avaliação de Investimentos, (Serrano et al; 2004)

The global analysis is a continuous and interactive analysis process and it is based on the reiterated evaluation of the investment with the objective of getting an integrated and global reading about the IS/IT investment project.

The global analysis and the results from the strategic alignment, the financial and the risk analysis are the base for positioning the project in the Global Evaluation Matrix. This work results may be the recommendations that will serve as work basis for the evaluation process. These recommendations can create a redesigning of the project and its consequent repositioning within the several features of the global analysis; it could also serve as a base to the technical opinion to be presented in the final evaluation report.

However, the methodology draft described above, helps managers getting important information about the project, but it is an incomplete system for supporting managers in their decision about the evaluations of IS/IT investments. It is not complete because it misses an improved qualitative evaluation of the projects and a more sophisticate solution for the multi-criteria investment analysis problem.

Multi-criteria analysis and qualitative analysis of the investment

There are multi-criteria analysis and qualitative evaluations about the IS/IT investment project that need to be placed through a rational process. According to Nielsen (2004), a rational evaluation process eliminates emotion from the choices. This process can be used in evaluating multiple items such as vendors, developmental frameworks, and business process best practices, and so on.

We have studied several tools for the support process of qualitative evaluation of the investment, such as the Analytical Hierarchy Process (AHP).

This study aims to use the AHP tool to support the managers within the decision regarding IS/IT investments. The following chapter puts forward an explanation about what it is and how it work.

Besides, the investment evaluation model is more comprehensively described in chapter 6, where we intend to present a Decision Support System composed by MAIS + AHP for evaluating IS/IT project investments.

4 The Analytical Hierarchy Process

4.1 What is the Analytical Hierarchy Process (AHP)?

The mathematician Thomas Saaty, based on works performed in the field of operations research, developed a mathematical model based on a pairwise weighting approach for multi-criteria decisions. This model is the Analytical Hierarchy Process (AHP). According to Chiou et al. (2005), the author Saaty (1971,1977, 1978 and 1980) originally proposed AHP, and this approach is now widely used in many fields, such as economic planning, portfolio selection and benefit/cost analysis by government agencies for resource allocation and so on. The AHP provides an analytical and a mathematical process resolution for the personal preferences and subjective observations of an individual or a group in decision-making, being a fine technique for dealing with problems that involve multi-criteria. It also involves the definition of various alternatives, the organisation of the objectives and the development of the decision hierarchy, to synthesize the results and examine how the modified variables affect the results. According to Saaty and Vargas (2000 op. cit. Scholl et al., 2005) "AHP is a compositional method combining preference judgments for single attributes (criteria, objectives) and their levels to general judgments on alternatives to find the most preferred solution to the problem". This technique has been used extensively since it was proposed, and it is crucial for the formalization of a complex problem using a hierarchical structure.

The identification of the decision hierarchy is the success key in supporting the decision.

According to Albayrak and Erensal (2004), the process of hierarchical decision based on information is simple, compreending three basic stages:

1. The design of the decision hierarchy - Information is decomposed into a hierarchy of criteria and alternatives;
2. The prioritization procedure - the information is then synthesized to determine the relative rankings of alternatives;
3. The calculation of results - both qualitative and quantitative criteria can be compared using informed judgments to derive weights and priorities.

Two features of the AHP differentiate it from other decision-making approaches:

- Its ability to handle both tangible and intangible attributes.
- Its ability to monitor the consistency used by a decision-maker to make his judgements.

Thus, the AHP allows us to construct hierarchical tree processes and then make judgments or perform measurements on pairs of element trees concerning a controlling element to derive ratio scales that are then synthesized throughout the structure in order to select the best alternative.

The Analytic Hierarchy Process and its Applications

According to Roper-Lowe and Sharp (1990), the AHP has been applied to problems of many disciplines. For example, applications in investment decisions for high-technology systems include the selection of computer applications like Financial or accounting software systems. Decisions concerning the selection of business computer systems might also be an appropriate application of AHP because it focuses on both tangible and intangible factors (cf. Seidmann and Arbel, 1984). Roper-Lowe and Sharp (1990) quote Boose and Bradshaw (1987), who have described how AHP is integrated into a workbench to collect human knowledge and preferences for storage in knowledge-based systems.

So is AHP a DSS? No, AHP is a theory of how prioritization or ranking decisions should be made, as well as a mathematically rigorous and proven process for supporting decision-making. It reduces one complex decision to a succession of pairwise comparisons, and then synthesizes the results. The aim is not only to help decision-makers to get the best decision, but also to provide a clear and rationale decision.

4.2 AHP and the process of choice

The process of choice may be one of the biggest difficulties facing AHP. In order to understand the choice process, we have to know how to make it. For example, according to Forman (2005), the choice process in the decision theory could be divided in four steps:

(1) Develop a hierarchy tree for the problem;

(2) Set up priorities;

(3) Synthesis;

(4) Sensitivity analysis.

However, the choice process can be treated through a composed procedure of more than four steps. Many other processes for decision-making have been published over the years, but most have similar components.

One of the most widely disseminated technique is the following seven steps method proposed by Kepner and Tregoe (1981).

1) Establish objectives

2) Classify the importance of objectives

3) Develop alternative actions

4) Evaluate alternatives against established objectives

- determine musts
- determine wants

5) Choose the best alternative to achieve the objectives as the tentative decision

6) Explore the tentative decision for future possible adverse consequences

7) Control the effects of the final decision by taking other actions to prevent possible adverse consequences from becoming problems, and by making sure the actions are carried out.

Another example of a decision process is presented on the study elaborated by Saaty (2001), the "Seven Step Process for Choice", this method of how people could work to support their choices is explained in Appendix II. However, based on the described methods, we could conclude that the working process of the AHP technique is similar to the choice processes. That is to say, one person with the AHP could do a complete decision choice process described on these methods, but this could also be done by more than one person, i.e., the AHP is a tool that could be used by a group of people to complete the choice process.

4.3 AHP for groups

In a multi-criteria group decision-making process, it is not easy to obtain a solution for the problem because of the different participant's conflict preferences and the intangible value weights for each criteria. Although, Wei et al (2000) based on the research of Madu (1994) and Bryson (1996), explains that AHP can be particularly useful in group's decision-making. Each member's assessments, of course, can be evaluated for priorities and inconsistency, and then the group rollup (and group segments) can be synthesized and viewed by the same way. This can be a powerful way to build consensus, as each constituents can see where they stand and compare it to the group as a whole. If the group has a high inconsistency ratio (more than 0.1, or so) segmenting might reveal agreement differences and why they occur. That, too, can also help lead to better understanding and consensus.

4.4 How AHP works?

The analytic hierarchy process methodology

The most creative part of decision making, that has an important effect on the outcome, is modelling the problem. In order to do such modelling, it is important to understand how AHP model works.

AHP begins with the objectives, and then with the break-down of a complex multi-criteria decision making problem into a hierarchy of interrelated decision elements (criteria decision alternatives). The AHP model is based on levels of comparisons and works by developing the criteria that are used to judge the alternatives and the priorities for those alternatives. The first comparisons are made at the lowest level, which involves attributes of each criterion. It also implements a pairwise comparison of the criteria with respect to the upper level goal, Saaty (1988). Finally, each alternative (highest level) is evaluated with each of the other alternatives.

To demonstrate how it works we could divide it into four steps:

- The Analytical Hierarchy Process Step-by-Step

The first step is developing a hierarchical representation of the problem (structuring the problem hierarchically) or, in other words, the principal idea is to build a hierarchy, which describes the problem, so the overall goal is placed at the top, the "parent" attributes, with the main attributes that can be further sub-divided in lower levels. However, the top level of hierarchy consists of only one element, which is the proposed main objective. The next level defines the attributes or criteria: these are the elements that affect the decision. At the bottom level, or the lowest level of the hierarchy, appear the elements, referred as decision alternatives or decision options.

However, between the top and bottom levels there are the relevant attributes of the decision problem to compare alternatives. The number of levels in the hierarchy depend on the complexity of the problem and in what is the hierarchy model that the decision maker developed for the problem. When managers or decision makers take policy decisions for investment planning, it is extremely important to evaluate carefully the possible alternatives. It is not easy to take decision about IS/IT investments, because the issues that one is trying to address are influenced by multiple factors, such as technical, political and financial issues, and so on.

In the second step, once the hierarchical representation is already identified, we have to adopt a policy analysis that allows generating the relational data for comparing the alternatives and to determine the relative priority of each attribute using the comparisons (a sequence of pairwise comparison judgments). The decision process becomes complex and increases the need for an approach that allows the decision-maker to break the evaluation process down into a series of assessments for the different factors involved. However, it is always important to remember that AHP makes assessments, prioritization and selection among options more readily measurable.

In the third step, we have to calculate the weights or priorities of the lowest level alternatives relative to the top-most objective. The goal of this stage is to derive weights for the lowest-level attributes. This is made by a series of pairwise comparisons in which every attribute on each level is compared in terms of their importance to the parent. Arithmetic Matrix allows the overall weights of the lowest-level attributes to be calculated. The options available to the decision-maker are scored with respect to the lowest-level attributes. This is also done by using the pairwise comparison technique.

The final step is to adjust the options' scores to reflect the weights given to the attributes and to sum the adjusted scores to yield a final score for each option.

The priority processes problem appears and one has to deal with it, because the priority criteria are implemented according to their importance in order to achieve the objective. This is even more important as the priorities are influenced by the alternatives on each criterion. The calculation of these priorities is derived or based on pairwise assessments, using ratios of measurements based on decisions from a scale, if such scale exists.

In the next section, some examples are provided to illustrate the Analytical Hierarchy Process.

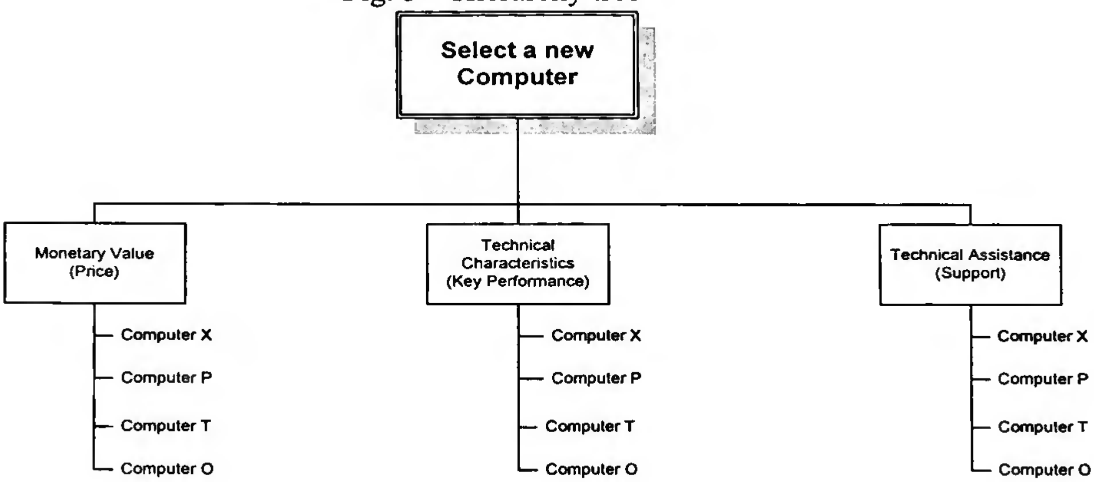
Developing the performance hierarchy

This essay aims to explain the steps of the AHP by using the example of making a recommendation for the best IS/IT investment for public organisations.

In order to simplify, we assume that there is one objective O_1, and that we are trying to establish a normalized set of weights to be used when comparing alternatives using this objective.

As we can see in the previous chapter, the first step of the AHP consists of developing a hierarchical structure of the assessment problem. The complex decision problem is structured as a hierarchy tree as we can see in Fig. 5.

Fig. 5 – Hierarchy tree



According to Fig. 5, the criteria and alternatives are established into a hierarchical structure similar to a family tree. The hierarchy has three levels: the objective of the problem at the top, multi-criteria that define alternatives in the middle, and competing alternatives (decision alternatives) at the bottom.

Once the problem has been devised and the hierarchy constructed, prioritization procedure starts in order to determine the relative importance of the elements within each level. The pairwise judgment starts from the second level of the hierarchy tree (first level of criteria) and finishes in the lowest level (alternatives).

The process of building this structure helps not only to identify more correctly all the elements of the decision, but also to be acquainted with (to recognize) the interrelationships between them. The question that arises is how to determine the relative importance of the criteria?

Now, we have to use some judgments to determine the ranking of the criteria. For example, we could consider that: Monetary value is 2 times more important than Technical Features; or Technical Features are 3 times more important than Technical Assistance; or Monetary Value is 4 times more important than Technical Assistance. These judgments are based on human opinions or in what we call intangible factors; the referred judgments are not very consistent. But, we have to start with something and these judgments are the beginning of a classification process. Although allowed, judgment inconsistency should be measured. This measure would help the decision maker to improve his judgment and to better understand the problem.

After developing the hierarchy tree, we have to determine the relative weights of the alternatives' comparison priorities and, for each priority, perform measurements.

The pairwise comparisons, or the choice of one or two elements on each paired comparison, determine the relative dominance or the relative importance of one criterion over another, and can be expressed by a classification rule with these conditions:

- In order to simplify, we assume that there are three (3) Criteria – C_1, C_2, C3 and four (4) Alternatives - A_1, A_2, A_3, and A_4.
- For a pairwise comparison Matrix M, where the number in the i_{th} row and j_{th} column gives the relative importance of A_i as compared with A_j.

Table 1 - Nine-point intensity of importance scale and its description

Definition	Intensity of importance
Equally important	1
Moderately more important	3
Strongly more important	5
Very Strongly more important	7
Extremely more important	9

Source: adapted from Saaty (1994)

Using the 1 – 9 scale, we could classify the pairwise comparison, for example:

– aij = 1 if the two objectives are equal in importance

– aij = 3 if Ai is moderately more important than Aj

– aij = 5 if Ai is strongly more important than Aj

– aij = 7 if Ai is very strongly more important than Aj

– aij = 9 if Ai is absolutely more important than Aj

– aij = 1/3 if Aj is moderately more important Ai

In order to determine the relative weights (the weights are determined using pairwise comparison between each pair of criteria); it is asked to make pairwise comparisons using a 1-9 preference scale (see Table 1). Each comparison is then transformed in a numerical value. For example, if Monetary value criteria is judged to be "Moderately more important" than Technical Assistance in supporting the choice for the best computer, a score of 3 is given.

In Table 2, it is illustrated the Matrix of the comparative values of the criteria elements.

Table 2 - Comparison of Criteria Elements

	Monetary Value	Technical Characteristics	Technical Assistance
Monetary Value	1/1	1/2	3/1
Technical Characteristics	2/1	1/1	4/1
Technical Assistance	1/3	1/4	1/1

In order to get the values to support the decision, we have to think how to turn this Matrix into a criteria-ranking vector. The question is how to get a ranking of priorities from a pairwise Matrix?

Pairwise comparison of criteria and calculating the relative weights

The process of using paired comparisons to develop the prioritization is a simple and intuitive approach: it puts some restrictions on the cognitive demand of the decision maker and provides a means for checking the consistency of the comparisons between the chosen alternatives. However, the problem is usually the criteria, whose choice is made by the decision-maker (irrelevant criteria is not included in the hierarchy). Yet, sometimes the criteria are measured on different scales, such as weight and length or even by intangible measures for which there are still no scales. This is one of the biggest problems, because measurements on different scales cannot be directly combined, towards ranking the alternatives.

According to Saaty (1999), there are at least three modes for arriving at a ranking of alternatives:

- Relative;
- Absolute;

- Benchmarking.

In a relative way, it ranks few alternatives by comparing them in pairs and it is particularly useful in new and exploratory decisions.

The absolute mode rates an unlimited number of alternatives (rated alternatives can then be compared against each other by using the relative mode to obtain further refinement of the priorities), one at a time, on intensity scales constructed separately for each covering criterion. It is particularly useful in decisions where there is a great deal of knowledge to judge the relative importance of the intensities and develop priorities for them.

Finally, in Benchmarking mode, alternatives are ranked by including a known alternative in the group and comparing it with the other.

The paired comparisons are used to express judgments and these are automatically linked to a necessary numerical scale of absolute numbers (derived from stimulus - response relations) from which the principal eigenvector of priorities is then derived. In the referred eigenvector, there are the representations of the dominance of each element with respect to the other elements. If one element does not have an important or particular property for the objective, it is automatically assigned the value zero in the eigenvector without being included in the comparisons.

Saaty (2001) recommends the eigenvector solution, which is a mathematical demonstration of how to obtain the final ranking for the criteria elements.

Synthesizing the idea of how to solve the eigenvector problem:

1. Raise the pairwise Matrix to powers that are successively squared each time;

2. Proceed with the row sums of the Matrix, which are then calculated and normalized;
3. The Matrix calculations finish when the sums in two consecutive operations have a very small value or are smaller than a prescribed value.

Next, the fractional values of the Matrix showed in Table 2, are converted to decimals, as represented in Table 3.

Table 3

	Monetary Value	Technical Characteristics	Technical Assistance
Monetary Value	1,0000	0,5000	3,0000
Technical Characteristics	2,0000	1,0000	4,0000
Technical Assistance	0,3333	0,2500	1,0000

The dominance along all possible paths is obtained by raising the Matrix to powers and normalizing the sum of the rows. This is the moment to proceed with the squaring Matrix as shown in Table 4.

Table 4

	Monetary Value	Technical Characteristics	Technical Assistance
Monetary Value	1,0000	0,5000	3,0000
Technical Characteristics	2,0000	1,0000	4,0000
Technical Assistance	0,3333	0,2500	1,0000

X

	Monetary Value	Technical Characteristics	Technical Assistance
Monetary Value	1,0000	0,5000	3,0000
Technical Characteristics	2,0000	1,0000	4,0000
Technical Assistance	0,3333	0,2500	1,0000

Then, we have to perform the calculation of the two Matrixes. We can observe an example for cell m(1,1) of the final Matrix in table 5: (1.000 * 1.000) + (0.5000 * 2.000) + (3.000 * 0.3333) = 3.000

Table 5

	Monetary Value	Technical Characteristics	Technical Assistance
Monetary Value	3,0000	1,7500	8,0000
Technical Characteristics	5,3333	3,0000	14,0000
Technical Assistance	1,1667	0,6667	3,0000

Now, the first eigenvector is processed with the sum of the row totals and finally normalized by dividing the row sum by the row totals.

Table 6

	Monetary Value	Technical Characteristics	Technical Assistance	Sum Rows
Monetary Value	**3,0000**	**1,7500**	**8,0000**	**12,7500**
Technical Characteristics	**5,3333**	**3,0000**	**14,0000**	**22,3333**
Technical Assistance	**1,1667**	**0,6667**	**3,0000**	**4,8334**

At this moment, we have obtained the first eigenvector, as shown on table 7. This process must be iteration-based. The process will be repeated until the vector (so called eigenvector) does not change or the change is extremely small compared with the vector of the previous calculation.

Table 7

Sum Rows		Eigenvector $= X_{1..3}$ / □ X
X_1 =	12,7500	0,319415182
X_2 =	22,3333	0,559497654
X_3 =	4,8334	0,121087164
□ X =	39,9167	1

To obtain the result for the next eigenvector, we must square the following Matrix.

Table 8

	Monetary Value	Technical Characteristics	Technical Assistance
Monetary Value	**3,0000**	**1,7500**	**8,0000**
Technical Characteristics	**5,3333**	**3,0000**	**14,0000**
Technical Assistance	**1,1667**	**0,6667**	**3,0000**

Then, proceed with the same calculation method as shown above. The result is the Matrix shown in table 9.

Table 9

	Monetary Value	Technical Characteristics	Technical Assistance
Monetary Value	27,6667	15,8333	72,5000
Technical Characteristics	48,3333	27,6667	126,6667
Technical Assistance	10,5556	6,0417	27,6667

Then compute once more the eigenvector, to do this, proceed with the same calculation method as shown above. The sum results can be observed in table 10 and the value of the second eigenvector is computed in table 11.

Table 10

	Monetary Value	Technical Characteristics	Technical Assistance	Rows Sums
Monetary Value	27,6667	15,8333	72,5000	116.0000
Technical Characteristics	48,3333	27,6667	126,6667	202,6667
Technical Assistance	10,5556	6,0417	27,6667	44,2640

Compute the eigenvector:

Table 11

Rows Sums	Eigenvector $= X_{1..3} / \Sigma X$
116.0000	0,3196
202,6667	0,5584
44,2640	0,1219
362,9306	1

This is the moment to compute the difference between the two eigenvectors and to determine if the vector in cause is acceptable, see table 12.

Table 12 - Difference between the Eigenvector

Eigenvector 1	Eigenvector 2	Difference
0,3194	0,3196	- 0,0002
0,5594	0,5584	0,0011
0,1210	0,1219	- 0,0009

The difference between the two vectors is extremely small. Thus, it is better to accept the eigenvector 2, which gives us the relative ranking of our criteria (table. 12a and table 12b).

Table 12a

	Monetary Value	Technical Characteristics	Technical Assistance
Monetary Value	1/1	1/2	3/1
Technical Characteristics	2/1	1/1	4/1
Technical Assistance	1/3	1/4	1/1

Table 12b

	Eigenvector 2	
Monetary Value	0,3196	The second most important criteria
Technical Characteristics	0,5584	The most important criteria
Technical Assistance	0,1219	The least important criteria

Summary of the AHP application for criteria selection:

In order to determine what IS/IT investment (Computer) to select, Saaty's (1980) AHP was applied to determine the priority values in the following way:

- First, the priority rankings were determined from a hierarchy that was based upon, for example, 3 criteria and 4 alternatives.

The ranking preservation is an intrinsic decision making. That is, any decision theory must have at least two modes of synthesis. In the AHP, they are called the distributive and ideal modes, holding guidelines for which mode to use. The rank can always be preserved by using the ideal mode in both absolute and relative measurement.

- Second, the criteria were compared on a pairwise basis and this produced a ranked score for each type of investment on each criterion. Multiplying these scores provides a summary score for each determined criterion and each of the alternatives was compared based on the criteria in the same way.
- Third, the eigenvalues of the square Matrix, the preference vector, are then computed to determine the relative ranking of the three criteria in selecting the best alternative.
- Fourth, based on the given preference vectors, the three evaluation criteria for the example selected are ranked as follows: Technical Characteristics is the most important criterion for the best computer investment whereas Technical Assistance is the least important.

Overall ranking of alternatives

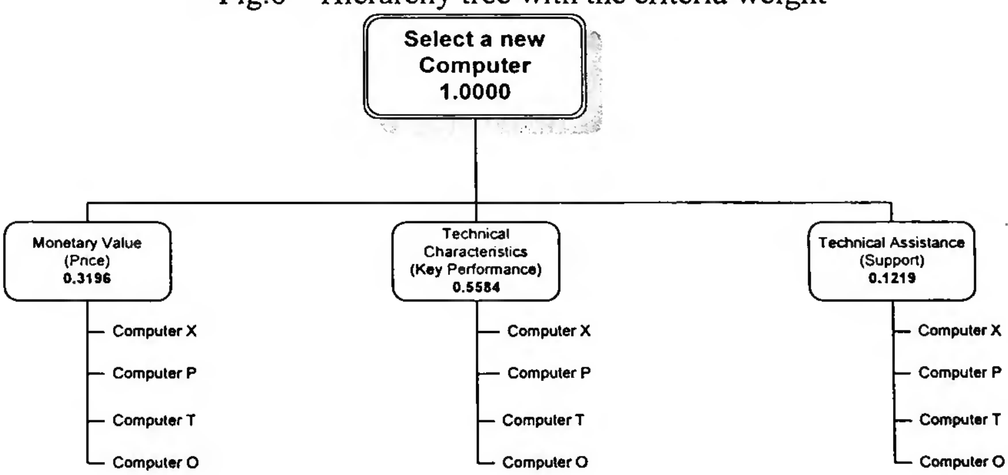
After setting up the hierarchy and pairwise comparisons of the criteria weights and the alternative scores, it is necessary to calculate the global value of the alternatives' priority. A proof demonstrated by Saaty (1994) shows that the optimal set of scores is the principal eigenvector of the pairwise comparison Matrix.

The principal vector is the relative ranking of the evaluation criteria with respect to the goal. Applying Saaty's eigenvector method to these data, it is possible to estimate the weights that are calculated for each pairwise comparison Matrix for each level of the hierarchy. In order to synthesize the results over all levels, the priorities at each level are weighted by the priority of the higher-level criterion according to the respective comparison.

The AHP eigenvector scaling technique modelled the relative weights for each category (priorities) and for each ratio (local weights). Global weights for each ratio were calculated as the product of its local weight and its category's priority.

In fig. 6, we can observe the tree with the criteria weight

Fig.6 – Hierarchy tree with the criteria weight



After computing the ranking values for criteria, we have to start thinking in calculating of the relative weights for the alternative elements. For each criterion we have to calculate the ranking for the alternative elements.

In each level, the elements are compared pairwise, according to their values of influence and based on the specified element in the higher level (Criteria). The decision maker must express his preference between each pair of elements (collecting input data of decision elements).

In terms of criterion 1 (Monetary values), the pairwise comparisons of the alternative elements are presented in table 13. Once more, we use the eigenvector to determine the relative ranking.

Table 13 - Comparison of Alternative Elements

Monetary Value	Computer X	Computer P	Computer T	Computer O
Computer X	**1/1**	**1/4**	**4/1**	**1/6**
Computer P	**4/1**	**1/1**	**4/1**	**1/4**
Computer T	**1/4**	**1/4**	**1/1**	**1/5**
Computer O	**6/1**	**4/1**	**5/1**	**1/1**

When we square the Matrix above we get this one in table 14.

Table 14

	Computer X	Computer P	Computer T	Computer O	Row Sums
Computer X	**4,0000**	**2,1667**	**9,8333**	**1,1958**	17,1958
Computer P	**10,5000**	**4,0000**	**25,2500**	**1,9667**	41,7167
Computer T	**2,7000**	**1,3625**	**4,0000**	**0,5042**	8,5667
Computer O	**29,2500**	**10,7500**	**50,0000**	**4,0000**	94,0000

After two iterations, computing the eigenvector, and the eigenvector result is the following (table 15):

Table 15

Row Sums	**Eigenvector**
355,8167	**0,1168**
748,5979	**0,2458**
184,9260	**0,0607**
1755,7656	**0,5765**
3045,1063	**1**

The relative ranking of the elements' alternatives, see table 16:

Table 16

	Eigenvector	Ranking
Computer X	**0,1168**	**3**
Computer P	**0,2458**	**2**
Computer T	**0,0607**	**4**
Computer O	**0,5765**	**1**

In terms of monetary value this analysis demonstrates that the element Computer O is the best value, computer P is the second best, computer X is in the third place and computer T is the fourth.

Criteria 2 – Technical Characteristics

Table 17 - Comparison of Alternative Elements

Technical Characteristics	Computer X	Computer P	Computer T	Computer O
Computer X	**1/1**	**2/1**	**5/1**	**1/1**
Computer P	**1/2**	**1/1**	**3/1**	**2/1**
Computer T	**1/5**	**1/3**	**1/1**	**1/4**
Computer O	**1/1**	**1/2**	**4/1**	**1/1**

When we square the Matrix above we get this one in table 18.

Table 18

	Computer X	Computer P	Computer T	Computer O	Row Sums
Computer X	**4,0000**	**6,1667**	**20,0000**	**7,2500**	37,4167
Computer P	**3,6000**	**4,0000**	**16,5000**	**5,2500**	29,3500
Computer T	**0,8167**	**1,1917**	**4,0000**	**1,3667**	7,3750
Computer O	**3,0500**	**4,3333**	**14,5000**	**4,0000**	25,8833

Then, compute the eigenvector. After two iterations, we get this result for the eigenvector, see table 19.

Table 19

Row Sums	**Eigenvector** = $X_{1..3}$ / □ X
665,8125	**0,3788**
509,6750	**0,2899**
130,4063	**0,0741**
451,7750	**0,2570**
1757,6688	**1**

The relative ranking of the elements' alternatives:

Table 20

	Eigenvector	**Ranking**
Computer X	**0,3788**	**1**
Computer P	**0,2899**	**2**
Computer T	**0,0741**	**4**
Computer O	**0,2570**	**3**

In terms of Technical Characteristics, this analysis demonstrates that the element Computer X is the best value, the computer P is the second best, computer O is in third place and computer T is fourth.

Criteria 3 – Technical assistance

Table 21 - Comparison of Alternative Elements

Technical Assistance	Computer X	Computer P	Computer T	Computer O
Computer X	**1/1**	**3/1**	**3/1**	**2/1**
Computer P	**1/3**	**1/1**	**4/1**	**3/1**
Computer T	**1/3**	**1/4**	**1/1**	**1/4**
Computer O	**1/2**	**1/3**	**4/1**	**1/1**

When we square the Matrix above, we obtain the Matrix in table 22.

Table 22

	Computer X	Computer P	Computer T	Computer O
Computer X	**4,0000**	**7,4167**	**26,0000**	**13,7500**
Computer P	**3,5000**	**4,0000**	**21,0000**	**7,6667**
Computer T	**0,8750**	**1,5833**	**4,0000**	**1,9167**
Computer O	**2,4444**	**3,1667**	**10,8333**	**4,0000**

Compute the eigenvector. After two iterations, we get this result for the eigenvector, see table 23:

Table 23

Row Sums	**Eigenvector**
971,7639	**0,4387**
656,3657	**0,2963**
174,7199	**0,0788**
412,1088	**0,1860**
2214,9583	**1**

The relative ranking of the elements' alternatives:

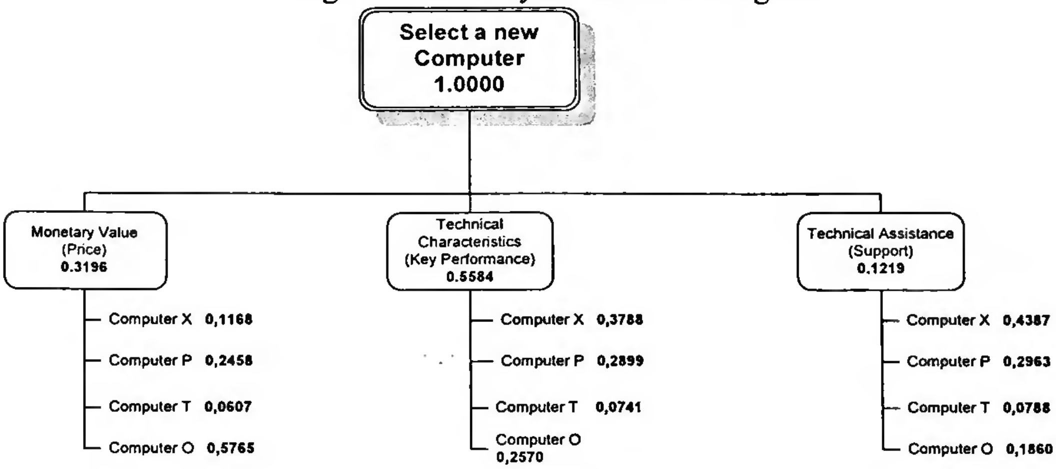
Table 24

	Eigenvector	**Ranking**
Computer X	**0,4387**	**1**
Computer P	**0,2963**	**2**
Computer T	**0,0788**	**4**
Computer O	**0,1860**	**3**

In terms of Technical Characteristics, this analysis demonstrates that the element Computer X is the best value, computer P is the second best, computer O is in third place and computer T is fourth.

At this moment, we have the values for the criteria and the values for the alternatives, seen in the hierarchy tree with all weights, Fig. 7.

Fig. 7 – Hierarchy tree with all weights



Now, we will calculate the Matrix with the ranking values. First, we have the Matrix with the final ranking weights for the alternatives as shown in table 25.

Table 25

	Monetary Value	**Technical Characteristics**	**Technical Assistance**
Computer X	**0,1168**	**0,3788**	**0,4387**
Computer P	**0,2458**	**0,2899**	**0,2963**
Computer T	**0,0607**	**0,0741**	**0,0788**
Computer O	**0,5765**	**0,2570**	**0,1860**

Second, we compute the Matrix of alternatives' weights with the vector obtained in the Ranking for the Criteria. The result is shown in the following table.

Table 26

Ranking For Criteria	
0,3196	Monetary Value
0,5584	Technical Characteristics
0,1219	Technical Assistance

For example, the value for the element Computer X is calculated as follows: (0,1168*0,3196)+(0,3788*0,5584)+(0,4387*0,1219) = 0,3023

The result of this calculation is presented by the following table.

Table 27

Computer X	**0,3023**
Computer P	**0,2766**
Computer T	**0,0704**
Computer O	**0,3504**

In conclusion, the best computer to buy is Computer O because it has the major value.

Thus, after analysing the example above, we find that the estimation of priorities from pairwise comparison matrices is one of the biggest AHP problems. The priority vector can be derived from the comparison matrices using different techniques, such as the Eigenvector Method (EVM) proposed by Saaty (1977). This traditional method proves that the main eigenvector of the comparison Matrix can be used as a priority vector for consistent and inconsistent preferences. Nevertheless, there are several other methods and we will discuss them in next section.

4.5 The challenge of prioritization

As we have seen in previous chapters, the AHP decision problem is hierarchically structured at different levels, when each level consists of a finite number of elements. The priorities represent the relative importance of the decision elements at that level. For all hierarchy levels, the prioritisation of the elements is carried out with respect to the elements of the upper level. The evaluation of the priorities at a certain level is performed by pairwise comparisons. In the pairwise comparison, it is assumed that the decision-maker can compare any of the two elements and can provide a numerical value of the ratio of their relative importance. In the decision-making field, the priority concept is of major importance, i.e., the importance of how the priorities are derived can make the difference between a wrong or right decision. This is why the estimation of the priorities from pairwise comparison matrices is one of the most important components of the Analytical Hierarchy Process (AHP).

In order to understand the importance of deriving priorities from comparison matrices, we have to consider prioritisation of n elements V_1 V_2 ..., V_n at the same level of the hierarchy. Comparing any of the two elements V_i and V_j the decision-maker assigns the value a_{ij}, which represents a judgement concerning the relative importance of preference of decision element V_i over V_j. If element V_i is preferred over V_j then $a_{ij} > 1$. Correspondingly, the reciprocal property $a_{ij} = 1/a_{ij}$ for j = 1,2, ..., n, and i = 1,2, ..., n is always maintained.

Each set of comparisons for a level with n elements requires n(n-1)/2 judgements. So, a positive reciprocal Matrix of pairwise comparisons $M = \{ a_{ij} \} \in \Re^{n \times n}$ is constructed. Then a priority vector $w = (w_1\ w_2\ ...,\ w_{n,})^T$ may be derived from this Matrix. The set of n relative priorities is normalised to the sum of one, therefore the number of independent normalised priorities is (n-1). When the decision-maker is perfectly consistent with his judgements, then all elements a_{ij} have perfect values $a_{ij} = w_i / w_j$. In this case we have $a_{ij} = a_{ik}a_{kj}$ for all i, j, k = 1, 2, ..., n. Then, the pairwise comparison Matrix M is consistent and can be represented as $M_x = \{ w_i / w_p \}$. The consistent priorities are unique and readily available by taking the elements in any column of the comparison Matrix M_x and then dividing each of them by the sum of all elements of the column.

However, the decision-maker's evaluations a_{ij} are frequently not perfect, they are only estimations of the exact ratios w_i / w_j. Such inconsistent judgements are more common and then M is an inconsistent Matrix, which can be considered as disturbing the consistent Matrix M_x. The inconsistent priorities are not unique and should be derived using an estimation technique.

The priority vector can be derived from the matrices using different techniques, as mentioned in the previous section: One of the most commonly used is the Eigenvector Method (EVM). However, there are several other techniques, for example, the Logarithmic Least Squares Method (LLSM) proposed by Crawford and Williams (1985), Direct Least Squares Methods (DLSM) proposed by Chu et al (1979), while Mikhailov, L. (2000) proposed the Fuzzy Programming Method (FPM) that is based on the geometrical representation of the prioritisation of the process.

The following paragraphs, present some of the prioritisation methods that can be used.

Least squares methods

According to Chu et al (1979, op. cit. Mikhailov, 2000), the Direct Least Squares Method (DLSM) is a method based on the hypothesis that the elements of the vector $v = (v_1, v_2, v_3, \ldots, v_n)^T$ should satisfy the property $a_{ij} \approx v_i / v_j$; as a result the priorities are formulated like a forced optimisation problem:

$$\min \sum_i \sum_j (a_{ij} - v_i/v_j)^2 \qquad (1)$$

Subject to

$$\sum_{i=1}^{n} v_i = 1, v_i > 0, \qquad i=1,2, \ldots,n \qquad (2)$$

There is no special treatment for the nonlinear optimisation problem above presented and, in general, it has multiple solutions. For example, in order to eliminate the disadvantage of the DLSM, Chu et al modified the objective function (2), presenting it in the following form:

$$\min \sum_{i}\sum_{j}(v_j - a_{ij}v_j)^2 \quad (3)$$

Weighted least squares methods

According to Mikhailov (2000) and Srdjevic (2002), the author Chu et al (1979) proposed this method as a modification of the direct least-squares method (DLS). The Weights measurements in Least Squares Method (WLSM) consist in the minimisation of (3), subject to the additive normalising and non-negative constraints given by (2).

$$\min \sum_{i}\sum_{j}(v_i - a_{ij}.v_j)^2 \qquad (4)$$

Subject to

$$\sum_{i=1}^{n} v_i = 1 \qquad (5)$$

The WLSM reduces the solution of the above optimisation problem to a system of linear equations that can be easily solved. Blankmeyer (1987) shows that the WLSM provides a unique and strictly positive solution ($v_i > 0$, i= 1,2,...,n).

Logarithmic least squares method (LLSM)

According to Mikhailov (2000) and Srdjevic (2002), the LLSM, also known as Geometric Mean Method (GMM), also uses the least square methods to define the objective function of the following optimization problem. The LLSM minimises the objective function:

$$\sum_i \sum_j (\ln a_{ij} - \ln W_i + \ln W_j)^2 \qquad (6)$$

Subject to the multiplicative normalising constraints

$$\prod_{i=1}^{n} w_i = 1, w_i > O, \qquad i = 1,2,...,n \qquad (7)$$

This method is widely used due to its simplicity.

Crawford and Williams (1985) have proved the validity of this method. They have shown that the solution for the problem (7) is unique and can be found as the geometric mean of the rows of Matrix A,

$$Wj = \prod_{j=1}^{n} (a_{ij})^{1/n}, \qquad i = 1, 2, ..., n \qquad (8)$$

Goal Programming method (GPM)

According to Mikhailov (2000) and Srdjevic (2002), this method, proposed by Bryson (1995), considers that the priorities are desired to satisfy the equalities

$$(\frac{w_i}{w_j})(\frac{\delta_{ij}^{+}}{\delta_{ij}}) = a_{ij} \quad i = 1 - 1,2,...,n, \quad j = 1,2,...,n, j > 1, \qquad (9)$$

$\delta_{ij}^{+} \geq 1$ and $\delta_{ij}^{-} \geq 1$ are additional deviation variables, which cannot be both greater than 1. The priorities are obtained as solutions of the following linear goal-programming problem:

$$\min \sum_{i=1}^{n} \sum_{j>1}^{n} (\log \delta_{ij}^{+} + \log \delta_{ij}^{-}) \qquad (10)$$

Subject to

Log wi – log wj + log δ_{ij}^{+} – log δ_{ij}^{-} = log aij, I = 1,2,…,n; j>I, (11)

Where all log δ_{ij}^{+} and log δ_{ij}^{-} are non-negative.

Summary

The prioritisation process solves the problem of having to deal with different types of scales, by interpreting their significance to the values of the user or users. Finally, a weighting and adding process is used to obtain overall priorities for the alternatives to contribute for the goal. This process of weighting and adding have to be done arithmetically prior to the AHP, in order to combine alternatives measured under several criteria having the same scale, which is used to obtain an overall result. A scale such as money is often common to several criteria. With the AHP, a multidimensional scaling problem is thus transformed in one-dimensional scaling problem.

When asked to rank or rate a list of things, according to some criterion, such as preference, value, risk or cost, one might be able to rank their order and even to assign some numbers to their relative positions on the list. However, two problems arise in that simple scenario:

- First, when there are more than a few items on the assessment list, it is difficult to keep all the prioritization considerations in one's mind at the same time – making it hard to think about it and to complete the task.
- Second, whatever measurement scale is chosen, it will be just ordinal at best. A rating 10 does not mean the preference, risk or whatever (One might be tempted to treat the numbers as a ratio scale, but there is really no basis for it.)

4.6 Theory of the consistency ratio

In order to measure the consistency of the evaluator's judgment through pairwise comparisons, the AHP model uses a consistency index (CI). The consistency index reflects the consistency of qualitative judgments of the importance of criteria and the impact of the degree (or strength) of importance on all comparisons.

However, an interesting side effect of asking a person or persons to make a series of pairwise ratio-based comparisons is the way that they "forget" prior assessments as they go on. If their understanding of the system is coherent, the whole set of pairwise comparisons should stack up in a self-consistent way.

In a preference assessment, if a person places A five times more important than B, and B five times more important then C, then A had to be twenty five times greater than C. However, this is not possible, as the scale lies between 1 and 9. Also, if A is much greater than B and B is much greater than C, and if A is slightly greater than C and B slightly greater than C, it has created a set of circumstances that do not make sense as a whole. It has revealed inconsistency. This could show that a respondent was not paying attention or that they do not understand the dynamics of the assessment well enough to see things clearly.

As it has been demonstrated in previous chapters, AHP is a method of breaking down a complex problem into its components level: these levels are set into a hierarchical order, in which each level or variable, is assigned a numerical value depending on its relative importance. The attribution of the values depends on subjective judgments that determine the overall priorities of the variables. Or, in other words, AHP is a method that derives ratio scales from reciprocal comparisons

The measure of consistency of pairwise comparisons

The authors Saaty and Vargas (1982) provide a table of different-order random matrices and their average consistencies. These random consistency numbers indicate on a random basis the numerical judgment, which can be used to compare with the CI. It should be noted that the quality of the output of the AHP is strictly related to the consistency of the pairwise comparison judgments given by decision makers. Saaty (1977) suggests a simple procedure to check consistency: The pairwise comparisons generate a Matrix of relative rankings for each level of the hierarchy. After all matrices are developed and all pairwise are obtained, it is the moment to proceed with the calculations of the relative weights or the degree of relative importance amongst the elements (eigenvector), in order to control the result of the method, the consistency ratio for each of the matrices and overall inconsistency (global weights) for the hierarchy are calculated.

In short, we have to calculate the eigenvector or the relative weights and the maximum eigenvalue λ_{max} for each Matrix of order n.

The deviations from consistency are expressed by the following equation consistency index and the measure of inconsistency is called the consistency index (CI).Compute the consistency index for each Matrix of order n, with the following formula:

$$CI = (\lambda_{\max} - n)/(n-1)$$

The ratio of CI to the random consistency number of the same size Matrix is called the consistency ratio (CR). The consistency ratio (CR) is used to estimate directly the consistency of pairwise comparisons. The consistency ratio (CR) is computed by dividing the CI by a value obtained from a table of Random Consistency Index (RI).

$$CR = CI / RI$$

Where RI is a known random consistency index obtained from a large number of simulations calculus, based on Saaty (2000), there is one table with the average random index (RI) based on the following Matrix.

Table 28 – Average Random Index

Size of the Matrix (n)	Random consistency Index (RI)
1	0
2	0
3	0.52
4	0.89
5	1.11
6	1.25
7	1.35
8	1.40
9	1.45
10	1.49

Source: adapted from Saaty (2000)

In this case, for the pairwise Matrix of three alternative with respect to Technical Characteristics criteria, means that the largest eigenvalue in the Saaty's EVM is $\lambda max = 3.03$, the Saaty's inconsistency index is CI = 0.002 and the consistency ratio is CR = 0.025. The consistency ratio for matrices n>=5 is CR < 0.1 (0.1 is the maximum allowable CR for the EVM); these values are obtained from Saaty (2000) and Cheng and Li (2001).

A CR less than .10 is considered to be appropriated. If the CR is more than .10, the evaluator should reassess the adequacy of his pairwise comparisons and make revisions.

In this application, all CR inconsistency ratios values are lower than 0.1 (CR < 0.1), therefore all the judgments are consistent. An acceptable consistency value helps to ensure the decision maker reliability in determining the priorities of a set of criteria.

The AHP will produce a prioritized evaluation of each of the alternatives. Each alternative (Management by Instruction, Objective, and Values) will receive a score in all criteria. The criteria scores are combined into an overall score. The overall score indicates the relative importance of each alternative.

AHP Summary

The AHP process determines the consistency ratio (CR) for all matrices. According to Saaty (1980), the suggested or acceptable upper limit for CR is less than 0.10; an identical or lower CR value will not affect the ratings. If the CR value is larger than 0.10, it means that there is a 10% chance that the elements have not been properly compared. In this case, the decision maker must review the comparisons made.

Inconsistency ratios (which involve some Matrix math) greater than 0.1 are generally viewed as a concern. Ratios lower than 0.1 reflect a coherent set of assessments. The inconsistency ratio, as well as AHP preference rankings, provide useful guidance about how to interpret information coming from an individual or a group.

In order to improve AHP's fit to the reality, where some features or elements just haver to be there, we have created the Cut-off Matrix for AHP.

4.7 Cut-off Matrix for AHP

As seen previously, the fact that AHP allows inconsistency may result from the fact that in making judgments people are likely to be cardinally inconsistent and ordinal intransitive. Otherwise people would be like robots, unable to change their minds upon new evidence and unable to look within for judgments which represent their thoughts and feelings.

After designing the preference matrices, a mathematical process begins in order to normalize and find the priority weights for each Matrix (using for example the EVM - eigenvalue method to estimate the relative criteria weights of the decision elements and rating the decision alternatives).

However, in order to improve the process of solving priority problems, we recommend a Matrix with cut-off values in order to warrant some features that must be present in the final choice.

What are the cut-off values?

- Cut-off values - The minimum preference value (based on the ranking for the criteria) that is permitted for the criteria elements based on qualitative and quantitative factors.
- The cut-off value Matrix – A Matrix where decision makers directly input the minimum preference values. The elements (the final ranking weights for the alternatives) of the Matrix cannot be lower than the decision maker selected minimum preference value, otherwise the respective alternatives should be eliminated from the AHP calculation for the final ranking result.

In order to explain the use of the cut-off Matrix we are going to use the above example of selecting a new computer. First, we have to think in the minimum preference values for the criteria. Second, the elements value of the alternatives final ranking Matrix should not be lower than the decision maker's choice in the minimum preference value (cut-off values) table.

Based on the minimum preference values table, we defined the cut-off values for the criteria elements.

Table 29 – Cut-off values reflecting the minimum Preference Value

	Minimum Preference Value
Monetary Value	**0,05**
Technical Characteristics	**0,10**
Technical Assistance	**0,10**

If the values of the final ranking weights for the alternatives are lower than the correspondent value of the minimum preference value, then we cut-off the value of the pairwise elements, the correspondent alternative will be deleted from the final ranking computed by AHP. For example, the Cut-off Values Matrix in terms of their applicability works according to table 30:

Table 30 – Cut-off Value Matrix

	Monetary Value	**Effect**	**Technical Characteristics**	**Effect**	**Technical Assistance**	**Effect**
Computer X	**0,1168 > 0,05**	✓	**0,3788 > 0,10**	✓	**0,4387 > 0,10**	✓
Computer P	**0,2458 > 0,05**	✓	**0,2899 > 0,10**	✓	**0,2963 > 0,10**	✓
Computer T	**0,0607 > 0,05**	✓	**0,0741 > 0,10**	✗	**0,0788 > 0,10**	✗
Computer O	**0,5765 > 0,05**	✓	**0,2570 > 0,10**	✓	**0,1860 > 0,10**	✓

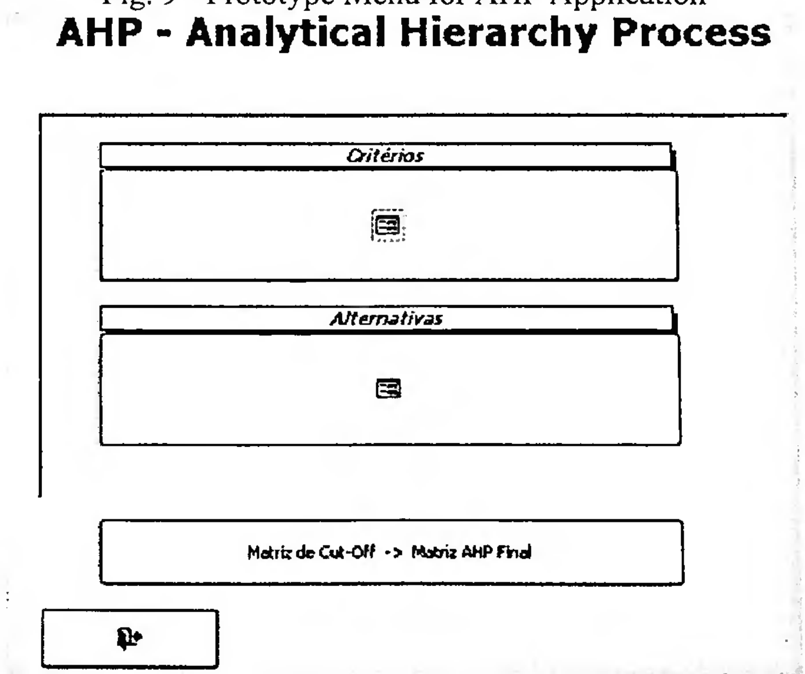
Using the Cut-off value Matrix above, the alternative "Computer T" is out of the calculation for the final ranking of the best computer to buy. The AHP computes the final ranking just for the alternative computers X, P and O.

4.8 The AHP – Discussion of implications to practice

In this section, we will use an example to demonstrate the usefulness of the AHP and the cut-off Matrix. As for the AHP, we intend to demonstrate that, based in a prototype developed with the Microsoft Access in Portuguese language, it is possible to structure the decision problem into a hierarchy that reflects the values, goals, objectives, and desires of the public organisation managers.

With the AHP approach, the decision makers can select the best investment strategy for the organisational Information System, through a process that evaluates a set of alternatives according to the criteria defined (see Figure 9).

Fig. 9 - Prototype Menu for AHP Application



Step 1: Setting up the hierarchy

The overall goal of our example is to find an answer for the following question: What is the most suitable strategy for the organization, the systems integration or not?

The first thing to do is to put the main objective – Finding the best strategy for IS/IT investments - and structure the problem into hierarchy tree levels with several different factors that contribute to the objective. The number of factors involved can vary from case to case in the AHP, so, our example includes four factors, which are:

- Strategic alignment;
- Benefits analysis;
- Financial analysis;
- Risk analysis.

In the prototype the criteria choices are selected in the screen shown in Figure 10 and the criteria fields are filled with the preferred criterion choices as we can see in Fig.11.

Fig. 10 – Criteria option

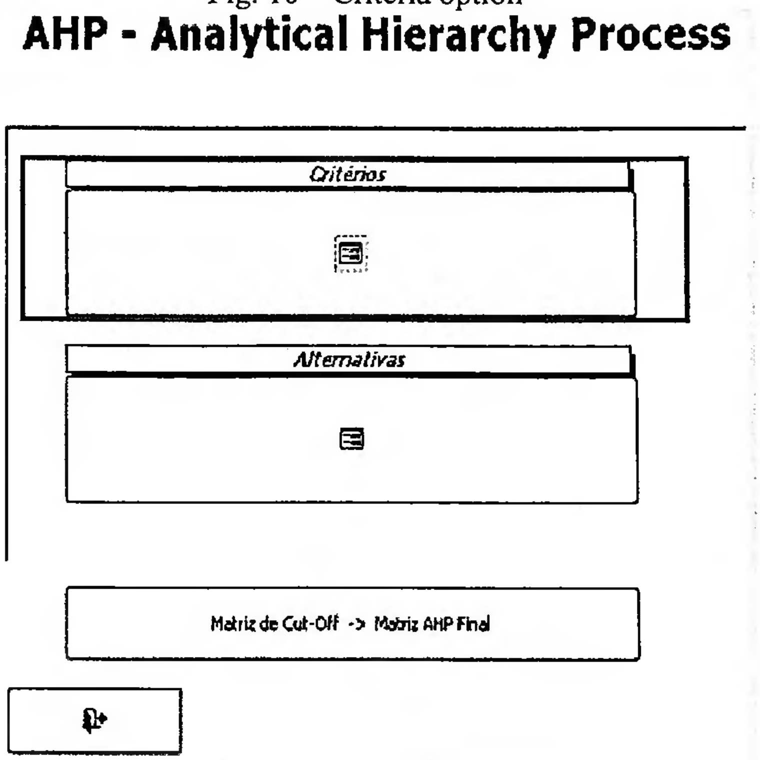
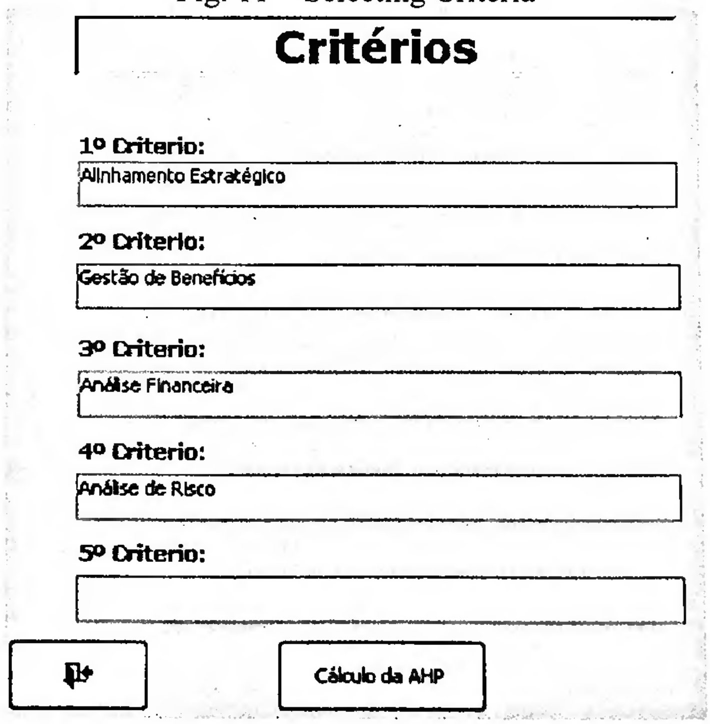


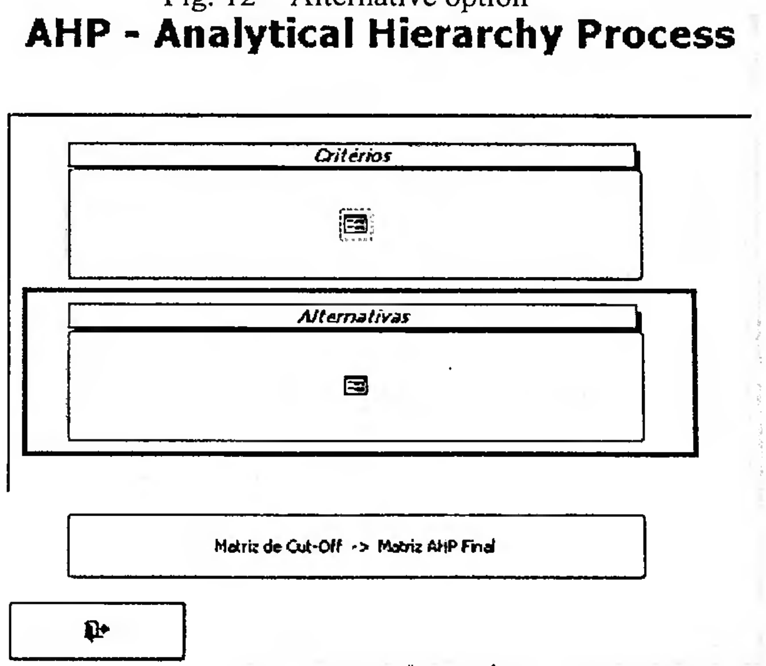
Fig. 11 – Selecting Criteria



The Strategic alignment and Risk analysis are obviously pertinent factors to the goal (choosing the best strategic investment in IS/IT systems), but Benefits analysis and Financial analysis are always very important considerations in IS projects.

The last level of the hierarchy describes the alternatives for the IS/IT strategic Investment Projects, which must be evaluated in terms of each criteria of the level above. In the prototype the alternative choices are selected in the screen in Figure 12.

Fig. 12 – Alternative option

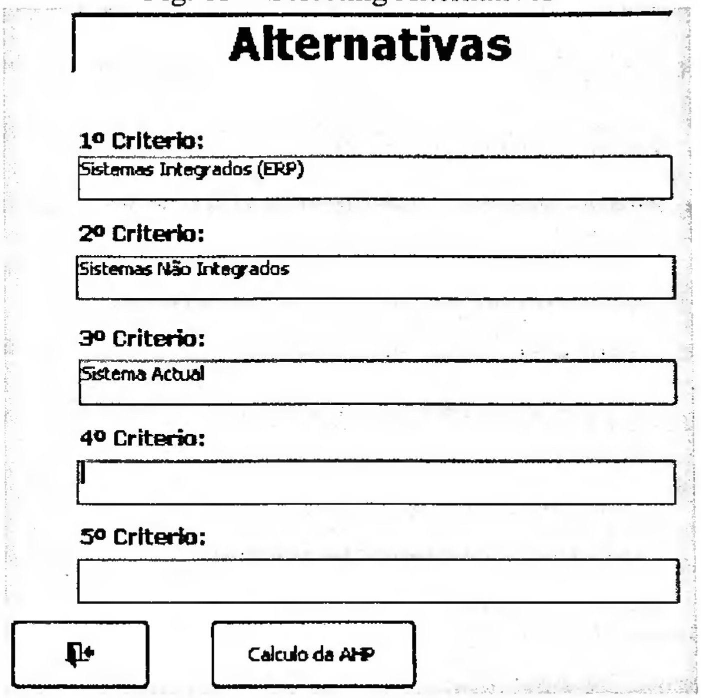


This example focuses on three alternatives.

- Enterprise Resource Planning System;
- Non Integrated System;
- Maintaining the actual system.

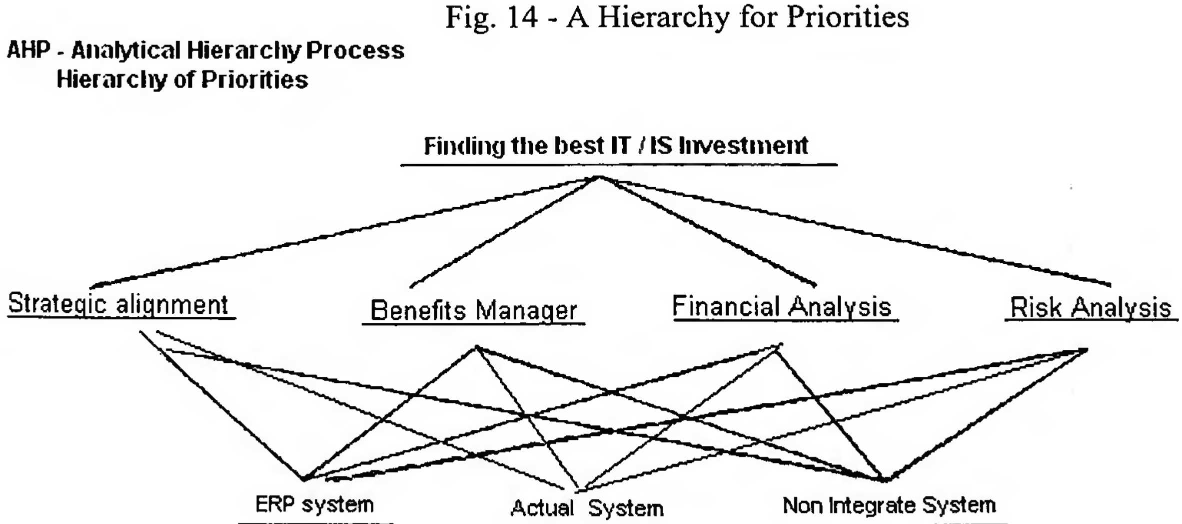
All these three are viable strategies for the organisational IS.

Fig. 13 – Selecting Alternatives



The AHP uses the judgements of the decision makers about the evaluation criteria, interaction between the criteria (importance) and alternatives, which is an interaction between the alternatives (preference) for supporting the decision maker choices of the Portuguese public administration. The Analytical Hierarchy Process will aid the process of deciding which alternative is the best approach to achieve this goal.

Fig. 14 - A Hierarchy for Priorities



The hierarchy tree (Fig. 9) shows that the decision makers criteria evaluation is supported by the Strategic alignment; Benefits analysis; Financial Analysis; Risk analysis, and the alternatives evaluation is supported by the ERP System (Integrated systems) and Non Integrated System (stand-alone applications systems).

The priorities are clear: the overall goal is to find the best strategic IS/IT investment. However, which is the best one? Does it consist in having a strategy of investing on an ERP system (integration of the information system and technology) or in following a strategy of lower price and individual acquisitions as defined by the Non Integrated system or in maintain the actual system.

Step 2: Comparison of Characteristics

In the next step, the factors from the second level of the hierarchy are compared with each other to determine the relative importance of each factor accomplishing the overall goal. The easiest and visually most structured way of doing this is to prepare a Matrix with the factors (in our example Strategic alignment, Benefits Manager, Financial Analysis and Risk Analysis) listed at the top and at the left, table 32, where it is illustrated the Matrix of the comparative values of the criteria elements.

Table 31 - Nine-point intensity of importance scale and its description

Definition	Intensity of importance
Equally important	1
Moderately more important	3
Strongly more important	5
Very Strongly more important	7
Extremely more important	9

Source: adapted from Saaty (1994)

Based on individual opinions or judgments of the decision-maker, the Matrix is filled in with numerical values denoting the left factors importance relative to the top factors importance. A high value means that the factor on the left is relatively more important than the factor at the top.

- Strategic alignment is considered to be four times more important (4x) than Benefits Manager, whereas Risk Analysis is only half as important as the Strategic alignment. When a factor is compared with itself, the ratio of importance is obviously one, resulting in a diagonal line across the Matrix.

Table 32 - Comparison of Criteria Elements

	Strategic alignment	**Benefits Management**	**Financial Analysis**	**Risk Analysis**
· **Strategic alignment**	1	4	3	2
Benefits Management	1/4	1	1/2	1/3
Financial Analysis	1/3	2	1	½
Risk Analysis	1/2	3	2	1

The Strategic alignment and Risk Analysis are considered the most important factors and, thus, are assigned the Matrix highest values. Strategic alignment is slightly more important than Risk Analysis and is mostly concerned with the cost of investments (Financial Analysis). Thus, in the Matrix, Financial Analysis is assigned the value 2, when compared to Benefits management.

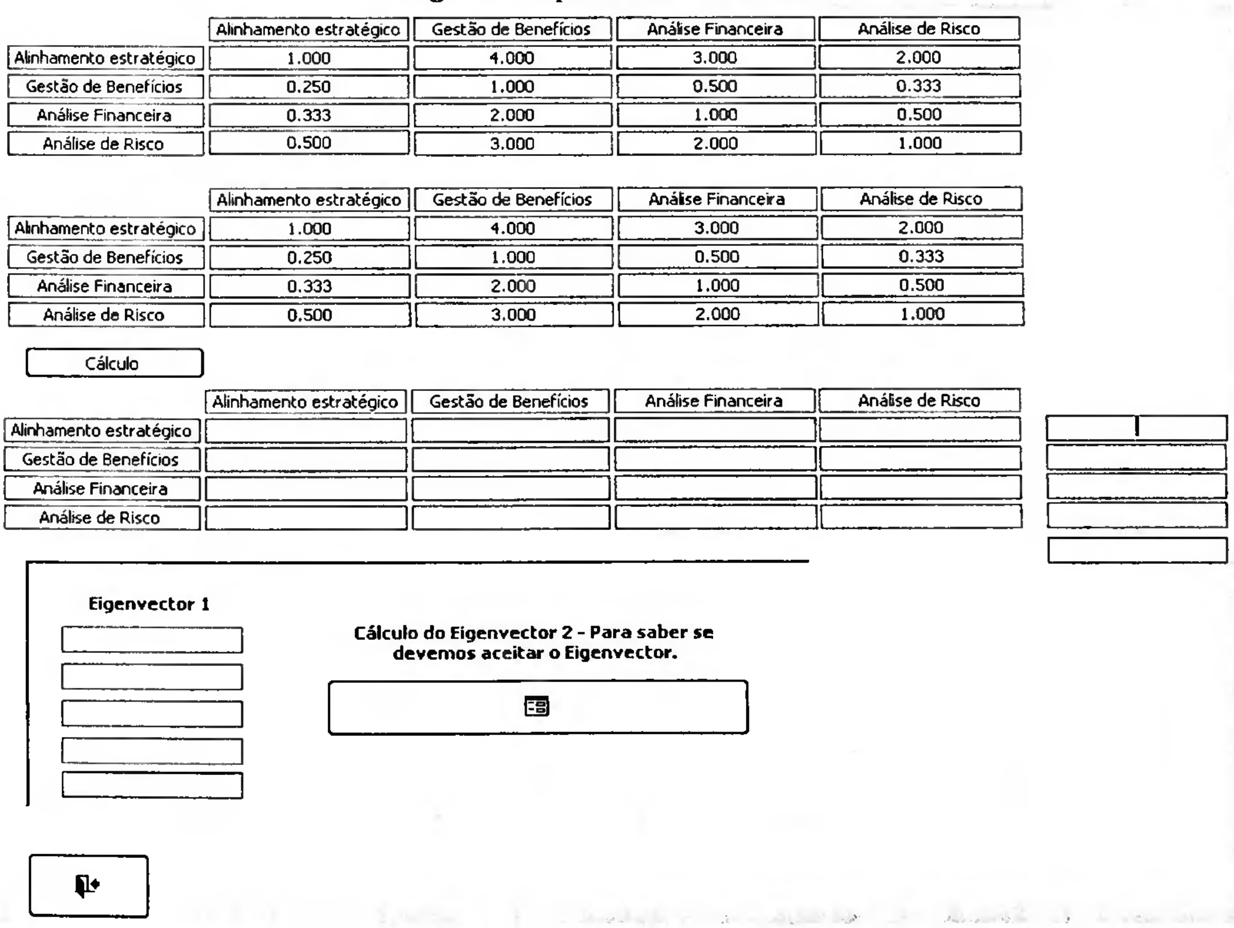
Next, the fractional values of the Matrix showed in Table 32 are converted to decimals, as represented in Table 33.

Table 33

	Strategic alignment	Benefits Management	Financial Analysis	Risk Analysis
Strategic alignment	1,0000	4,0000	3,0000	2,0000
Benefits Management	0,2500	1,0000	0,5000	0,3333
Financial Analysis	0,3333	2,0000	1,0000	0,5000
Risk Analysis	0,5000	3,0000	2,0000	1,0000

In the prototype, the first square criteria Matrix looks like Fig. 15.

Fig. 15 – Square Criteria Matrix



	Alinhamento estratégico	Gestão de Benefícios	Análise Financeira	Análise de Risco
Alinhamento estratégico	1.000	4.000	3.000	2.000
Gestão de Benefícios	0.250	1.000	0.500	0.333
Análise Financeira	0.333	2.000	1.000	0.500
Análise de Risco	0.500	3.000	2.000	1.000

	Alinhamento estratégico	Gestão de Benefícios	Análise Financeira	Análise de Risco
Alinhamento estratégico	1.000	4.000	3.000	2.000
Gestão de Benefícios	0.250	1.000	0.500	0.333
Análise Financeira	0.333	2.000	1.000	0.500
Análise de Risco	0.500	3.000	2.000	1.000

Cálculo

	Alinhamento estratégico	Gestão de Benefícios	Análise Financeira	Análise de Risco
Alinhamento estratégico				
Gestão de Benefícios				
Análise Financeira				
Análise de Risco				

Eigenvector 1

Cálculo do Eigenvector 2 - Para saber se devemos aceitar o Eigenvector.

The dominance along all possible paths is obtained by raising the Matrix to powers and normalizing the sum of the rows. This is the moment to proceed with the squaring Matrix as shown in Table 34.

Table 34

	Strategic alignment	Benefits Management	Financial Analysis	Risk Analysis
Strategic alignment	1,0000	4,0000	3,0000	2,0000
Benefits Management	0,2500	1,0000	0,5000	0,3333
Financial Analysis	0,3333	2,0000	1,0000	0,5000
Risk Analysis	0,5000	3,0000	2,0000	1,0000

X

	Strategic alignment	Benefits Management	Financial Analysis	Risk Analysis
Strategic alignment	1,0000	4,0000	3,0000	2,0000
Benefits Management	0,2500	1,0000	0,5000	0,3333
Financial Analysis	0,3333	2,0000	1,0000	0,5000
Risk Analysis	0,5000	3,0000	2,0000	1,0000

Then, we have to perform the computed values of the two matrices in table 35.

Table 35

	Strategic alignment	Benefits Management	Financial Analysis	Risk Analysis
Strategic alignment	3,9999	20,0000	12,0000	6,8332
Benefits Management	0,8333	3,9999	2,4166	1,4166
Financial Analysis	1,4166	6,8332	3,9999	2,3332
Risk Analysis	2,4166	12,0000	7,0000	3,9999

Once the Matrix has been filled out, the decision-maker can move on to step 3, in which the eigenvector vector is established.

Step 3: Establishing the eigenvector Vector

In this step, the decision-maker uses the numbers from the Matrix above (table 35) to get an overall priority value for each factor. In order to do this, the evaluator calculates the sum of the values in each row of the Matrix and divides each of the results by the sum of the results for all the rows. The eigenvector calculations are displayed in table 36 below.

Table 36 - The Eigenvector Computation

Strategic alignment:	3,9999 + 20,0000 + 12,0000 + 6,8332	=	42,8331
Benefits Manager:	0,8333 + 3,9999 + 2,4166 + 1,4166	=	8,6664
Financial Analysis:	1,4166 + 6,8332 + 3,9999 + 2,3332	=	14,5829
Risk Analysis:	2,4166 + 12,0000 + 7,0000 + 3,9999	=	25,4165
			91,4989 Total

Eigenvector

==>	42,8331	:	91,4989	=	0,4681
	8,6664	:	91,4989	=	0,0947
	14,5829	:	91,4989	=	0,1594
	25,4165	:	91,4989	=	0.2778

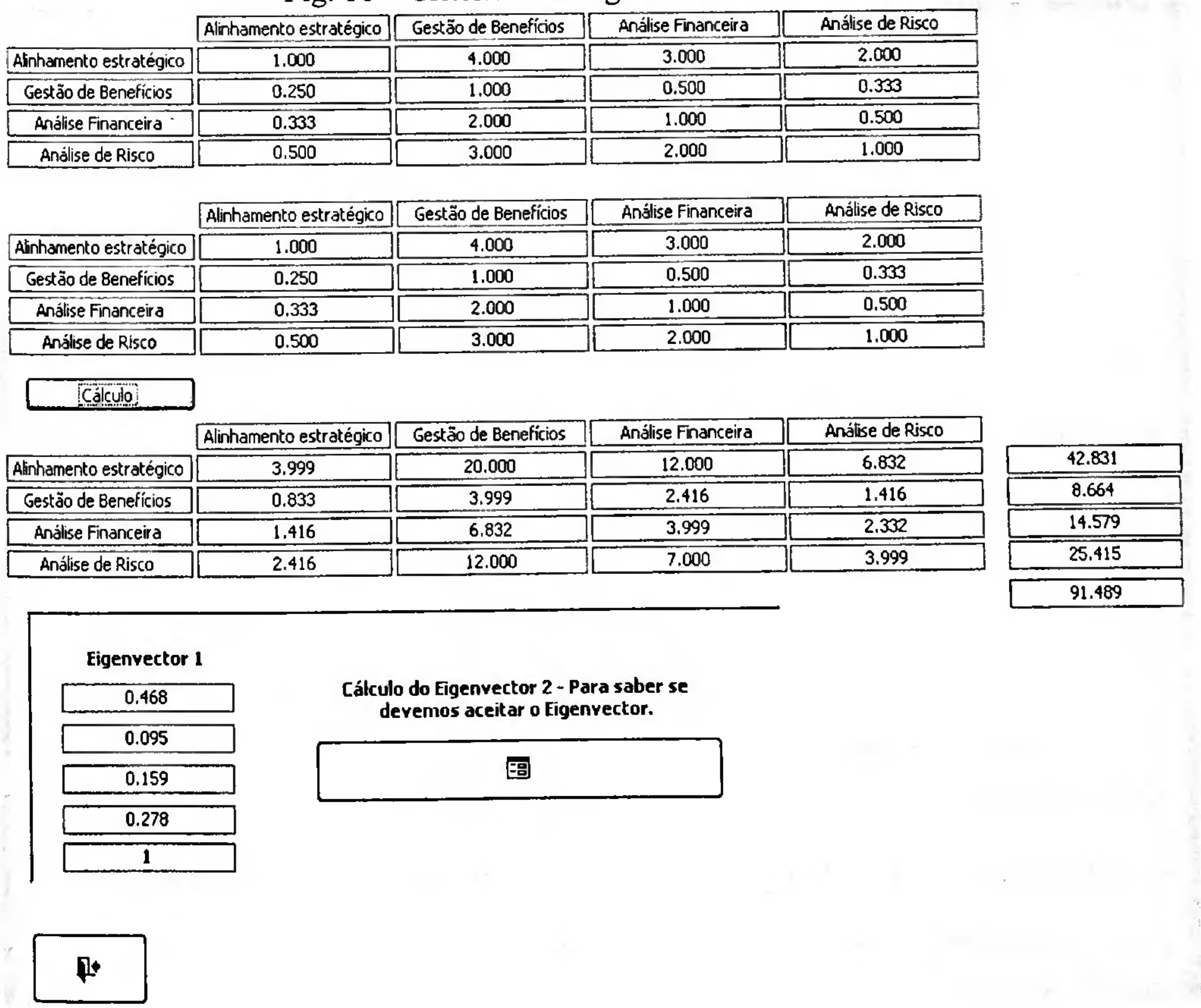
To obtain the result for the next eigenvector, we must square the Matrix in table 37.

Table 37

	Strategic alignment	Benefits Management	Financial Analysis	Risk Analysis
Strategic alignment	3,9999	20,0000	12,0000	6,8332
Benefits Management	0,8333	3,9999	2,4166	1,4166
Financial Analysis	1,4166	6,8332	3,9999	2,3332
Risk Analysis	2,4166	12,0000	7,0000	3,9999

In the prototype, the calculus for the first criteria eigenvector squares the criteria Matrix by pressing the "Cálculo" button.

Fig. 16 – Criteria first Eigenvector calculation



	Alinhamento estratégico	Gestão de Benefícios	Análise Financeira	Análise de Risco
Alinhamento estratégico	1.000	4.000	3.000	2.000
Gestão de Benefícios	0.250	1.000	0.500	0.333
Análise Financeira	0.333	2.000	1.000	0.500
Análise de Risco	0.500	3.000	2.000	1.000

	Alinhamento estratégico	Gestão de Benefícios	Análise Financeira	Análise de Risco
Alinhamento estratégico	1.000	4.000	3.000	2.000
Gestão de Benefícios	0.250	1.000	0.500	0.333
Análise Financeira	0.333	2.000	1.000	0.500
Análise de Risco	0.500	3.000	2.000	1.000

Cálculo

	Alinhamento estratégico	Gestão de Benefícios	Análise Financeira	Análise de Risco	
Alinhamento estratégico	3.999	20.000	12.000	6.832	42.831
Gestão de Benefícios	0.833	3.999	2.416	1.416	8.664
Análise Financeira	1.416	6.832	3.999	2.332	14.579
Análise de Risco	2.416	12.000	7.000	3.999	25.415
					91.489

Eigenvector 1

0.468
0.095
0.159
0.278
1

Cálculo do Eigenvector 2 - Para saber se devemos aceitar o Eigenvector.

We proceed with the same calculation method as shown above, and result is the Matrix shown in table 38.

Table 38

	Strategic alignment	Benefits Management	Financial Analysis	Risk Analysis
Strategic alignment	66,1775	323,9928	192,1620	110,9946
Benefits Management	13,5129	66,1775	39,2481	22,6650
Financial Analysis	22,6650	110,9946	65,8439	38,0250
Risk Analysis	39,2481	192,1620	113,9970	65,8439

Then compute once more the eigenvector. The calculus of the second eigenvector is shown in Table 39:

Table 39 - The Eigenvector Computation

Strategic alignment:	66,1775 + 323,9928 + 192,1620 + 110,9946	=	693,3269
Benefits Manager:	13,5129 + 66,1775 + 39,2481 + 22,6650	=	141,6030
Financial Analysis:	22,6650 + 110,9946 + 65,8439 + 38,0249	=	237,5285
Risk Analysis:	39,2481 + 192,1620 + 113,9970 + 65,8439	=	411,2510
Eigenvector			1483,7101 Total

==>	693,3269	:	1483,7101	=	0,4673
	141,6030	:	1483,7101	=	0,0954
	237,5285	:	1483,7101	=	0,1601
	411,2510	:	1483,7101	=	0,2772

This is the moment to know if we should keep one of the eigenvectors or proceed with the computation of more eigenvectors. Thus, we must compute the difference between the two eigenvectors and determine if the vector (the second eigenvector) is acceptable, see table 40.

Table 40 – Difference between the Eigenvector

Eigenvector 1	Eigenvector 2	
0,4681	0,4673	0,0008
0,0947	0,0954	-0,0007
0,1594	0,1601	-0,0007
0,2778	0,2772	0,0006

Now the difference of the previous work out eigenvectors is computed. That difference to four decimal places it is extremely small. At this point the referred difference is checked and if it is around 0 it is better to accept the eigenvector 2, which gives us the criteria relative ranking, see table 41.

Table 41- The Criteria Relative Weight Ranking

	Eigenvector 2	
Strategic alignment	0,4673	The most important criteria
Benefits Management	0,0954	The least important criteria
Financial Analysis	0,1601	The third most important criteria
Risk Analysis	0,2772	The second most important criteria

After setting up the hierarchy and pairwise comparisons of the criteria weights, it is necessary to calculate the final ranking of the alternatives' priority.

In the prototype, the calculus for the final eigenvector criteria (the second eigenvector) works like this – First square the criteria Matrix by press the "Cálculo" button. Next, it is compared the two achieved eigenvectors, and as we could see the difference between them it is very small (around 0), then it should be select the second eigenvector by press the button "Aceitar eigenvector 2".

Fig. 17 – Criteria final ranking eigenvector computation

	Alinhamento estratégico	Gestão de Benefícios	Análise Financeira	Análise de Risco
Alinhamento estratégico	3.999	20.000	12.000	6.832
Gestão de Benefícios	0.833	3.999	2.416	1.416
Análise Financeira	1.416	6.832	3.999	2.332
Análise de Risco	2.416	12.000	7.000	3.999

	Alinhamento estratégico	Gestão de Benefícios	Análise Financeira	Análise de Risco
Alinhamento estratégico	3.999	20.000	12.000	6.832
Gestão de Benefícios	0.833	3.999	2.416	1.416
Análise Financeira	1.416	6.832	3.999	2.332
Análise de Risco	2.416	12.000	7.000	3.999

Cálculo

	Alinhamento estratégico	Gestão de Benefícios	Análise Financeira	Análise de Risco	
Alinhamento estratégico	66.150	323.928	192.120	110.946	693.144
Gestão de Benefícios	13.504	66.150	39.231	22.650	141.536
Análise Financeira	22.650	110.946	65.814	38.000	237.410
Análise de Risco	39.231	192.120	113.970	65.814	411.135
					1.483.226

Eigenvector 1	Eigenvector 2	Cálculo	
0.468	0.467	0.001	Alinhamento estratégico
0.095	0.095	0	Gestão de Benefícios
0.159	0.160	-0.001	Análise Financeira
0.278	0.277	0.001	Análise de Risco
1	1		

Ranking de pesos dos Critérios

Alinhamento estratégico	0.467	O critério mais importante
Gestão de Benefícios	0.095	O critério menos importante
Análise Financeira	0.160	O terceiro critério mais importante
Análise de Risco	0.277	O segundo critério mais importante

Formulário Inicial

Aceitar Eigenvector 2

Cálculo do Eigenvector 3 - Para saber se devemos aceitar o Eigenvector.

After computing the final ranking criteria, the overall ranking of alternatives is calculated.

Step 4: Overall ranking of alternatives

Now, the decision-maker has to focus his attention from level 2 to level 3 of the hierarchy, at the bottom of which begins the pairwise comparison of the three alternative elements to be compared, which are the ERP system (Integration of the information system), the Non Integrated systems and the actual system, see table 42. The comparison of these three alternatives focuses on how much better is one than the others towards the satisfaction of the criteria from level 2.

Table 42 – Comparison of IS/IT Investments

Strategic alignment	ERP System	Non Integrate System	Actual System
ERP System	**1**	**2**	**4**
Non-Integrated System	**1/2**	**1**	**4**
Actual System	**1/4**	**1/4**	**1**

Benefits Manager	ERP System	Non Integrate System	Actual System
ERP System	**1**	**1**	**4**
Non-Integrated System	**1**	**1**	**3**
Actual System	**1/4**	**1/3**	**1**

Financial Analysis	ERP System	Non Integrated System	Actual System
ERP System	**1**	**1/3**	**2**
Non-Integrated System	**3**	**1**	**3**
Actual System	**1/2**	**1/3**	**1**

Risk Analysis	ERP System	Non Integrated System	Actual System
ERP System	**1**	**4**	**4**
Non-Integrated System	**1/4**	**1**	**2**
Actual System	**1/4**	**1/2**	**1**

In order to illustrate how the numerical values were assigned, it is useful to look in detail one or two examples. In table 42, the Strategic Alignment shows that ERP System is deemed twice more desirable than Non Integrated Systems and is 4 times more desirable than Actual System, in terms of the impact on the organisation. This situation is due to the fact that IS/IT pooling, which is necessary for the use of integrated systems, immediately cuts down the number of several standalone systems in the organisation and thus reduces the cost of necessary extra investments. In terms of financial analysis, Non Integrated Systems seem more desirable, because it is, at first glance, a much cheaper policy than the construction of an integrated system, even when the financial analysis of employing enforcement officers for using IS/IT Systems (ex. Computer administration and working with operational software) in outsourcing is considered. However, both alternatives (ERP and Non-Integrated system) are more desirable than the actual system when the financial analysis criterion is considered. The other two tables show similar evaluations of the three alternatives for IS/IT Investment in terms of their validity for benefits analysis and risk analysis.

At this moment, the decision makers have to determine the relative ranking of the alternatives for each criterion.

Step 5: Establishing priority vectors for alternatives

In terms of the first criterion (Strategic alignment), the pairwise comparisons of the alternative elements are presented in table 43, and once more we use the eigenvector to determine the relative ranking. This follows the same procedure as in step 3.

Table 43 – Comparison of Alternative Elements

Strategic alignment	ERP System	Non Integrate System	Actual System
ERP System	**1**	**2**	**4**
Non-Integrated System	**1/2**	**1**	**4**
Actual System	**1/4**	**1/4**	**1**

When we square the Matrix in Table 43, we get the Matrix in Table 44.

Fig. 18 – First alternative eigenvector calculation in Strategic alignment criteria

Critério 1

Alinhamento Estratégico	Sist. Integrado ERP	Sist. Não Integrado	Sist. Actual
Sist. Integrado ERP	1.000	2.000	4.000
Sist. Não Integrado	0.500	1.000	4.000
Sist. Actual	0.250	0.250	1.000

	Sist. Integrado ERP	Sist. Não Integrado	Sist. Actual
Sist. Integrado ERP	1.000	2.000	4.000
Sist. Não Integrado	0.500	1.000	4.000
Sist. Actual	0.250	0.250	1.000

Cálculo

	Sist. Integrado ERP	Sist. Não Integrado	Sist. Actual	
Sist. Integrado ERP	3.000	5.000	16.000	24.000
Sist. Não Integrado	2.000	3.000	10.000	15.000
Sist. Actual	0.625	1.000	3.000	4.625
				43.625

Eigenvector 1
0.550
0.344
0.106
1

Cálculo do Eigenvector 2 - Para saber se devemos aceitar o Eigenvector.

The final eigenvector alternatives computation for the Strategic Alignment criteria works like this: First, square the alternatives Matrix by pressing the "Cálculo" button. Then the two achieved eigenvectors are compared, and, as we could see in Fig. 19, the difference between the two vectors is very small (around 0). Afterwards the second eigenvector should be select by pressing the button "Aceitar eigenvector 2"

Fig. 19 – Strategic alignment final Eigenvector calculation

Critério 1

Alinhamento Estratégico	Sist. Integrado ERP	Sist. Não Integrado	Sist. Actual
Sist. Integrado ERP	3.000	5.000	16.000
Sist. Não Integrado	2.000	3.000	10.000
Sist. Actual	0.625	1.000	3.000

	Sist. Integrado ERP	Sist. Não Integrado	Sist. Actual
Sist. Integrado ERP	3.000	5.000	16.000
Sist. Não Integrado	2.000	3.000	10.000
Sist. Actual	0.625	1.000	3.000

Cálculo

	Sist. Integrado ERP	Sist. Não Integrado	Sist. Actual	
Sist. Integrado ERP	29.000	46.000	146.000	221.000
Sist. Não Integrado	18.250	29.000	92.000	139.250
Sist. Actual	5.750	9.125	29.000	43.875
				404.125

Eigenvector 1	Eigenvector 2	Cálculo	
0.550	0.547	**0.003**	Sist. Integrado ERP
0.344	0.345	**-0.001**	Sist. Não Integrado
0.106	0.109	**-0.003**	Sist. Actual
1	1		

Critério 1 Aceitar Eigenvector 2

AHP - Critério 2

In terms of Benefits Management, the calculation of the priority vector is the same as for the above criterion.

Table 46 – Comparison of Alternative Elements

Benefits Management	ERP System	Non Integrate System	Actual System
ERP System	**1**	**1**	**4**
Non-Integrated System	**1**	**1**	**3**
Actual System	**1/4**	**1/3**	**1**

When we square the Matrix in Table 46, we get the Matrix in Table 47.

Table 47 – Benefits Management Square Matrix

Benefits Management	ERP System	Non Integrate System	Actual System
ERP System	**3,0000**	**3,3333**	**11,0000**
Non-Integrated System	**2,7500**	**3,0000**	**10,0000**
Actual System	**0,8333**	**0,9166**	**3,0000**

Then the Matrix is squared 2 times and after the second iteration, the difference between the two vectors is extremely small (around 0). The computed eigenvector for the Benefits Management has the values in table 48.

Table 48 – The Benefits Management Eigenvector

Benefits Management	**Eigenvector** $= X_{1..3} / \sum X$	**Ranking**
ERP System	**0,4579**	**1**
Non-Integrated System	**0,4160**	**2**
Actual System	**0,1260**	**3**
	1	

In the prototype, the first square alternatives Matrix, based on the benefits management criteria, is in Fig. 20.

Fig. 20 – First alternative eigenvector calculation in Benefit Management

Critério 2

Gestão de Benefícios	Sist. Integrado ERP	Sist. Não Integrado	Sist. Actual
Sist. Integrado ERP	1.000	1.000	4.000
Sist. Não Integrado	1.000	1.000	3.000
Sist. Actual	0.250	0.333	1.000

	Sist. Integrado ERP	Sist. Não Integrado	Sist. Actual
Sist. Integrado ERP	1.000	1.000	4.000
Sist. Não Integrado	1.000	1.000	3.000
Sist. Actual	0.250	0.333	1.000

Cálculo

	Sist. Integrado ERP	Sist. Não Integrado	Sist. Actual	
Sist. Integrado ERP	3.000	3.332	11.000	17.332
Sist. Não Integrado	2.750	2.999	10.000	15.749
Sist. Actual	0.833	0.916	2.999	4.748
				37.829

Eigenvector 1
0.458
0.416
0.126
1

Cálculo do Eigenvector 2 - Para saber se devemos aceitar o Eigenvector.

Then, the final eigenvector alternatives computation for the Benefits Management criteria, works like this: First, square the alternatives Matrix by pressing the “Cálculo” button. Next, the two achieved eigenvectors are compared, and, as we can see in Fig. 21, the difference between the two vectors is zero. Afterwards the second eigenvector should be selected by pressing the button “Aceitar eigenvector 2”

Fig. 21 – Benefit management final Eigenvector calculation

Critério 2

Gestão de Benefícios	Sist. Integrado ERP	Sist. Não Integrado	Sist. Actual
Sist. Integrado ERP	3.000	3.332	11.000
Sist. Não Integrado	2.750	2.999	10.000
Sist. Actual	0.833	0.916	2.999

	Sist. Integrado ERP	Sist. Não Integrado	Sist. Actual
Sist. Integrado ERP	3.000	3.332	11.000
Sist. Não Integrado	2.750	2.999	10.000
Sist. Actual	0.833	0.916	2.999

Cálculo

	Sist. Integrado ERP	Sist. Não Integrado	Sist. Actual	
Sist. Integrado ERP	27.326	30.065	99.309	156.700
Sist. Não Integrado	24.827	27.317	90.230	142.374
Sist. Actual	7.516	8.270	27.317	43.103
				342.177

Eigenvector 1	Eigenvector 2	Cálculo	
0.458	0.458	0	Sist. Integrado ERP
0.416	0.416	0	Sist. Não Integrado
0.126	0.126	0	Sist. Actual
1	1		

Critério 2 Aceitar Eigenvector 2

AHP - Critério 3

In Benefits Management, the analysis demonstrates that the alternative ERP System is the best value and the Actual System the worst value.

Next, the third criterion, the Financial Analysis, comparison of alternatives is shown in Table 49:

Table 49 – Comparison of Alternative Elements

Financial Analysis	ERP System	Non Integrated System	Actual System
ERP System	1	1/3	2
Non-Integrated System	3	1	3
Actual System	1/2	1/3	1

When we square the Matrix in Table 49, we get the Matrix in Table 50.

Table 50 – Financial Analysis Square Matrix

Financial Analysis	ERP System	Non Integrate System	Actual System
ERP System	3,0000	1,3333	5,0000
Non-Integrated System	7,5000	3,0000	12,0000
Actual System	2,0000	0,8333	3,0000

We Square the Matrix 2 times and, after the second iteration, the difference between the two vectors is extremely small (around 0). The computed eigenvector holds the values in table 51.

Table 51 – The Financial Analysis Eigenvector

Financial Analysis	Eigenvector $= X_{1..3} / \sum X$	Ranking
ERP System	**0,2493**	**2**
Non-Integrated System	**0,5936**	**1**
Actual System	**0,1570**	**3**
	1	

In the prototype, the first square alternatives Matrix, based on the financial analyses criteria, is in Fig. 22.

Fig. 22 – First alternative eigenvector calculation in Financial Analysis

Critério 3

Análise Financeira	Sist. Integrado ERP	Sist. Não Integrado	Sist. Actual
Sist. Integrado ERP	1.000	0.333	2.000
Sist. Não Integrado	3.000	1.000	3.000
Sist. Actual	0.500	0.333	1.000

	Sist. Integrado ERP	Sist. Não Integrado	Sist. Actual
Sist. Integrado ERP	1.000	0.333	2.000
Sist. Não Integrado	3.000	1.000	3.000
Sist. Actual	0.500	0.333	1.000

Cálculo

	Sist. Integrado ERP	Sist. Não Integrado	Sist. Actual	
Sist. Integrado ERP	2.999	1.332	4.999	9.330
Sist. Não Integrado	7.500	2.998	12.000	22.498
Sist. Actual	1.999	0.833	2.999	5.831
				37.659

Eigenvector 1
0.248
0.597
0.155
1

Cálculo do Eigenvector 2 - Para saber se devemos aceitar o Eigenvector.

The final eigenvector alternatives computation for the Financial Analysis criteria, works like this: First, squares the alternatives Matrix by pressing the "Cálculo" button. Then the two achieved eigenvectors are compared, and as we can see in Fig. 23, the difference between the two vectors is very small (around 0). Afterwards the second eigenvector should be selected by pressing the button "Aceitar eigenvector 2"

Fig. 23 – Financial analyses final Eigenvector calculation

Critério 3

Análise Financeira	Sist. Integrado ERP	Sist. Não Integrado	Sist. Actual
Sist. Integrado ERP	2.999	1.332	4.999
Sist. Não Integrado	7.500	2.998	12.000
Sist. Actual	1.999	0.833	2.999

	Sist. Integrado ERP	Sist. Não Integrado	Sist. Actual
Sist. Integrado ERP	2.999	1.332	4.999
Sist. Não Integrado	7.500	2.998	12.000
Sist. Actual	1.999	0.833	2.999

Cálculo

	Sist. Integrado ERP	Sist. Não Integrado	Sist. Actual	
Sist. Integrado ERP	28.977	12.150	45.968	87.095
Sist. Não Integrado	68.966	28.968	109.457	207.390
Sist. Actual	18.234	7.655	28.977	54.866
				349.351

Eigenvector 1	Eigenvector 2	Cálculo	
0.248	0.249	-0.002	Sist. Integrado ERP
0.597	0.594	0.004	Sist. Não Integrado
0.155	0.157	-0.002	Sist. Actual
1	1		

Critério 3 Aceitar Eigenvector 2

AHP - Critério 4

In terms of Financial Analysis, this analysis demonstrates that the Non-Integrated System has the best value and the Actual System has the worst value.

Finally, in terms of Risk Analysis, the comparison of alternatives is in table 52.

Table 52 – Comparison of Alternative Elements

Risk Analysis	ERP System	Non Integrate System	Actual System
ERP System	**1**	**4**	**4**
Non-Integrated System	**1/4**	**1**	**2**
Actual System	**1/4**	**1/2**	**1**

When we square the Matrix in Table 52, we get the Matrix in the Table 53.

Table 53 – Risk Analysis Square Matrix

Risk Analysis	ERP System	Non Integrate System	Actual System
ERP System	**3,0000**	**10,0000**	**16,0000**
Non-Integrated System	**1,0000**	**3,0000**	**5,0000**
Actual System	**0,6250**	**2,0000**	**3,0000**

We Square the Matrix 2 times and, after the second iteration, the difference between the two vectors is extremely small (around 0). The computed eigenvector for the Risk Analysis has the values in table 54.

Table 54 – The Risk Analysis Eigenvector

Risk Analysis	Eigenvector $= X_{1..3} / \sum X$	Ranking
ERP System	**0,6607**	**1**
Non-Integrated System	**0,2081**	**2**
Actual System	**0,1311**	**3**
	1	

In the prototype, the first square alternatives Matrix based on the Risk analysis criteria, is in Fig. 24.

Fig. 24 – First alternative eigenvector calculation in Risk Analysis

Critério 4

Análise de Risco	Sist. Integrado ERP	Sist. Não Integrado	Sist. Actual
Sist. Integrado ERP	1.000	4.000	4.000
Sist. Não Integrado	0.250	1.000	2.000
Sist. Actual	0.250	0.500	1.000

	Sist. Integrado ERP	Sist. Não Integrado	Sist. Actual
Sist. Integrado ERP	1.000	4.000	4.000
Sist. Não Integrado	0.250	1.000	2.000
Sist. Actual	0.250	0.500	1.000

Cálculo

	Sist. Integrado ERP	Sist. Não Integrado	Sist. Actual	
Sist. Integrado ERP	3.000	10.000	16.000	29.000
Sist. Não Integrado	1.000	3.000	5.000	9.000
Sist. Actual	0.625	2.000	3.000	5.625
				43.625

Eigenvector 1

0.665
0.206
0.129
1

Cálculo do Eigenvector 2 - Para saber se devemos aceitar o Eigenvector.

Next, the final eigenvector alternatives computation for the Risk Analysis criteria, works like this: First, square the alternatives Matrix by pressing the "Cálculo" button. Then the two achieved eigenvectors are compared, and, as we can see in Fig. 25, the difference between the two vectors is very small (around 0). Afterwards the second eigenvector should be selected by pressing the button "Aceitar eigenvector 2"

Fig. 25 – Risk analyses final Eigenvector calculation

Critério 4

Análise de Risco	Sist. Integrado ERP	Sist. Não Integrado	Sist. Actual
Sist. Integrado ERP	3.000	10.000	16.000
Sist. Não Integrado	1.000	3.000	5.000
Sist. Actual	0.625	2.000	3.000

	Sist. Integrado ERP	Sist. Não Integrado	Sist. Actual
Sist. Integrado ERP	3.000	10.000	16.000
Sist. Não Integrado	1.000	3.000	5.000
Sist. Actual	0.625	2.000	3.000

Cálculo

	Sist. Integrado ERP	Sist. Não Integrado	Sist. Actual	
Sist. Integrado ERP	29.000	92.000	146.000	267.000
Sist. Não Integrado	9.125	29.000	46.000	84.125
Sist. Actual	5.750	18.250	29.000	53.000
				404.125

Eigenvector 1	Eigenvector 2	Cálculo	
0.665	0.661	0.004	Sist. Integrado ERP
0.206	0.208	-0.002	Sist. Não Integrado
0.129	0.131	-0.002	Sist. Actual
1	1		

Formulário Inicial

Critério 4
Aceitar Eigenvector 2

In terms of Risk Analysis, this analysis demonstrates that the ERP System has the best value, and once again, the Actual System has the worst value.

Finally, after obtaining all the eigenvectors from alternative weight calculus, we proceed with the creation of the final ranking weights Matrix for the alternatives, see Table 55.

Table 55 – Alternatives weights ranking

	Strategic alignment	Benefits Management	Financial Analysis	Risk Analysis
ERP System	0,5469	0,4579	0,2493	0,6607
Non-Integrated System	0,3445	0,4160	0,5936	0,2081
Actual System	0,1085	0,1260	0,1570	0,1311

Step 6: Use of the Cut-Off value Matrix:

We use the Cut-off values Matrix to purge the alternatives which are not getting the minimum preference values, in order to set the calculation of the final ranking criteria.

First, based on the minimum preference values table, see Table 56, we defined the cut-off values based on the eigenvector with the criteria relative ranking.

Table 56 – Cut-off values reflecting the minimum Preference values

	Minimum Preference Value
Strategic alignment	0,25
Benefits Management	0,10
Financial Analysis	0,20
Risk Analysis	0,15

If the values of the minimum preference values are higher than the correspondent value of the alternatives final ranking weights, then we cut-off the value of the pairwise elements.

The cut-off values Matrix is applied in Table 57:

Table 57 - Cut-off Value Matrix

	Strategic alignment	Effec	Benefits Management	Effec	Financial Analysis	Effec	Risk Analysis	Effec
ERP System	0,5469 > 0,25	✓	0,4579 > 0,10	✓	0,2493 > 0, 20	✓	0,6607 > 0,15	✓
Non-Integrated System	0,3445 > 0,25	✓	0,4160 > 0,10	✓	0,5936 > 0,20	✓	0,2081 > 0,15	✓
Actual System	0,1085 > 0,25	✕	0,1260 > 0,10	✓	0,1570 > 0,20	✕	0,1311 > 0,15	✕

The decision makers use the cut-off values directly into the final ranking weights for the alternatives. Based on the above example, we can say that the Actual System alternative is obviously out of the calculation for the final ranking result of the best IS to buy. In conclusion, the AHP computes the final ranking alternatives' priorities just for the ERP System and the Non-Integrated System.

Step 7: Obtaining the final overall ranking:

The last step in AHP is to obtain the overall ranking of the two alternatives by mathematically combining the two priority matrices, see Table 58, where A is the eigenvector with the criteria relative ranking priorities and B is the alternatives ranking weight Matrix.

Table 58 - Overall Ranking

A*B =

0,4673
0,0954
0,1601
0,2772

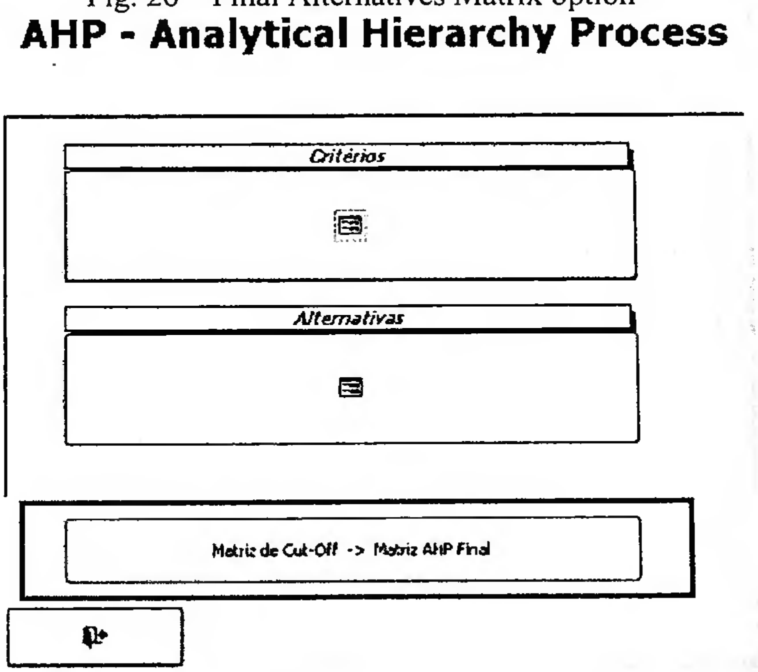
0,5469	0,4579	0,2493	0,6607
0,3445	0,4160	0,5936	0,2081

=

(0,4673 * 0,5469) +	(0,0954 * 0,4579) +	(0,1601 * 0,2493)+	(0,2772 * 0,6607)=	0,5223
(0,4673 * 0,3445) +	(0,0954 * 0,4160) +	(0,1601 * 0,5936)+	(0,2772 * 0,2081)=	0,3534

For the Prototype, in order to initiate the final alternative ranking calculation using the cut-off value table we have to press the "Matriz de Cut-Off -> Matriz AHP Final' Button, see Fig. 26.

Fig. 26 – Final Alternatives Matrix option



The final alternative ranking calculation in order to achieve the best IS/IT investment is in Fig. 27.

Fig. 27 – Final Alternatives Matrix based on Cut-Off values

Matriz de Valores Cut-Off

	Valores de Cut-Off
Alinhamento estratégico	0.250
Gestão de Benefícios	0.100
Análise Financeira	0.200
Análise de Risco	0.150

Critérios

Alternativas	Alinhamento estratégico			Gestão de Benefícios			Análise Financeira			Análise de Risco		
Sist. Integrado ERP	0.547	0.250	OK	0.458	0.100	OK	0.249	0.200	OK	0.661	0.150	OK
Sist. Não Integrado	0.345	0.250	OK	0.416	0.100	OK	0.594	0.200	OK	0.208	0.150	OK
Sist. Actual	0.109	0.250	NOK	0.126	0.100	OK	0.157	0.200	NOK	0.131	0.150	NOK
	1.000			1.000			1.000			1.000		

Cálculo

Critérios

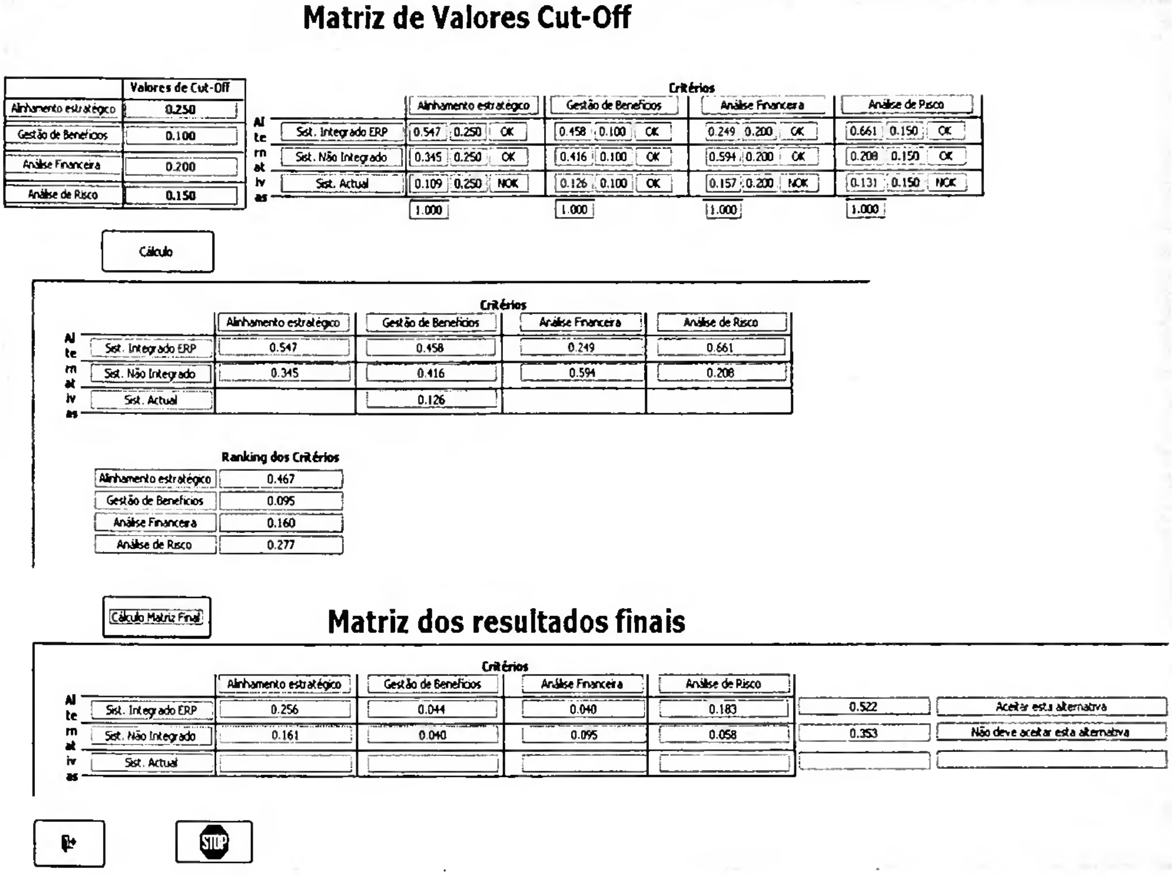
Alternativas	Alinhamento estratégico	Gestão de Benefícios	Análise Financeira	Análise de Risco
Sist. Integrado ERP	0.547	0.458	0.249	0.661
Sist. Não Integrado	0.345	0.416	0.594	0.208
Sist. Actual		0.126		

Ranking dos Critérios

Alinhamento estratégico	0.467
Gestão de Benefícios	0.095
Análise Financeira	0.160
Análise de Risco	0.277

The Matrix calculations results computed by the prototype gave us a simpler and more accurate way of calculating the best IS/IT investments strategies. The calculations gave us the power to do a multiple amount of functions at one time with a greater opportunity to structure the way of thinking and reduce human error.

Fig. 28 – Final overall view



Matriz de Valores Cut-Off

	Valores de Cut-Off
Alinhamento estratégico	0.250
Gestão de Benefícios	0.100
Análise Financeira	0.200
Análise de Risco	0.150

Critérios

Alternativas	Alinhamento estratégico			Gestão de Benefícios			Análise Financeira			Análise de Risco		
Sist. Integrado ERP	0.547	0.250	OK	0.458	0.100	OK	0.249	0.200	OK	0.661	0.150	OK
Sist. Não Integrado	0.345	0.250	OK	0.416	0.100	OK	0.594	0.200	OK	0.208	0.150	OK
Sist. Actual	0.109	0.250	NOK	0.126	0.100	OK	0.157	0.200	NOK	0.131	0.150	NOK
	1.000			1.000			1.000			1.000		

Cálculo

Critérios

Alternativas	Alinhamento estratégico	Gestão de Benefícios	Análise Financeira	Análise de Risco
Sist. Integrado ERP	0.547	0.458	0.249	0.661
Sist. Não Integrado	0.345	0.416	0.594	0.208
Sist. Actual		0.126		

Ranking dos Critérios

Alinhamento estratégico	0.467
Gestão de Benefícios	0.095
Análise Financeira	0.160
Análise de Risco	0.277

Cálculo Matriz Final

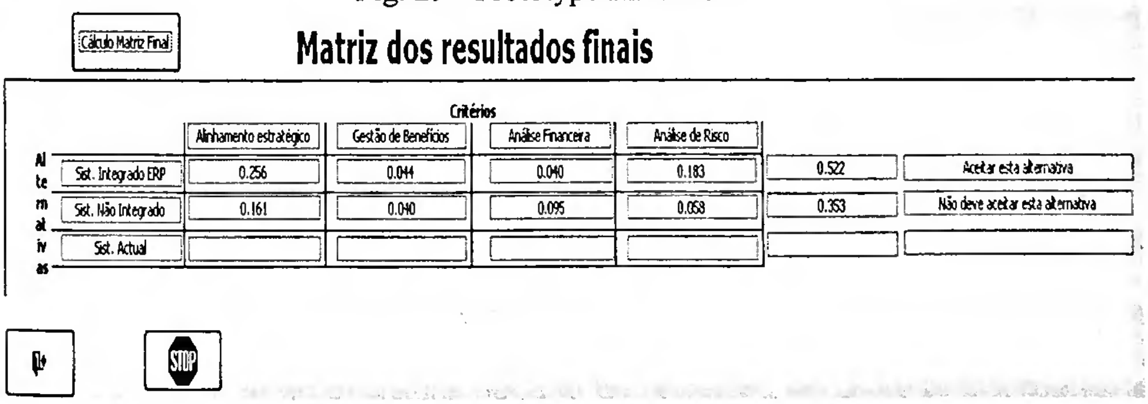
Matriz dos resultados finais

Critérios

Alternativas	Alinhamento estratégico	Gestão de Benefícios	Análise Financeira	Análise de Risco		
Sist. Integrado ERP	0.256	0.044	0.040	0.183	0.522	Aceitar esta alternativa
Sist. Não Integrado	0.161	0.040	0.095	0.058	0.353	Não deve aceitar esta alternativa
Sist. Actual						

The final result is established as illustrated in Fig. 29:

Fig. 29 - Prototype final result



Cálculo Matriz Final

Matriz dos resultados finais

Critérios

Alternativas	Alinhamento estratégico	Gestão de Benefícios	Análise Financeira	Análise de Risco		
Sist. Integrado ERP	0.256	0.044	0.040	0.183	0.522	Aceitar esta alternativa
Sist. Não Integrado	0.161	0.040	0.095	0.058	0.353	Não deve aceitar esta alternativa
Sist. Actual						

The result shows that ERP Systems (information system integration project) have been given the overall rating of 0.5223 and the raising of the Non

Integrated Systems have been given the rating of only 0.3534. Therefore, the choice for investment in ERP - Integrated systems is the best strategic IS/IT Investment, first because at long term it helps reducing the cost of IS/IT investment projects in the Portuguese public administration.

4.9 AHP synthesis

In synthesis, we could express the same as Steward and Mohamed (2003), that is, AHP enables the decision-maker to structure a complex problem in the form of a simple hierarchy to evaluate a large number of quantitative and qualitative factors in a systematic manner under multiple, and perhaps conflicting criteria. Also, as Roper-Lowe and Sharp (1990) say, the AHP is particularly appropriate for information technology decisions because it can involve and take into account the views of many stakeholders, and IS/IT decisions often involve several business departments as well as technicians. It is, indeed, the technicians inevitably have to score the options for building and weighing the attribute hierarchy. There is a risk in scoring the options; in fact, an expert who has a vested interest in a particular solution can deliberately give incorrect scores in favour of his interest.

One advantage of the AHP is the flexible modelling and measurement approach to evaluation, another advantage of use this method is that it provides documentation about how and why a particular decision was taken; this is particularly useful when decisions need to be reviewed because of the changing circumstances of the organisational matters. In addition, similar decisions may arise again and the hierarchy can be used as a starting-point for building another hierarchy. Decision documentation is also very valuable to understand why wrong decisions were taken, with the objective of improving the decision process.

In their studies about the AHP and its application to an Information Technology decision, Roper-Lowe and Sharp (1990) revealed the following strengths and weaknesses of the AHP:

Strengths

- Structuring a problem as a hierarchy is a useful aid to understand problems and drive discussions about them.
- The process can reveal issues, which have not been previously explicitly stated.
- The process is easy to understand and so decision-makers feel comfortable with it.
- The nine-point scale is readily accepted as a tool for comparing intangible attributes with other intangible attributes.
- Weighing the attributes and scoring the options leads to useful data about people's concerns and preferences.

Weaknesses

- The simplicity of the hierarchical structure may hide important interdependencies and so oversimplify problems.
- Difficulties arise when comparing tangible with intangible attributes.
- It is difficult to interpret final scores because of their unknown statistical significance, uncertainty about how decision-makers use the scales and because the AHP does not yield a unique solution. The process may not therefore produce a definitive result.

The AHP can be used to measure and synthesize a multi-criteria IS/IT investment evaluation problem. Because it helps the decision-makers in:

- Focussing on objectives rather than criteria. This will make clear when double counting is inappropriate (and, in some cases, when it is appropriate).
- Having the decision maker(s) derive priorities for the relative importance of the major objectives by making pairwise comparisons.
- Having the decision maker(s) derive priorities for the relative importance of the sub-objectives by making pairwise comparisons.
- Extracting the most attractive alternatives from the initial ratings and performing sensitivity analyses. Revising judgments or model structure as necessary. Refining alternative priorities derived from ratings with more accurate priorities and derived from pairwise comparisons. The extracted set of alternatives could influence the judgments or model structure.

Certainly, multi-attribute weighting techniques, such as AHP are very general and can be applied to any decision-making or evaluation methodology in any organisation. Furthermore, the AHP must, of course, be regarded as a supplement to other appraisal techniques. Furthermore, the AHP can be a valuable technique in a Decision Support System.

5 A DSS model for evaluating IS/IT investments

The DSS development model will always be an analysis based on the following aspects:

- The benefit level to obtain (direct and indirect benefits);
- The organisation objectives fulfilled by the benefits will give answer;
- The degree of explanation of the benefit, gauged through a set of suitable measures;
- The impact scope of the project in the organisation;
- The existence, or not, of a responsible person, assigned to guarantee the conclusion of the DSS;

By choosing this specific DSS model, there are some points to take into consideration: first we should begin with the two essential subjects before any development, which are how and when to evaluate the IS/IT investment projects. In relation to this, there are, among others, two interrelated questions:

- How can we evaluate the investment in a system before its implementation?
- When and how to decide in which projects should we invest?

To answer these questions, we have analysed different IS/IT investment evaluation techniques, from authors such as Andresen (1999a), who considers that there are at least 30 methodologies for the evaluation of IS/IT system benefits and for supporting the human judgment on that subject. The same author, in 2002, made reference to a literature search, which identified as many as 82 methods for evaluating the information technology, and there are undoubtedly many more methods developed continuously.

In this work, we have provided a solution for the evaluation of IS/IT investments by the Portuguese public administration, which is not easily done and requires several steps to be accomplished. One necessary step is to choose an IS/IT evaluation method among the available methods that fulfil the requirements of the necessary IS/IT investment evaluation for the Portuguese public administration.

Regarding the methods above-mentioned and according to Strassmann (1985), Lincoln et al. (1990) and Parker and Benson (1998), the methods to analyse the value of the investment could be based on financial measures, such as the ROI (Return on Investment) or the Net Present Value (NPV). These methods are, however, inadequate when intended to evaluate the investments in information technologies, because that evaluation only uses the monetary value measure. However, there are more complex methods that allow a better IS/IT investment evaluation, such as:

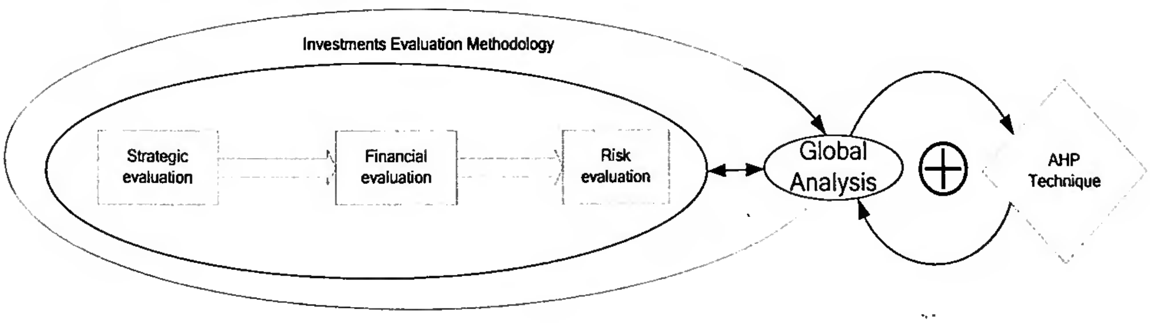
- Information Economics (IE);
- Analytical Hierarchy Process (AHP);
- Possibility Theory;
- Return on Management (ROM);
- SESAME.

Nevertheless, the same authors referred that these methods are difficult to use. But organisations need to undertake a rigorous evaluation process before implementing IS/IT, if they are to achieve improvements in their services performance. Otherwise inefficiencies in decision-making and resource deployment will prevail. Thus, in order to thwart this referred aspects, this work intends to present a DSS Model-Driven which includes a system that uses accounting and financial models, representation and optimisation that emphasizes the access and the manipulation of models, and jointly with statistical analysis tools, it allows the most elementary functionality level.

This type of DSS uses data and parameters supplied by the decision makers to help them analysing certain problems, but these systems are not usually intensive users of data.

In this study, the presented method is based on Investment Evaluation Methodology, which is the MAIS – Metedologia de Avaliação de Investimentos, proposed by Serrano et al (2004), and in the multi-criteria analysis technique, which is the AHP – Analytical Hierarchy Process, proposed by Saaty (1980). With these, it could be created a model to be used by public administration to support decision agents on their choices about investments in IS/IT projects.

Fig. 30 - An implemented model based on the IEM + AHP

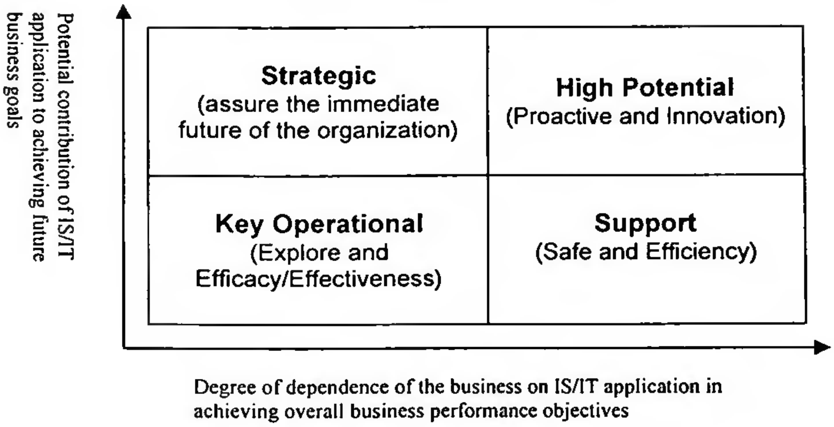


1. Strategic alignment of the investment project.

The strategic evaluation analysis is based on the use of techniques, such as the McFarlan Matrix and the benefits management methodology proposed by Ward and Murray (2000).

The McFarlan Matrix is the technique that allows positioning and gauging the importance of the project to the organisation development strategy.

Fig. 31 – McFarlan Matrix



Source: Ward and Griffiths (1996)

In order to determine the project alignment, the investment project objectives and the strategic organisation objectives have to interchange, obtaining the following Matrix.

Fig. 32 – Project alignment

Strategic objectives		Project	
Objective	Pond ration	Investment obj. 1	Investment obj. n
1	50%	3	
2	20%	2	
3	15%		
4	10%	1	
5	5%		3

Legend	
1	Determinant
2	Very important
3	Important
4	Not very important

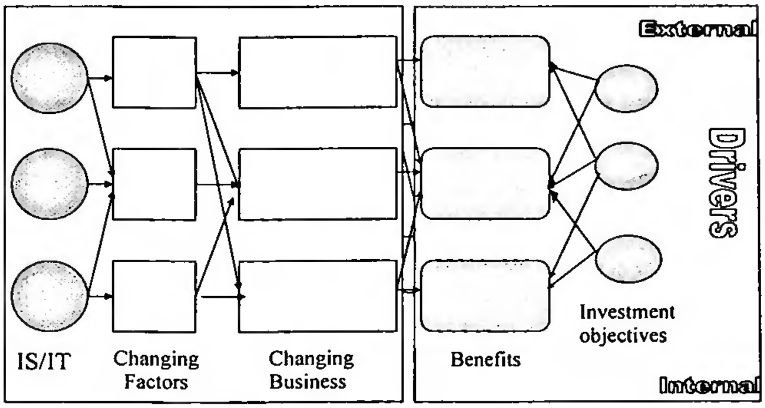
Project Scope impact

Alignment: Low, Medium and High

Source: This figure is adapted from the Metodologia de avaliação de investimentos, proposed for the IIMF, (Serrano et al, 2004)

The benefits management methodology is the instrument that gives support to the IS/IT projects investment benefits identification.

Fig. 33 – Benefits Management



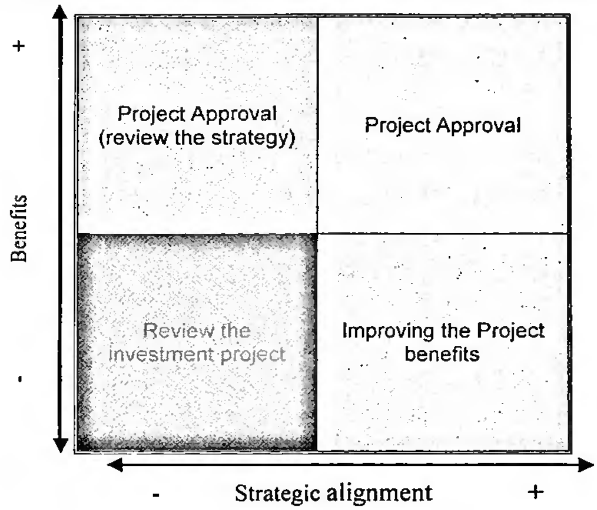
Source: Serrano, A., Caldeira, M. and Guerreiro, A. (2004)

The benefits administration methodology, proposed and developed by John Ward (1996), is a method that gives support to the IS/IT investment benefits identification. The benefits identification analysis results give the following type of information about the IS/IT investment project:

- At the project alignment with organisation strategic objectives:
  - Objective of the investment;
  - The contribution and grade of contribution for the business strategic objectives;
  - If the project gives response to a legal obligation.
- At level of direct and indirect benefits, the most important information is:
  - The benefits to obtain;
  - The contribution of the benefit for the organisation objectives;
  - The project impact scope.

In conclusion, the objective is to identify the benefits to obtain with the project, along with a sustainability base for the evaluation of the investment return and the rationality of the same. The position of the project according to strategic alignment and the benefits to get should be represented in the following Matrix.

Fig. 34 – Strategic alignment / Benefits Matrix



Source: This Figure is adapted from the Metodologia de avaliação de investimentos, proposed for the IIMF, (Serrano et al, 2004)

Besides the strategic alignment model, the IS/IT project investment evaluation tool is composed by the financial analysis model.

2. Financial analysis;

In the financial analysis, the focus goes to the capital investment and its impact in the investment processes. This analysis is based on information obtained from the following elements:

- Investments' Cash-flow analysis;
- Investment discrimination and its impact on the costs exploration activity;
- Financial quantification methods of benefits;
- Integration in the investments financial evaluation methodology.

In theory, the organisations fulfilment with the financial evaluation obtains the following information:

At the expense level

- The detail of expenses / Capital investment (independently from the financing source) in the following categories: Software, Hardware, External Consulting, Development of applications, Personal, instruction and other expenses;
- The detail of expenses foreseen with the exploitation of the new-implemented system in the following categories Software, Hardware, External Consulting, Development of applications to the measure, Personal, instruction and other expenses.

At the financial benefits level

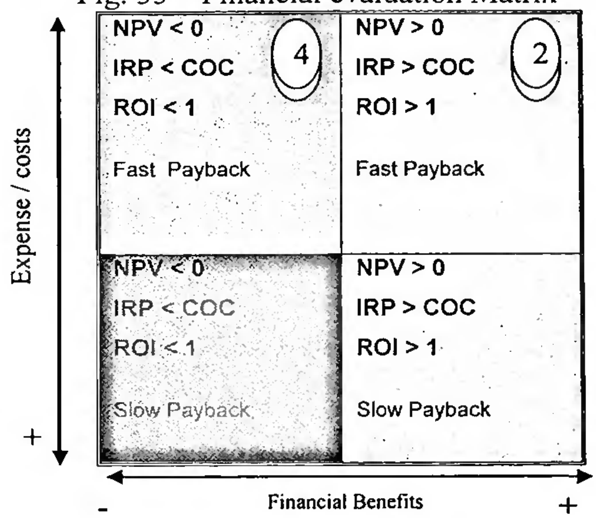
- The savings generated in face of the present situation, for the organisations and for the public, during the useful life of the project;
- The increment of revenues generated in face of the present situation, for the public administration, during the useful life of the project

By the analysis of data generated by these instruments, organisations have the information to evaluate the value of the investment and the impact of that investment in the organisation process.

The data processing creates the picture summary of the project cash flow, which allows defining the values of the financial evaluation features, such as the NPV, IRP, ROI and Payback. For example, the combination of these features, within multi-criteria analysis, originates the positioning of the project in the Financial Evaluation Matrix (Fig. 35). In the following figure the Fast or Slow Payback time attribution, will always depend on the decision maker's choice. For example to

Slow Payback choice, it could be more than 7 years and less than it could be Fast Payback.

Fig. 35 – Financial evaluation Matrix



Source: Expanded from the Metodologia de avaliação de investimentos, proposed for the IIMF, (Serrano et al, 2004)

After the analysis of the Financial Evaluation Matrix, the investment project should have the following recommendations:

Fig. 36 - Recommendations

1	Accept the project.
2	Accept, but the management should take a careful financial approach of the project.
3	This condition is not possible, so the project should be financial re-dimension in order to a possible acceptance.
4	Not accept.

The Financial Evaluation Matrix is one of the instruments of the interactive investment evaluation process; however, this process is not exclusively for financial evaluation. It is also used to analyse the investment project risk, and the instrument to do it is the Risk Evaluation Matrix.

In this work, the analysis of the investment risk is based on two bibliographical references: the Chapter 6 of the Risk Assessment Guide for Administration Quality in IT Shell 4 and Strategic Planning Information Systems.

3. Risk analysis;

In order to identify and evaluate the potential strategic or organisational project risks, managers have to analyse and answer questions, such as: Does it represent an important change for the organisation, after the conclusion of the project?

As for the technological risks, the question could be whether the technology to use is recent or not?

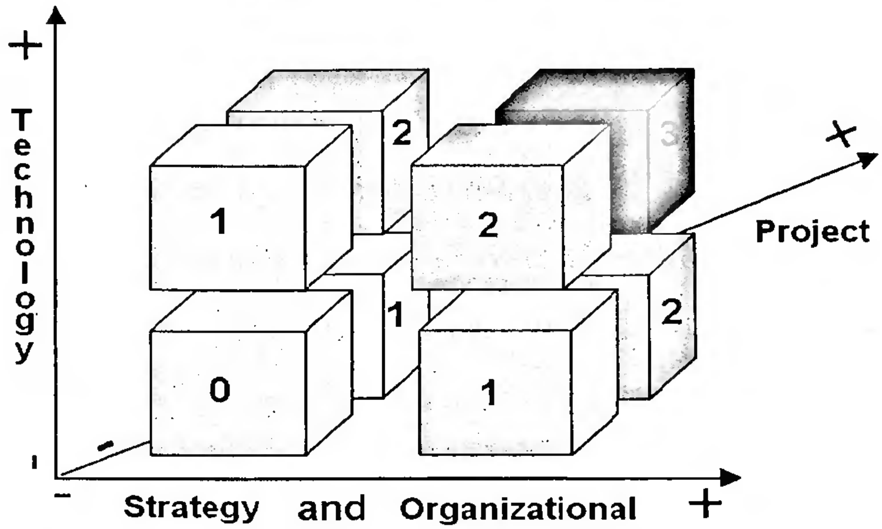
In what concerns the project risks, the question could be whether there is a project management technology?

For each of the above-describe features, managers have to classify them as low, medium or high risk.

The fourth feature is the success critical factors, which is the qualitative information evaluation. The main function of the qualitative information evaluation is the validation of the answers' coherence of the previous three features and the support of clear meetings and the revaluation of the proposed project.

The result of the evaluation will be presented in a three-dimensional referential, as exemplified in Fig 37.

Fig. 37 - Risk evaluation in the three axes



Source: Expanded from the Metodologia de avaliação de investimentos, proposed for the IIMF, (Serrano et al, 2004)

The reference of risk evaluation presented in the illustration is an instrument of interactive evaluation, and exclusively in terms of analysis of risk, it should point for the following classification in Fig. 38.

Fig. 38 – Classification Risk

0	**Minimal risk**
1	**One Risk - Project to approve, it has a medium risk level**
2	**Two Risks - Project to be re-evaluated., it has a medium high risk level**
3	**Three Risks - project not approved it as a high risk level**

Source: Expanded from Metodologia de avaliação de investimentos, proposed for the IIMF, (Serrano et al, 2004)

4. Global Analysis

The global analysis is a continuous and interactive analysis process and is based on the iterative analysis evaluation of the investment (Strategic Evaluation + Financial Analysis + Risk Analysis), with the objective of getting an integrated and global reading about the IS/IT project investment.

5. AHP Support Analysis.

The Analytical Hierarchy Process approach is used in the IS/IT investment choice, because it gives to the managers the capability to handle qualitative and quantitative data in order to better analyse which is the best IS/IT investment.

The AHP can be characterized as a multi-criteria decision technique in which qualitative factors are of major importance. So, the AHP can be, by itself, an excellent base technique for the supporting of decision system, which means that AHP is a useful decision analysis tool and could work integrated in an Investment Evaluation Methodology (IEM) or independently of the IEM. One of the main objectives of using the AHP approach in this study is to demonstrate that such technique could be used by the public administration managers to obtain the necessary help and to clarify their investment doubts, in order to take the most correct decision in IS/IT investments.

6 Discussion

Investment on information system and information technology is widely regarded as having an enormous potential for reducing costs and enhancing competitiveness in organisations. However, the speed of the changes in IS/IT technology creates serious starting problems for any investment. Any long-term project could be superseding by others, before it has ended and is definitely outdated by the time it is fully implemented. However, this could not be a reason to deny the need to evaluate IS/IT investments projects. Also, if IS/IT is to emerge as a beneficial corporate tool, the decision to invest needs to be examined as rigorously as any other type of investment.

That is why we think it is time to begin a discussion about IS/IT investments in the field of Portuguese public administration. The model we propose is to increase value for referred discussion.

First, because we begin to use an investment evaluation methodology, based in the MAIS, which is a methodology proposed by Serrano et al. (2004). The Investment evaluation methodology is expanded with AHP, which is a multi-criteria decision technique that can combine quantitative and qualitative factors, for turning it more functional, mainly at measuring intangible effects.

The AHP analysis and results (presented on the examples above) have demonstrated that the process presented is a useful and practical method for supporting decisions on IS/IT project investments. It has the advantage of being a good formal and systematic method approach.

There are also quantitative and qualitative methods discussed in this work, such as Information Economics; Multi-Objective, Multi-Criteria Methods; Value

Analysis and Critical Success Factors, which can be used by the Portuguese public organisation managers for the evaluation of IS/IT investments.

In this section, several recommendations and ideas remain opened for possible future works, which intends to give continuity to the work initiated, and to complement it or adapt it to the new future reality of the Portuguese public organisations. Because of this, it has been judged relevant to continue the discussion about the evolution of the DSS and its applicability to the selection of the best IS/IT investments for public organisations.

7 Summary and contribution

In this work we have presented a new methodology for evaluating IS/IT investments for public sector organisations, because there is obviously a need for more systematic and consistent evaluation approaches for evaluating strategic IS/IT investments in organisations. The proposed methodology aims the systematisation of the evaluation process, whose main objective is to achieve proposed benefits and to obtain gains in quality of services or organisations productivity by the introduction of a new information system or technology.

We have therefore presented a model, which is the base to evaluate the investments for an information system or technology based on strategic alignment policy, financial analysis approach, and risk analysis. To overcome some limitations of the model in the evaluation of non-financial or non-quantitative issues, we also proposed the AHP tool, which helps and supports the decisions makers in their choices about what IS/IT system to acquire, with the objective of bringing benefits to the organisation, which could be less administrative work, improved public services and reduced costs.

In this work, we have analysed the application of the recommended methodology in the context of acquiring operational software or a new computer. This decision-making model, aimed at supporting public managers in their decisions on IS/IT investments in the Portuguese public administration, was based on the MAIS methodology and AHP technique, whose satisfaction would allow the organisation accomplishment for the best IS/IT vendor proposal.

Besides these efforts, future developments for the approach taken with the presented methodology (MAIS + AHP) can also be undertaken. The presented model should be applied in the future to other types of investments in public sector organisations as, for example, for evaluating or even initiating changes in work profiles, in order to achieve new executions and normalization of the work proceedings, taking in attention the evolution of the society in technological terms. In this way, new techniques could be implemented to this model, in order to evaluate innovations process or even strategy changes. The proposed methodology is the base for a valuable DSS model for analysing strategic IS/IT investments, which are tangible and intangible by nature. These approaches can have significant direct and indirect impacts on multiple functions within the organisation and they can help managers on selecting the investments about redesigning the logistic chain, renewing the services, renewing the services policy completely, increasing the size of the organisation by mergers, establishing new alliances by information technology, and so on.

The proposed decision making process and the decision support system method hold the following objectives:

The primary focus of this study was to give an historical perspective of the DSS, which consisted on a literature review on the models' evolution of Decision Support System in the organisations. This revision drove to the systematisation of the motivations that drive the adoption of the DSS for the organisations.

The second objective was the study of a formal method for evaluating the IS/IT Investments based on properties, such as Strategic alignment of the investment project, Financial analysis and Risk analysis. This methodology needs to be complemented by a decision support system tool.

The third objective was to recommend a tool for constructing a decision support system that helps public organisations managers on IS/IT investments. In order to do this, several tools were analysed with the purpose of evaluating the evolution of the DSS. In an experimental way, it has verified and validated the AHP – Analytical Hierarchy Process Model.

The AHP contribution to the model

The intention of joining the AHP with the MAIS is because we think it is possible for public administration managers to fully understand all the facts in the IS/IT investments evaluation. These facts could be the weigh of the criterion in analysis, the pluses and minuses of the choice alternatives and all the features they have to re-evaluate until the communication of their decision. Once an initial decision is made, it is not final. Even with a strong decision, the decision maker is always subject to external pressures from special interest groups such as, suppliers, customers, employees, trade unions or politicians. Objectives that were thought to be central to a decision, under these outside influences, become less central or less dominant and a re-evaluation becomes necessary. Gradually, priorities are changed until a new, re-shaped, decision emerges. Without a decision model like the one we propose, the audit-trails could be lost and executives find it impossible to systematically review or retrace the steps and sub-decisions made in the decision process. The difficulty of conducting a proper review increases exponentially with the number of objectives.

As we already explained, the transitivity is important in multi-criteria decision-making, thus the analytic hierarchy process (AHP) is criticized since it suffers from scale transitivity. This work reviews the scale proposed by Saaty (1980), and then discusses the transitivity of AHP scales. In order to deal with the transitivity problem, AHP provides a consistency index for testing pairwise comparisons consistency. This work proposes a contribution to improve the fit to the judgmental preferences, by using the implementation of the cut-off values table.

8 Conclusion

The IS/IT are changing the way public managers undertake the development of their organisations' operations, and service deliveries, providing new ways of approaching the relationships between public administration agencies and the citizens they serve. Within the past ten years, awareness and usage of IS/IT in public administration organisations has increased dramatically, since the new information and computer systems have the capacity to perform operational processes and to improve and change the way organisations operate. In one way or another, the information systems and other technological innovations influence most public organisation operational processes.

The Portuguese public organisation managers must pay attention to the importance of investments evaluation in information technologies regarding public administration. Within organisations, the IS/IT investments are often characterized as strategic, however, the referred investments generate an array of benefits that sometimes are difficult to qualify and quantify for evaluation purposes.

This is one of the reasons why it is important to help public administrators on their IS/IT acquisitions, considering the role public organisations play in our lives, the significance of these and other impacts must not be ignored.

In order to perform more successfully the acquisition process, it is important to make an ex-ante analysis of investments, and to do that, the organisations need to evaluate the best IS/IT acquisition in advance, in way to obtain the most excellent service to the citizen at the lowest investment cost. That is to say, saving as much as possible of the treasury and rendering the best service to the citizen.

However, nowadays there are organisations that spend too much on IS or IT considering the service that is rendered, and managers do not have help available to evaluate the best price and quality IS/IT investments. The IS/IT investments are instruments to implement corporate strategies and they are necessary for the success of public organisational processes and for the citizens they serve.

This is an important issue in Portuguese public organisation, and our study reveals that there is no Decision Support System to assist managers in their decision task to buy new technology (Software and hardware).

This thesis intends to address the evaluation of IS/IT investment through financial, quantitative, qualitative multi-criteria evaluation methods and techniques in order to recommend a Decision Support System model for analysing the IS/IT investments projects.

In this model, all the properties, or features of the investments are modelled as attributes. The decision criterion is chosen in order to have a correct and successful structure for the decision problem. Then, we defined a DSS model based on the methodology for evaluation of IS/IT investments projects, which is based on the MAIS previously referred, and assembled with the AHP technique.

There are a number of general lessons to withdraw from this research that might contribute to other studies about the implementation of a decision support system, using one investment evaluation methodology improved by a simple decision-making tool to deal with complex, unstructured and multi-attribute problems, such as the AHP. The analysis and results of the examples presented in this work have demonstrated that the AHP process is useful and can be a practical method to evaluate the investments in IS/TI systems.

In conclusion, AHP is one of the most used processes in the decision-making problem, which has been used to support numerous decision makers of several organisations (public and private) all over the world. This technique is very useful for the evaluation of IS/IT investment analysis because it helps the decision makers in:

- Structuring the hierarchy during the investment evaluation. The hierarchical building step is a powerful instrument, because it helps in furthering thinking and understanding about the problem and reduces the chances of issues being overlooked.
- Conducting the study and discussion about the investment with the maximum interaction possible, to ensure that decision makers understand all the investment necessary steps, and how to make comparisons between criteria based on the cut-off values Matrix.
- Understanding that the comparison process is one of the most critical and important aspects of the AHP study. That is why the decision makers have to train a lot to understand the definitions and guidelines on determining the comparison Matrix. The question here is how to make the comparison between criteria?
- Calculating the weights, these are determined for each level in the hierarchy from various comparisons matrices, based on the eigenvector or on any other of the studied methods.
- Scoring factor performance is a fuzzy activity, since it involves measuring performance using subjective data.

In this work, the proposed investment evaluation model, not only focuses on tangible costs, benefits and risk factors, but it goes beyond the traditional selection approaches by incorporating the wider intangible value. This new promising method to support decision making on IS/IT investment analysis uses the AHP technique as an important instrument to assess the relative weighting of the intangible criteria and sub-criteria. It also provides a formal mathematical model with a rigorous approach to deal with multi-criteria IS/IT strategic investment decision.

The proposed technique has been tested in the theory examples, and we have found that such technique is a useful tool for reaching the desired result. In that way, we agree that public administration managers have a tool to deal with strategic investments, which are tangible and intangible by nature, expensive, resources consuming and have long-term impacts. Moreover, the proposed DSS for the IS/IT investment analysis is in theory a good instrument to help the organization administrators on selecting the best systems or technology, in order to get the necessary and fast changes in the organisations' environment. It is an important instrument, because it could cause new and improved demands on the methods for supporting investments strategic decision-making by public organisation managers. The DSS is also important because organisations must adapt quickly and flexibly to changing circumstances, and this instrument surely helps their managers in this demand.

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APPENDIX I

At the conceptual level, Power (2001) based on the Alter (1980) classification proposed the following taxonomy with these five generic types of DSS:

- Data-Driven

  This includes: the administration file systems (file drawer), the administration of reports/maps systems, the data warehouse and analysis systems, EIS (Executive information systems), spatial decision support systems and Business Intelligence systems are also examples of DSS guided to the data.

  The main characteristic of this type of model is the access and manipulation of big databases, contributing and taking care of the data and maintaining the data well structured. The DSS data driven and tools like OLAP (Online Analytical Processing), supply a high functionality level support to the decision.

- Model-Driven

  It includes systems that use representation models, optimization models, accounting and financial models. This type of DSS emphasizes the access and the manipulation of models, and jointly with statistical analysis tools, it allows the most elementary functionality level.

  This type of DSS uses data and parameters supplied by the decision makers, to help them to analyze certain problems, usually, these systems are non-intensive users of data.

- Knowledge-Driven

The DSS knowledge suggests actions and recommendations for the managers. This type of system consists in the specialized knowledge of a certain area. The knowledge system related to the concept of data mining can also be part of this type of systems. The tools used to build it, some times, are called intelligent decision support methods.

The data mining tools can be used to create hybrid DSS that can have more data and knowledge components.

- Document-Driven

This type of system was created to help managers to keeping and managing non-structured documents and web pages. The DSS guided to the documents, integrates a variety of storage technologies and processing for a complete analysis and documental treatment. The searching motors become a powerful tool when associated with DSS guided to the document management.

- Communication-Driven

This type of DSS includes the communications, the collaboration and the support technology to the decision that do not fit in the classification of DSS identified by Alter (1980). The decision support system in-group (DSSG) is a hybrid system composed by a communication system and a decision model. Examples of this kind of systems are the Interactive video system, E-mail and bulletins (Bulletin Board).

APPENDIX II

The choice problems could be decomposed in following steps:

Step 1, which has the problem definition and the research for the best alternatives in order to get the best solution, this step could be synthesized like this:

1a: Problem identification;

1b: Identify objectives and alternatives, and make a list of the advantages and disadvantages for each alternative which is frequently useful in identifying the objectives;

1c: Research the alternatives.

In Second (or it's better to say in Step 2), it takes place the elimination of the alternatives that are not necessary or do not bring great benefits to the organisation. For that, it is indispensable to:

2a: Determine what he calls the "musts" – something that it is necessary;

2b: Eliminate alternatives that do not satisfy the "musts".

In third place (or Step 3), it is necessary to create a structure or a decision model forming a hierarchy tree to include goals, objectives, sub objectives and alternatives. Add other factors (such as actors and scenarios) as required.

In the fourth place, or better say Step 4, it is required an evaluation of the factors in the model by making pairwise relative comparisons, to do that it is important to analyze that process in two ways:

- First, Use all the available data based on facts, and interpret the data, as it relates the satisfaction of the organisations objectives. That is, do not assume a linear utility curve without thinking about whether it is a reasonable assumption.

- Second; Use the knowledge, experience and intuition for those qualitative aspects of the problem or when hard data is available.

In fifth place (Step 5) we proceed with the synthesis to determinate and identify the "best" alternatives.

In Step 6, we proceed with the examination and verification of the decision. This is an iterate process, or is better to say, first examine the solution and perform what Thomas Saaty calls, sensitivity analyses. If the solution is influenced by factors in the model for which it does not have the best data available, is better to consider spending some time and money to collect the necessary data and iterate back to step 4. In the following of this, check the decision against *intuition*. If this is the case, ask ourselves why the intuition tells us that a different alternative is best. Observe if the reason(s) is already in the model. If not, revise the model (and or judgments). Iterate as required. In general, we will find that both our model and intuition may change, (i.e. we are learning). When our intuition (possibly different now than it was before) and the model agree, continue to step seven.

In Step 7, this is the moment for document the decision and for justification and control. In this step, judgments must be integrated carefully and based on mathematical procedure. In this step, there are some aspects to take in to consideration, that is, the experience, knowledge, and power of each person involved in the decision.