INDUSTRIAL PROCESSES INTEGRATION

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Resumo

Os procedimentos *top bottom* para desenvolver modelos de avaliação multi-critério têm sido amplamente utilizados nas mais diversas áreas de aplicação. No entanto, a aplicação dessa abordagem em ambientes corporativos é muito pouco documentada. Com o objectivo de contribuir para a literatura, ao resolver um problema de decisão real de uma empresa de petróleo e gás relativamente à selecção e implementação de uma plataforma de integração de dados, esta dissertação aplica um metodologia combinando conceitos de medição de valor multi-critério com processos participativos dando ênfase especial ao desenvolvimento de dois processos web-Delphi modificados, tecnicamente fundados na abordagem MACBETH. Estes foram desenvolvidos a fim clarificar o sistema de valores dos atores envolvidos nos processos através da colecção dos seus juízos sob valor na forma de comparações qualitativas entre os níveis da escala de desempenho em cada um dos múltiplos critérios de avaliação e sua ponderação, respectivamente. Por um lado, os resultados desses processos em relação ao problema de decisão em questão serviram de informação para que a empresa construísse o modelo de avaliação multi-critério pretendido, tendo um grupo estratégico tomando as decisões finais com base na compilação de julgamentos fornecida pelos participantes nos processos Delphi. Por outro lado, forneceram informações valiosas sobre a confiabilidade do Delphi desenvolvido em ambientes corporativos.

Palavras-chave: *top bottom*; modelo de avaliação multicritério; Processos participativos; Delphi; MACBETH.

Abstract

Top bottom procedures to develop multicriteria evaluation models have been widely used in the most diverse areas of application. However, the application of this approach in corporate environments is very little documented or not at all. Aiming to contribute to this literature, while solving a real decision problem of an oil & gas company regarding the selection and implementation of a data integration platform, this dissertation applies a framework combining concepts of multicriteria value measurement with participatory processes giving special emphasis to the development of two modified web-Delphi processes technically sound in MACBETH. These were developed in order to make clear the value system of the actors engaging in the processes through the collection of their value judgments in the form of qualitative pairwise comparisons between performance scale levels on each one of multiple evaluation criteria and their weighting, respectively. On the one hand the resulting outcomes of this processes regarding the decision problem at hand, served as feed in information for the company to construct the aimed multicriteria evaluation model, having a strategic group make final decisions based in the provided compilation of judgments form the participants in the Delphi processes. On the other hand these provided valuable insight regarding the reliability of Delphi developed in corporate environments.

Key-words: Top bottom; multicriteria evaluation model; Participatory processes; Delphi; MACBETH.

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1. Introduction

The oil & gas industry are leaders in technology innovation when it comes to the extraction, production, and pipeline delivery of fuel energy. However, many oil & gas producers are still catching up when it comes to optimizing business processes. The supply chain has many moving parts, and the more of those parts you can automate the more it benefits every partner in the value chain. Using manual data entry not only slows operation but also introduces more opportunities for human error. Other industries have learned the lesson of automation, but the oil & gas still lags behind. Being fully aware of this global trend for automation of business processes and of the benefits it has to offer, Galp has felt the need to step into this new era aiming at data automation integration of its industrial process. Galp is an integrated energy player being the only integrated group of petroleum products and natural gas in Portugal, with activities ranging from the exploration and production of oil and natural gas, to the refining and distribution of petroleum products and to the distribution of gas and to the generation of electricity. Galp's organic structure, at the operational level, is based on five business units that are integrated into three business segments as follows:

- Exploration & Production: Exploring and production;
- Refinement & Marketing: Supply, refining & planning, Iberian oil marketing & international oil and New energies;
- Gas & power: Gas & power.
  (from https://www.galp.com/corp/pt/sobre-nos/a-galp/organizacao)

In this context Galp is undergoing a transformational moment within the processes involved in the Oil management, which demands actions with a structural impact on information systems and how they integrate and support the business processes. Galp intends to implement an integration platform aiming at higher integration, flexibility, coordination and efficiency, easing the access to information so as to support better decision making and improve the capacity to respond to market moves. In order to do so an internal contest was carried out at Galp for tenders to present their solutions to this problem.

This dissertation comes in this context answering to a specific call from the company. To evaluate tending options and appraise the best Enterprise Management System solution, i.e. data integration platform, proposal the construction of a multicriteria evaluation model was in place. The purpose of this dissertation is to present the work developed by author, collaborating with Galp, towards the model building process highlighting the practices carried out by IST.

The application of top-bottom approaches for developing multicriteria evaluation models is widely in practice in the most diverse areas of application. Studies regarding the employment of technics for breaking down the value systems of the actors have been made available through documentation [1]. However the case regarding corporate environments is much different due to the property nature of the developed practices and results. In this context this dissertation suggests and applies a social-technical methodological approach to the problem of breaking down the value system of the actors in corporate environments through the district working areas of the company, combining concepts from multicriteria

value measurement with participatory methods to build the multicriteria evaluation model. To enable the evaluation of options participatory Delphi processes (non face-to-face) and Decision Conferencing processes (face-to-face), are developed respectively. The employment of the latter to wrap up the process is known to be necessary and justifiable due to the complexity of developing evaluation multicriteria models without face-to-face interactions [2]. Thus the focus of study in this dissertation is the employment of two modified web-Delphi processes technically sound in MACBETH (Measuring Attractiveness by a Categorical Based Evaluation Technique) to collect value judgments of an enlarged group of participants to inform the decision conferencing processes, in the form of qualitative pairwise comparisons between performance scale levels on each one of multiple evaluation criteria and their weighting, respectively.

Literature emphasizes the benefits of Delphi studies in other contexts where these have revealed to be a major asset [3]. The efficiency of top bottom approaches is known to be questionable in contexts were pressures from dominant actors are present, as is the case of corporate environments having a hierarchical structure of employees [1]. Anonymity being one of the key features of a Delphi process allows for the value system of the actors engaging in the process to be “freely” expressed undoing pressures to conform [3]. Furthermore the employment of multiple rounds in the Delphi processes contributes to the assessment of the reliability and stability of the answers provided by the participants in the processes [3]. Finally the use of a web-based environment to develop the Delphi processes is tested aiming at increasing the efficiency of the Delphi processes through automation of the practices involved in this participatory method.

The structure of this dissertation report is presented as follows: section 2 presents a literature review with the purpose of framing the decision problem at hand in a theoretically context and to configure the adopted approach; section 3 presents the methodological framework applied; section 4 presents the selected results and analyses of the application; finally section 5 discusses the outcomes of the application.

To preserve industrial confidentiality some of the data presented have been altered or disguised.

2. Literature review

Considering the problematic of this dissertation, which was previously introduced, in this next section a review of literature is presented regarding the subject at hand in view of introducing the theoretical basis of this work. This section is configured as follows:

- Enterprise Management Systems' selection criteria
- Multi-Criteria Decision Analysis (MCDA)
- Participatory Methods

Although little or no literature is available regarding the task of selecting an Enterprise Management System (EMS), especially in the specific context of energy, selection processes that resemble similar software selection (Enterprise Resource Management software) have been documented in a general context, even though most of them neglect the reporting of the specific area for which the software application is intended. Rather these documented studies focus mostly in the selection methodology of the system and on the criteria used to carry out this task. Thus, being these later the starting focus point of this work, the documented information was taken as reliable and suitable literature review in this context and presented in sub-section 3.1.

EMS selection is one of the most important decision making issues covering both qualitative and quantitative factors for organizations. MCDA has been found to be a useful approach to analyze these conflicting aspects [4]. Hence, given the problematic of the case study we are inserted in, the use of a multicriteria approach was a natural and convenient course of action. Sub-section 3.2. entails the employment of a system measurement of performance in view of aggregating and interlinking the previously appointed criteria of the model. The perspective of using of using a multicriteria evaluation model that will enable not only the assessment of the performances of the various considered indicators, but also its partial and overall value was introduced. The MCDA thematic was explored resorting to the MACBETH approach.

Afterwards (sub-section 3.3.) participatory methods in the perspective of MCDA are presented as a social tool to aid the technical activities of a MCDA's framework, enabling the collection and application of actors' input in the process of model building. This strand was exploited in the Delphi's method outlook.

2.1. Enterprise management systems' selection criteria

The process of selecting Enterprise Management Systems (EMS) is a common practice in organizations nowadays, aiming to optimize the organization's processes. EMS are a type of application software package that encompass many IT (Information Technology) functions [4]. These are usually referred to as a category of business-management software that an organization can use to collect, store, manage and interpret data from the most various business activities.

Modern practices in business industries have given an increasing importance to software procurement. Due to this fact, a clear trend in this sector, regarding both private and public companies has been

verified: the fast and wide proliferation of large packed ready-made systems available [5]. Application software packages, in a general way, are defined by a vendor to provide a set of standard functions that are usable for different sorts of companies [4]. Selecting an EMS is one of the most difficult investment projects, considered a costly, time and resource consuming process [6][4]. Despite the fact that many of these projects have led to considerable development in different areas, and have also attained competitive advantages for organizations, there is a variety of reported cases in which organizations have failed while attempting to carry out projects of this nature [6]. A successful project involves selecting a software system and vendor, implementing this system, managing business processes change and examining the practicality of the system [4]. Some causes for the failure of these processes have been identified. Amongst them is the fact that project managers pay attention only to the technical and financial aspects of the project and ignore the other aspects. Choosing the EMS package that best meets the organizational needs and processes is crucial to ensure a successful implementation and use of this. Package software implementation success is beneficially associated with the best fit between software vendor and user organization. Selecting the wrong package may cause a misfit between the package and organizational goals or business processes. All this process of selecting a software package and vendor, implementing the software package and maintaining it is a very critical one since its outcome will affect the company in either one of two ways, positively or negatively [4]. Still, the exact selection of a suitable choice is of great importance since it has an intensive effect on acceptability, usefulness and in creating cooperation regarding the use of the new system within the organization [6].

Both Laudon and Laudon (1998) and Hecht (1997) documented that the selection of the most appropriated software solution is a semi-structured decision problem without agree-on and formal procedure [7]. Researchers have defined software acquisition as the following decision process: “clearly define the need that should be fulfilled with the help of a software product and/or related service; find suitable products and services in the market that may help in the fulfillment of such a need; establish appropriate criteria for the evaluation of the software system; evaluate products and services in the light of these criteria; select the best available product and service, or the best possible combination of products and services; and negotiate the final contract with the product vendor or service provider” [5].

Regardless, the reported failures regarding the implementation of software, have led to an increase in the market risk of these products and to the pessimism of managers and investors towards them. This issue and the recognition of one important factor related to the failure of these projects, i.e. lack of appropriate criteria, has caused researchers to identify the effective criteria in choosing these systems. This has become a vital and important task [6].

When choosing the most suitable EMS for an organization many parameters and factors are involved. Choosing the right parameters and factors to be considered, in each project situation, is a task of great importance. The neglect of this task often leads to serious difficulties in the project and may imply its failure. Over time, researchers have reported and published their work on this subject.

Different approaches have been exploited in order to assess which criteria are in fact of relevant importance, when it comes to the evaluation and consequent selection of an EMS. While some authors

have simply appointed criteria ungrouped or uncategorized, others conducted and reported their studies in the exact opposite approach. Criteria have been reported in three ways: regarding vendor or customer's evaluation/selection criteria, categorized according to the company's size (small, medium or large size companies) or clustered in groups or fields. Others have developed specific models to in view of easing the process, as Stefanou (2001) how developed a conceptual framework, applicable to any type of organization (with any kind of activity), which enabled the making of correct and scientific decisions. According to this framework, two groups of criteria should be taken into consideration: strategic and operational. Likewise, Lien and Chan (2009) developed a 5-layer model to assist the process of selecting a software package to be implemented in organizations, in which the different layers consider different aspects of the process (i.e. goal, groups of criteria and sub-criteria and choices the organization is interested in). [6]

One of the approaches taken is the identification of criteria which from the costumers perspective regarding the vendor. Siriginidi (2000) states that the most important features for costumers are the stability and history of the vendor, last 12 month track record of sales, and implementation support from suppliers and improvement of the software packages. In the same line of thought and in the same year Sprott documented criteria such as applicability, adaptability, integration and upgradability of the software.

Regarding the companies' size Rao (2000) concluded that some of the most basic criteria for a large company are of extreme influence on small or medium companies. Bernroider and Kock (2001) also identified 29 criteria as relevant of the evaluation and selection of an ERP system, from which 12 had a strong relation with the organizations' size. The most relevant factor in this particular categorization seems to be the budget factor. The risk factor is way bigger in small and medium companies. Whereas large companies may be able to undertake the risk of engaging in a project for the evaluation and selection of ERP system small and medium companies have to consider this matter with way more caution due to issues related to the companies' capital. Thus, affordability seems to be the number one criteria related with companies' size in projects of software selection. [6][7]

Yet another perspective taken in this matter has been the clustering of the criteria into groups or fields for posterior evaluation and selection of the software. Most of the criteria clusters are sorted in relation with two distinct strands: vendor and software. Some other authors also incorporate a cluster with respect to criteria related to the specific project itself and yet others one cluster with relation to user's criteria. Within the cluster of software criteria, two groups emerge in the literature: the functional and technical evaluation criteria [6][5]. These seems to be the most dominant approach which at the same time permits the most promising results in the framework of these projects of EMS evaluation and selection. On the one hand, criteria with respect to functionality address three main aspects: which functional areas are covered by the software; how flexible the product is with respect to adaptability and openness; and some EMS specific features. On the other hand, the technical criteria all involve some kind of measuring which yields to the corresponding domains and attributes [5]. It should be noted that these mentioned clusters, which ever they might be, do not retain an agreed upon number of sub-criteria in the available literature review in

order to reach process optimization. This quantity varies vastly from one reported case to another, making clear the idea that each project is a project with its own needs and features [6].

Key-idea: Projects of evaluation and selection of EMS are of extreme dimension and importance to organizations. The most important recognized factor related to the failure of these projects is the lack of appropriate criteria within the framework of the project's sphere. Hence, the task of assessing these is of vital importance for the project to succeed.

2.2. Multi-Criteria Decision Analysis (MCDA)

Nowadays the process of making decisions has drawn-out of its classical approach: optimizing a single objective function over a set of feasible solutions. Conflicting aspects such as multiple criteria and stakeholders' opinions are to be considered in the same decision scope, which usually leads to a satisfactory decision rather than an optimal one. This setup becomes a is more relevant when groups are involved, such as in organizational decision making, or in other situations in which multiple stakeholders are involved [8]. Bana e Costa and Vansnick observed that decision making is ultimately a human activity in which value judgments of the actors regarding the desirability or attractiveness of organizational decision opportunities and alternative courses of action play a crucial role [9]. This evolution and consciousness regarding decision making features has led to the Multi-Criteria Decision Analysis (MCDA). Belton and Stewart define MCDA as "an umbrella term, which describes a collection of formal approaches that seek to take explicit account of multiple criteria in helping individuals or groups explore decisions that matter" [10]. MCDA is a structured framework with two components: a technical and a social component. The technical component entails the employment of a set of technics to support the different steps of the development of a multicriteria evaluation model, whereas the social component is meant to capture the points of view of the participants involved, in order to create a "shared understanding of the issue" [11]. A general groundwork for the development of a multicriteria evaluation model includes four modeling steps, beginning with the definition of the object of the decision and ending with the activity of decision aid, as follows: (i) structuring the decision problem, (ii) articulating and modeling the preferences, (iii) aggregating the alternative evaluations (preferences) and (iv) making recommendations [8][12].

Many MCDA methods have been developed throughout time. All methods have in common that they allow taking the multidimensionality of decision problems into account by using multiple criteria, instead of one common denominator. However, these methods differ from one and other in the way the idea of multiple criteria is operationalized. In particular, each method shows its own properties with respect to the way of assessing criteria, the application and computation of the weights, the mathematical model utilized, the model to describe the system of preferences of the entity facing the decision making, the level of uncertainty embedded in the data set and the ability for stakeholders to participate in the process. Throughout time, MCDA methods have been extensively used to solve namely two types of problems; for solving problems that require the selection of a solution (i) from a multiattribute discrete set of options or (ii) from a continuous set of options. Regarding the first, one option is chosen from a set of finite and

determined options. Considering the latter, the amount of options is not predetermined. Rather, these are only “implicitly known” and goals are given through clear objective functions. Each option with regard to each goal can be assigned a certain value and the solution is calculated with the help of a certain procedure. [13]

In order to handle problems which setups require the selection of a solution from a finite and determined set of options, outranking or multi-attribute value theory methods are generally utilized. Whereas outranking methods consider a finite set of alternatives, which are valued at the light of a group of criteria through the building of non-compensatory relations between the alternatives, multi-attribute value theory methods aim at the definition of an unique function which is meant to aggregate the different utility functions [14]. Contemplating multi-attribute value theory methods, mathematical models can be utilized in order to aggregate the different utility functions to enable the evaluation phase of the model building. This implies the weighting and scoring of the options. Unfortunately, some processes widely used in practice to accomplish the aforementioned tasks break the necessary theoretical principles underlying an accurate procedure. Methodologically correct procedures for weighting and scoring are based on qualitative and quantitative value judgments, depending on the used technics. Examples of these two opposite approaches are the Simple Multi-Attribute Rating Technique (SMART) and the Measuring Attractiveness by a Category-Based Evaluation Technique (MACBETH). [2]

The MACBETH approach

As referred, a possible decision-aid approach to multicriteria value measurement is MACBETH. Its goal is the “measurement of the attractiveness or value of the options through a non-numerical pairwise comparison questioning mode, which is based on seven qualitative categories of difference in attractiveness” [2]. In practice to facilitate the comparison of options, the decision maker is questioned regarding the relative attractiveness of two options, being asked to verbally judge their difference in attractiveness , e.g. “considering options x and y, such that x is equal to or preferable to y, the difference of attractiveness between the options is: no difference (indifference), very weak, weak, moderate, strong, very strong, or extreme? [15] [16][17]. Hence, it can be said that MACBETH is founded on value measurement differences and based on pairwise comparisons [10].

The technique follows a constructivist approach and social-technical process. The first is related with co-constructing through interaction with the decision makers. This implies that the actors of the process interactively consider the available options and their consequences, until a consensus reached. Thus, as an optimal consequence of this approach, the actors decide upon the best options in a constructive practice. The latter combines the technical elements of the method with the social aspects of the interaction between the actors [2]. Due to the high level of interaction amongst participants, the identification of a suitable panel, both relevant and experienced, is of paramount importance when considering the approach in question. The continuous discussion between participants in the process,

regarding the issues up to consideration, enables improvements and adjustments of the model, while taking into account the know-how and experience of the actors.
The construction of the multicriteria evaluation model, resorting to the MACBETH approach involves three phases: structuring, evaluation and testing.

Structuring

It is often the case that the actors are primarily "interested in the correct specification of their decision problem". Thus the structuring phase frequently begins with the task of framing the problem [18]. Afterwards, the process usually follows a discussion regarding the different points of view (PsV) about how potential actions should be evaluated. Bana e Costa et al. define a "point of view" (PV) as any aspect that (i) emerges during the discussion as relevant for evaluating potential actions, (ii) in the perspective of at least one actor, and (iii) has a value meaning that is well defined and understood by everybody so as to avoid ambiguity and misunderstanding [19]. In this sense, stated objectives and concerns of the actors, as well as active characteristics of the organizations and possible consequences of potential actions, are all PsV [17]. The facilitator has a key role at this stage of the model structuring since it is meant to stimulate the reflection process of/between the actors in order to progressively make all sorts of PsV emerge, clarify their meaning and analyze why and in what way they are relevant [19]. This process must be carried out in view of establishing a family of "fundamental points of view" (FPsV = PV_1, PV_2, … , PV_k), and their clear description. Each of the elements of this family being an individual PV, or a cluster of several of them which are interrelated, that will serve as a decision "criterion" in terms of which the actors agree to a separate evaluation of potential actions. Ultimately, a FPV is a key PV that, first, the actors desire to isolate from the other PsV, as an evaluation axis, and second, verifies the necessary preference independence conditions [19][17]. A family of FPsV can be defined as a set of PsV that are consensual, i.e. all the actors involved should agree with the defined set of criteria; operational; exhaustive i.e. the problem must be defined in all its relevant aspects; and non-redundant, i.e. criteria evaluating features already evaluated by other criteria should be removed, without affecting the previously mentioned conditions [17][20]. In addition, the criteria should be preferably independent, i.e. the preference for an alternative in a given criterion should not depend on the existing preference for this alternative in another criterion [20]. FPsV are most commonly sorted out into areas of concern, hence reflecting broad values of interest [17].
In order to operationalize a criterion a performance descriptor is associated with it. A performance descriptor is an ordered set of plausible impact levels with respect to each FPV, intended to serve as a basis to describe in the most possibly objective way the impacts of alternatives. This matches Bouyssou's criterion definition as "a tool allowing for the comparison of alternatives according to a particular PV" [17]. A performance descriptor can be direct or natural, i.e. its levels directly reflect effects, indirect, i.e. an indicator of causes more than effects, or an index relating several indicators, or constructed i.e. a finite set

of reference levels. Furthermore, descriptors can be qualitative or quantitative, or even pictorial [17]. Bana e Costa et al. have suggested than when setting a performance descriptor two particular reference levels must be defined: Good, which is an unquestionable attractive level; and Neutral, which is a level that is neither attractive nor repulsive [21]. The definition of these two reference levels is meant to allow the comparison of attractiveness between levels and is of particular worth when dealing with a "problematic of absolute evaluation". This problematic implies that an individual assessment of the possible options, regarding the problematic, is favored over the comparison of these options to one and other [17].

It is possible that the set of criteria is ill defined to begin with, in which case a redefinition of these is necessary. This redefinition can be accomplished through a cyclic process of structuration, as described above.

Evaluating

Having concluded the structuring phase of the multicriteria evaluation model, the process of evaluating the available options can now start. In view of doing so, several interactive activities take place. In order to measure the (partial) attractiveness of the alternative options in each FVP, cardinal value functions are to be constructed upon the respective descriptors of impact which were previously defined; to harmonize the partial values across FPsV, scaling constants are to be assigned to the plausible ranges of the impact levels. At this stage it is necessary to define a mathematical model witch objective is to convert performance into value. The outputs of the aforementioned activities will then feed in the mathematical model which will enable the evaluation of the alternative courses of action with a well-defined overall score [17]. The most commonly used mathematical model is the denominated additive aggregation model described by the following equation,

$$V(a) = \sum_{j=1}^{n} p_j \times v_j(a)$$

$$With \sum_{j=1}^{n} p_j = 1 \ and \ p_j > 0 \ (j = 1, \dots, n)$$

Being,

$V(a)$ – global attractiveness of alternative a

p_j – weighting coefficient of criterion j

$v_j(a)$ – partial value of alternative a with regard to criterion j

Although other technics (numerical and non-numerical) may be employed when carrying out the referred tasks, the MACBETH approach is known to be suited to support both the construction of cardinal value functions and the determination of scaling constants (weights hereinafter) [21].

Building value functions

Comparing the different options in each FPV (criterion), with the respective reference levels good and neutral, might be interesting from the qualitative appraisal considering the capacity of each available option in the various components of competitiveness. Nevertheless, this does not enable the measurement of the intensity of neither their weaknesses (if below neutral) nor of their strengths, i.e. how weak or strong are the different options in each FPV (criterion). In order to achieve this, a cardinal value function has to be defined for each descriptor. [17]

Assessing weights

To perform an evaluation of the overall attractiveness of each option in terms of a determined FPV (criterion), first the 0-100 scales of partial values need to be "harmonized" in some way. For this purpose weights are determined [17]. "The most critical mistake" appointed by Kenney is the determination of (additive) weights without reference to the impact scales [22]. Rather, the adopted weighting procedure should consist of anchoring on two impact levels not dependent on a particular set of actions and determining the weights indirectly by applying MACBETH to holistic semantic judgments of difference of overall attractiveness between fictitious actions defined by the anchor levels, in the framework of a simple aggregation model [21].

Testing

Having concluded the structuring and evaluation phases of the model's construction it is time to appraise the requisiteness of the developed model. In view of verifying if the model respects the intrinsic characteristics of a requisite model, several approaches can be adopted [23]. A new model is considered requisite if it is sufficient in form and content to resolve the issues at hand [11]. An approach to be taken is the performance of sensibility and robustness analysis. These are intended to assess the resilience of an option when faced with alterations in the model's parameters. These analyses also enable the provision of adequate recommendations [19]. Taking a different approach, in the particular case of an organization requiring the development of a model for a specific organizational activity that is carried out quite often, a good way to test the new model is to use detailed historical data testing the model in past encountered scenarios regarding the specific organizational activity [23].

In the end of the testing phase if the developed model isn't found to be classified as requisite, it should be fine-tuned or even rebuilt if necessary [23].

Key idea: MCDA has been found to be a powerful tool in problems dealing with multiple criteria. The MACBETH approach in the decision making scope is presented as a technique which aims at the scoring of available options on an interval scale of measurement through the development of a multicriteria model evaluation. MACBETH possesses the advantage of abstaining decision makers to have to directly assigning the numerical scores required by other techniques, when dealing with the model building tasks.

2.2.1. Participatory methods

The need for interdisciplinary and participatory processes that combine, interpret and communicate the value and knowledge of the actors in a MCDA processes is already great and still increasing. Participatory methods have proven to be a powerful tool in aiding the social component of MCDA's framework, providing several ways for the incorporation of the actors' input into the process while enabling the creation of a shared understanding of the issue, a sense of common purpose and commitment to the way forward [11]. The more MCDA is used in an integrated and interactive way the more likely it is the full achievement of the potential benefits of the process. MCDA tools have helped to create conditions for a meaningful and effective interaction, which has been found to be one of the key objectives for designing participatory processes. [24]

When executing a participatory MCDA process different social approaches imply different outcomes, in terms of the nature of the collected information. All the approaches of this typology possess both iterative and interactive characteristics, as is typical in the particular case of participatory social processes meant to complement the technical components of a MCDA framework. It is an established fact that approaches that adopt more intensive interactions imply a higher usage of resources. Having various ways to apply MCDA to synthesize actors' input in the decision process, three different approaches will be broadly addressed hereinafter. [24]

The decisions conferences' methodology bases itself in the 5th principal of process consultancy, which states that "it is the client who owns the problem and the solution". This decision aiding methodology assumes that the problem-owners own all the necessary information, in the form of both hard data and judgment, to resolve the issues at hand. The facilitator assumes the overall task of arriving at an agreed prioritization of options, while the actors of the process contribute the content. The multicriteria model is developed on-the-spot representing the collective view of the group of actors at any point [11]. The aim of this approach is to combine group process facilitation, preference modeling and information technology with the concept that a group can achieve better results that an individual working on his or her own, hence making decision conferences a highly interactive approach [24].

Another approach for involving actors with MCDA is decision interview. These are usually part of an iterative participation and learning process, aimed at building common understanding and finding or constructing broadly acceptable options through the identification of key trade-offs and balancing between important objectives. Tasks are carried out in close co-operation with the actors of the process, thus crystallizing the reasoning behind the "impacts" of the options and pinpointing gaps in knowledge and previously ignored uncertainties. This approach gathers a large amount of information regarding the desirability of the different alternatives for different actors. Although the temptation of aggregating the collected data is a constant, especially in situations dealing with large data sets, it is suggested that the results are also presented in an individual way in order to enable the identification of groups of similar opinion. Summarizing, the approach in question provides strong interactivity with the actors through facilitated meetings and personal computer-aided interviews of actors. [24]

Yet another approach which can be taken when employing participatory methods with the goal of assisting MCDA is the Delphi process. Those who seek to utilize Delphi usually recognize the need to structure a group communication process in order to obtain a useful result for their objective, which ever it might be [25]. The actors involved in the processes are submitted to a series of questionnaires aimed for the systematic collection and aggregation of informed judgments from the group on specific questions and issues [26]. Delphi's characteristics of successive interrogation and questioning format make it a highly resource and time consuming technique. This technique is perhaps the most elaborate and restrictive of interaction between actors, while being at the same time the most iterative one of all three approaches presented [27].

It should be noted that participatory methods designed for group interactions can either be presential (e.g. decision conferences, decision interviews and Delphi) or non-presential (e.g. Delphi). This is not so relevant when dealing with the collection of hard data but it has proven to be when the objective is rather to collect actors' judgments on determined issues and in particular situations.

The Delphi approach

Origins of Delphi

For several decades, organizations have tried to collect knowledge and expertise in order to improve decision making and make predictions about the future regarding a variety of disciplines. At the light of these efforts, the Delphi method was conceived in the early 1950s by workers at The Rand Corporation (Santa Monica, California) under the patronage of the US Air Force. Back in the days, the corporation was conducting a military defense project, aiming to apply experts' opinion to the selection of an optimal US industrial target system. Consequently, Delphi emerged as a necessity of gathering expert input in a systematic way by the means of questionnaire with controlled opinion feedback. [3]

More than 50 years have passed since the first Delphi experiment took place. After the first publication describing the method in the 1960s, and as a result of the declassification of the Delphi method by the American Armed Force from its previous category as reserved for military use, it became a quite popular method spreading itself rapidly, both geographically and thematically. Since then, in these following decades and until the present day, Delphi has become widely used and recognized as a tool for judgment, forecasting and decision-aiding. The method was named after the ancient Greek oracle at Delphi, who offered visions of the future to those who seek advice. More broadly, the Delphi method has been defined in its early days as a procedure to "obtain the most reliable consensus of opinion of a group of expert by a series of intensive questionnaires interspersed with a controlled opinion feedback" [28]. Since its primary definition, later applications of the technique have eliminated the restriction of the obligatory search for consensus, so that today it might be defined as a social research technique whose aim is to obtain a reliable group opinion using a group of experts**.** The authors of the book The Delphi Method – Technics and Applications [25] came to approach this interpretation of the method as a persistent perception error on Delphi [29]. In their book they clearly state that Delphi is a "method for structuring a group

communication process" as opposed to a method aimed to produce consensus. Indeed, the Delphi method tends to move the group's responses toward consensus, although achieving consensus in itself is not necessarily the central goal or measure of method process success. The value of Delphi lays in the ideas it generates, regardless of whether the consensus has been evoked or not [30]. In fact, literature provides a quite vocal approach on Delphi, which aim is exactly the opposite of generating consensus. The Policy Delphi structure was designed by Dr. Turoff to produce the strongest opposing arguments about resolutions to a policy issue [29]. The Delphi method, including all its adaptations of which the Policy Delphi is but one example, was intended to both allow access to positive attributes and pre-empt negative impacts of face-to-face interactions. Being a tool used in judgment and forecasting situations in which some form of human judgmental input is necessary. From a physical and practical point of view, Delphi enables input from a larger number of participants than could feasibly be included in a group or committee gathering, and from members who are geographically dispersed. At the same time it permits for participants to engage in the questioning process in an asynchronous way, allowing the management of different time availabilities amongst the respondents.

Defining characteristics of Delphi

Essentially four key features may be regarded as necessary for defining a procedure as "Delphi", as it follows:

- Anonymity;
- Iteration;
- Controlled feedback;
- Statistical aggregation of group response [3].

Anonymity is accomplished through the use of questionnaires. These provide means for the participants to express their individual opinions and judgments privately, discarding undue social pressures as from dominant or dogmatic individuals, or from a majority [3]. As the anonymity of the participants' answers is kept through the process this should ideally empower each group member to take into consideration each idea based in merit alone, rather than on a basis of potentially invalid principles (e.g. the status of an idea's proponent). Moreover, being this an iterative questioning process over a number of rounds, the respondents are provided with the opportunity to either keep or change their previous stated answers, without fear of coming to be less highly respected by the rest of the group [3]. This encourages participants to take a more personal viewpoint rather than a cautious position. The participants must be consulted at least twice on the same question, thus being given the chance to reconsider their answer at the light of the group feedback provided between each questionnaire iteration. Feedback is termed "controlled" in the sense that the facilitator decides on the type of feedback and its provision [31]. This feedback serves to inform the group individuals of the opinions of their anonymous fellow participants in the questionnaire. It is often provided as a summary statistical aggregation of the group response but not

always, as quantitative feedback can also be given to the group. Accordingly, questions are formulated so that the answers can be processed in both a quantitatively and statistically way. Occasionally, additional information may also be presented to the participants, apart from the statics or quantitative distribution regarding the group response. In some cases participants provide comments associated with their answers, especially when these answers fall outside pre-specified limits or none of the available standardized answers suit they're opinion or judgment. In this way feedback comprises the opinion of all the group members instead of just the most vocal. All of the afore mentioned attributes are key elements in effective group decision making and are necessary attributes of a Delphi procedure. Nevertheless, there are innumerous ways in which they can be applied.

Evaluation of Delphi

Some of the strongest advantages of the Delphi method have been broadly drawn upon and addressed in the previous sections. In fact, some of Delphi's key features may be categorized as advantages of the method. In a more specific intake some of Delphi's advantages may be appointed as it follows: reduction in the influence of some undesirable physiological effects amongst participants, selective feedback of relevant information, more extensive considerations thanks to possible large number of rounds, statistical results, flexible methodology and simple execution. Delphi presents a good solution particularly in the case of absence of historical data. It is a designated inexpensive method to organize and administer and is one of the few forecasting technics that has fair good prediction accuracy over different time horizons[3].

Despite the advantages that Delphi poses, some shortcomings have been appointed in studies regarding conceptual and methodological inadequacies[3][32]. Departing from a broader overview of these shortcomings, the following methodological weaknesses have been documented: doubtful reliability of the basic source of information (participants in the questionnaire), assuming consensus/agreement, per se, as an implication the participants' accurate input and controlled feedback as a limitation of interactions amongst participants which is intimately related with the restriction to the possibility of social compensation for individual contribution to the group (reinforcement and motivation normally provided by the support and social approval of other expert group members are absent from the process)**.**

Regarding the reliability of the basic source of information, a number of studies have considered the role of Delphi's participants and how their attributes, or the absence of these, relate to the effectiveness of the process. The participant's expertise or knowledge about the topic up to consideration is regarded as one of the main requirements for their engagement in the process. Yet, in some circumstances the nature of the panel of participants is neglected in terms of expertise buy a number of possible reasons, one of which being the lack of criteria for distinguishing an expert from an inexpert. There is also a void in evidence with respect to the fact that the judgment of experts is more reliable when compared to the one of inexpert [3]. Regardless, many authors have commented on the nature of the panel from the outlook of accuracy. It has been vastly documented that panels were more accurate when constituted by expert groups rather

than inexpert ones. It was found that the most accurate Delphi respondents changed their estimates less on the first rounds unlike those who were essentially less accurate. These results appear to support the Theory of Errors (by David Buss and Martie Haselton), in which accuracy is improved over rounds as a consequence of the panel experts clinging on, while less-expert panelists swing towards group average. The value of expertise has been addressed with the suggestion that there is a connection between expertise and the nature of the task. Expertise is only helpful up to a certain level for forecasting tasks, but of greater importance for estimation tasks. Furthermore, it has been found that some variations of the Delphi method greatly restrict the scope of the expert's responses, thus diminishing the usefulness of the expert panel[33].

Consensus is one of the most antagonistic components of Delphi. As a consequence, it has been a widely discussed topic concerning Delphi. In fact, the discussion that surrounds consensus in the Delphi context is one of many stands. To begin with, consensus measurement, which is often referred to as agreement, greatly varies due to the fact that there is a controversial understanding of the term. As a consequence, researchers have used many different measures in order to determine the level of agreement among the panel[31]. It was been documented that the standards of consensus in Delphi research have never been rigorously established [34].

Additionally, it has been argued that assuming consensus/agreement, per se, as an implication the participants' truthful input on a topic is not an accurate proceeding. Regardless of whichever measurement of consensus is taken, consensus has been empirically determined by measuring the convergence of the respondents' answers over the questionnaires' iterations; with an augmented convergence, associated with an implicit reduce in variance, being taken as an indicative that greater consensus ,i.e. agreement, has been achieved [35]. Results have suggest that variance reduction with respect to the participants' answers is typical in a Delphi process, even though these claims seem to be simply reported unanalyzed rather than supported by some type of analysis [28][36]. In fact, the trend of reduced variance is so common in a Delphi process that the phenomenon of increased consensus no longer appears to be of interest from an experimental point of view [35]. However, some controversy does exist concerning whether a reduction in variance over rounds, reflects in fact true consensus, i.e. agreement. After all, Delphi has been advocated as a method to reduce group pressures to conform, and both increased consensus and increased conformity ultimately came across as a convergence of the respondents' answers. Bottom line is, proponents of Delphi argue that results demonstrate consensus/agreement whilst critics state that this referred consensus/agreement is only apparent, and that the verified reduce in variance is due to reasons other than genuine acceptance of the rationale behind the position, such as social-psychological factors leading to conformity [35]. In addition, an alternative perspective on this issue has been provided stating that respondents with more extreme views were more likely to drop out of a Delphi procedure as oppose to those with a more moderate view concerning the topic up to consideration [37]. This suggests that consensus also benefits from attrition [35].

Nevertheless, the measurement of consensus in itself should be taken as a valuable asset of data analysis and interpretation in Delphi. Regardless, many studies have used it as a stopping criterion of rounds, in some specific cases when a pre-defined level of agreement (i.e. consensus) was achieved, which is not recommended [31]. Rather, the number of rounds should be based on when the stability in the participant's answers is attained [29].

Dajani et al. (1979) have defined stability as "the consistency of responses between successive rounds of a study". It has even been appointed that consensus is meaningless if group stability has not been reached before hand; group stability is hence considered the necessary criterion. The results of two different Delphi rounds, concerning stability, are not statistically different for a certain projection. In turn, a determined degree of consensus, as a reduction of variance towards agreement, may be found in an unstable situation. In view of this, a stopping criteria hierarchy (Figure 1) has been introduced in the literature which lies in the basic premise that the measurement of consensus should only take place if the stability of the answers is attained first [31].

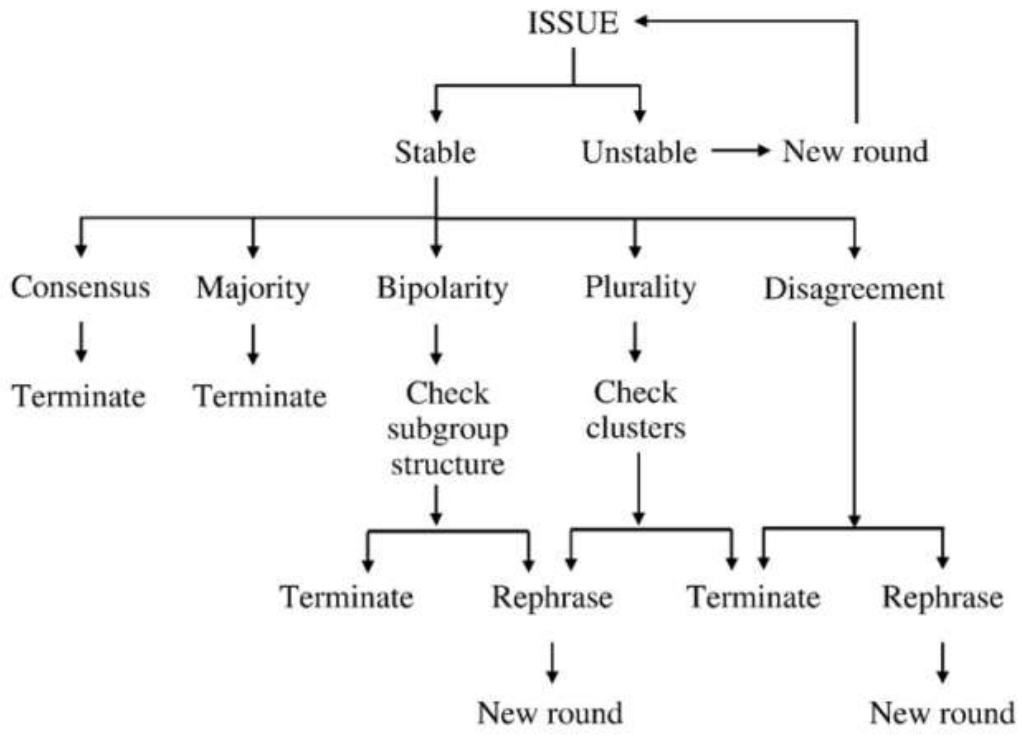


Figure 1 – Hierarchical stopping criteria for Delphi studies. (From Dajani et al.)

Dajani et al. (1979), Schibe (1975) and Linstone (1978) establish a working definition of 15% threshold for stability [31].

Ironically, some of the advantages of Delphi are also its disadvantages as it is the case of controlled feedback. Controlled feedback in the Delphi process is intended to reduce the effect of noise. Noise being referred to as communication which occurs distorting the data and which deals with group and/or individual interests rather than focusing on problem solving. Information as a result of this so called noise,

generally consists of bias not related to the study [38]. Controlled feedback in this sense is viewed upon as an advantage. Still despite its merit, controlled feedback as a short come of the method can be linked to the already discussed controversial topic of consensus. The feedback of group response, controlled by the facilitator, usually leads to declining variance, i.e. convergence, in the participants' answers over succeeding rounds. This implies that the facilitator has the power to induce consensus by the means of the provided feedback, by the refinement of the questions and the design of the questionnaire [31]. This particular situation may lead to a biased response from the participants' behalf, thus not reflecting their true thoughts regarding the scope of the Delphi study.

As mentioned before, feedback can be given to the respondents by the means of summary statistics, rationales or both. The pros and cons of these approaches have been discussed in the literature. In the case of summary statistics, these can either be presented numerically or graphically. They usually comprise measures of central tendency, and frequency distributions. Thus, a graphical representation of results may benefit the participants' interpretation of this feedback. These tend to show the majority opinion which is not informative enough. Woundenberg (1991) concluded that feeding back summary statistics induces conformity to the majority opinion, which poses a downfall. Addressing the rationale feedback provision, it has been found that it prevents experts from simply changing their opinion in the direction of the majority (Bolger et al., 2011) since it shows why experts hold certain options (Meijring and Tobi, 2016). Unfortunately, Bolger et al. (2011) concluded that study participants tended to ignore feedback of rationales and merely used summary statistics to change their opinion. The remaining option of providing both summary statistics and rationales was proposed by several authors (Murphy et al., 1998; Rowe et al., 1991 and Wright, 2011), still little empirical evidence in support of this proposal has been documented [31].

Additionally to the above discussed drawbacks, Delphi has been targeted by critics due to the following conceptual weaknesses: the possibility of its poor application, as the potential for sloppy execution and crudely designed questionnaires by the employment of questions and problems which are badly formulated and insufficient analyzed results[39]. The time variable has also drawn a number of criticisms with reference to the long times involved in accomplishing the process[30].

It is of worth noting that some of these shortcomings of Delphi are inherent in other qualitative forecasting techniques as well. When comparing the specific case of statistical groups and classic direct interaction groups with the method, it shows mostly positive results in favor of Delphi. Nonetheless, some other comparisons have been made with other techniques. These have led to inconclusive results, which have demonstrated themselves unable to prove Delphi's superiority nor it's inferiority[27].

Key aspects of Delphi's application

When it comes to applying the Delphi method there are 4 key-aspects to consider as shown in the scheme bellow (Figure 2). These 4 key-aspects can also be referred to as phases of implementation. Let us consider the analogy that the first key-aspect corresponds to the first phase of implementation, the

second key-aspect corresponds to the second phase of implementation, and so on and so, on until the fourth and final key-aspect, evaluation. The first and third phases are panel intervening phases whereas the second and fourth phases are of the competence of the facilitator.

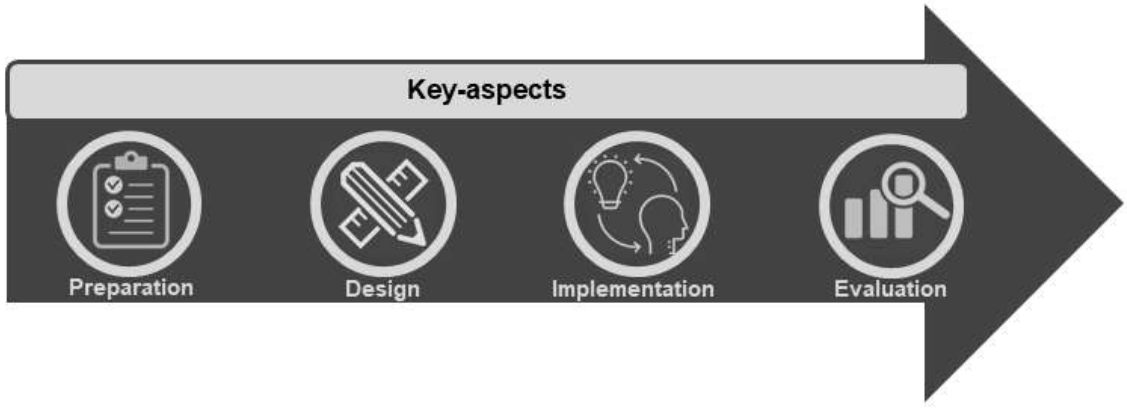


Figure 2 – Key-aspects to consider while applying the Delphi method.

All of these four phases encompass important aspects to take into consideration while applying the method. These are sorted by phase hereinafter.

- First phase: Preparation

In this phase the identification and selection of experts is carried out. Despite the fact that defining and using the term 'expert' is problematic, as discussed in previous sections of this dissertation, while attending to this task some criteria should be taken into account. These should be established on the basis of expertise and knowledge of the issue to be investigated, willingness and ability to participate. The homogeneity or heterogeneity of the panel should also be taken into consideration and are linked to the sample size which should as well be based on the complexity of the problem and availability of resources [40][35][41]. Furthermore, in this first phase, the preparation of the evidence and data as well as of the supporting letters must be taken care of.

- Second Phase: Design

When designing a Delphi process, a number of focal points are in order for attention. Such are as it follows: design of the first round, total number of rounds, number of questions and response categories, and the type of feedback to be provided to the panel and the stopping criteria.

With respect to the first round, when the framework is transposed into a set of questions, the facilitator is to choose between the exploratory and confirmatory approach. The exploratory approach implies an open first round with well-structured open-ended questions whereas the confirmatory implies a closed first round.

The total number of rounds depends on whether consensus is being used as a stopping guideline (despite all the controversy around this topic) or if the number of rounds has been set a priori. Three rounds are the optimal. With two rounds stability cannot be confirmed (physical meetings are counted as rounds). The

facilitator is responsible for the employment of an explicit number of rounds and for the record of responses rates for each round.

Considering the number of questions and response categories, the advised minimum number of issues should be six. These must flow into a logical organization of the framework which should ideally reflect a perceived simplicity of the subject matter. Little or no literature is currently available on the optimal number of response categories concerning scales. The use of scales of seven, nine and ten categories has been reported. Scales constituted by an uneven number of categories imply the existence of a midpoint usually between a positive or negative answer. Consequently, a six point scale is used to obtain a solely positive or negative decision about each statement. Whichever scale is used, it should include a 'no comment' option for participants who don't fell qualified to answer a question [40][41].

Feedback was been appointed as a trigger for the success of the Delphi process. The facilitator can decide the form in which this feedback is presented to the respondents from summary statistics, rationales or both. Superficial types of feedback imply reduce in performance [40][29][41].

The considered stopping criteria are most frequently a stipulated a priori number of rounds, based upon a subjective analysis of the round results or based in the level of agreement. Nonetheless, the issue around stopping Delphi processes based on the level of agreement, i.e. consensus, is not recommended and was already been discussed in the previous section [31]

- Third phase: Implementation

The time requirements in which the process will be carried out must be planned. The wider the time gap, the more change in an individual's circumstances, knowledge and situational context. During the time in which the rounds are taking place, a high level of communication must be maintained with the participants. The documentation of results includes consistently recording divergent views at a similar level of detail

- Fourth phase: Evaluation

The evaluation phase may be carried out through the means of testing for the reliability and validity of the answers, trustworthiness of these or post-group consensus.

Reliability is the extent to which a procedure produces similar results under constant conditions on all occasions. Validity is divided into external and internal. External validity measures the generalizability of the findings whereas internal validity refers to the confidence placed in the cause and effect relationship, normally proven by experimental research [26].

Trustworthiness is includes the parameters of credibility, dependability, conformability and transferability. Credibility is comparable to internal validity and relates to the degree to which data can be believed. Dependability, in preference to reliability, refers to the stability of the collected data. Conformability relates to the concept of objectivity. And finally, transferability reports the application of the findings to other settings.

Regarding the post-group consensus, this concerns the extent to which individuals individually agree with the final group aggregate, after the Delphi process has been completed (Rowe and Wright, 1999).

Delphi Designs

Delphi has experienced a series of developments in the subsequent decades to its conception. The extensive documentation about the method and its employment across a broad spectrum of topics, motivated a series of changes in order to adapt transversally in different areas of concern [29]. Areas like Government, Environment, Medical and Social studies plus Business and industrial research have greatly used Delphi studies in order to aid an extensive diversity of topics [42]. This fact makes it hard to draft an explicit all-encompassing definition of the method, giving emphasis to the fact that it is still in a developmental stage. Hasson and Keeney refer to 10 types of Delphi designs, which were identified by Keeney, in one of their many papers regarding the method [42]. These are presented hereinafter (Table 1) along with their aims, administration methods and recommended number of rounds.

Table 1. Delphi designs: aim; administration and number of rounds (adapted from F. Hasson and S. Keeney, "Enhancing rigour in the Delphi technique research")

Design	Aim	Administration methods	Number of rounds
Classical	To build consensus	Postal	Four
Modified	To both build consensus and predict future events	Varies	Three or less
Decision	To structure decision making/creating the future	Varies	Varies
Policy	To generate opposing views	Can vary, including bringing participants together in a group meeting	Varies
Real time/consensus conference	To build consensus	Computer technology that panelists use in the same room to achieve consensus	Varies
Web-Delphi	Depends on research	On-line instrument	Varies
Technological	Depends on research	Hand-held keypads allowing responses to be recorded and instant feedback provided	Varies
Online	Depends on research	On-line instrument	Varies
Argument	To develop arguments, expose reasons	Varies	Varies
Dissaggregative policy	To construct future scenarios	Varies	Varies

Innovation of Delphi

“Delphi has come a long way in its brief history, and it has a long way to go” by Olaf Helmer (1910-2011). Years ago, after being involved in its development at the Rand Corporation, Olaf anticipated the potential importance of the Delphi method as he called for its solidification. Today, had he be alive, he could look up to his comments on the method with great satisfaction.

While preforming the literature review on the Delphi method, it was possible to identify two trends in the method’s development. These are the Real-time Delphi and the integration of different techniques along with the Delphi method itself, which may be referred to as the Hybrid Delphi.

The strand of the practical application of the Delphi method, per se, has had some interesting developments in these late years. Some recent publications, as the one by Ted Gordon and Adam Pease entitled “RT Delphi: an efficient “round-less almost real time Delphi method” [30] , exemplify how computers and the internet have enhanced the original concept of Delphi. As these tools are easily accessible in a global way nowadays, this allows for computer-mediate asynchronous communication hence, making it possible for the user to engage in the process in any given phase of a decision at any time [29]. This metamorphosis in Delphi’s application seems to be the most outstanding development in the method. It also appears as a response that attenuates the criticism to the time-consuming peculiarity of the process.

Key idea: Participatory methods have proven to be a powerful tool in aiding the social component of MCDA’s framework, providing several ways for the incorporation of the actors’ input into the process while enabling the creation of a shared understanding of the issue. The Delphi method enables the involvement of the actors in the process of model building while keeping anonymity of the actors, thus preventing the external influences of the group of actors in one’s input.

3. Methodology implemented in the framework of the project

This section includes the approach taken for the solving of the decision problem at hand. In a brief remark Galp, the leading oil & gas company in Portugal, intends to select and implement the best EMS solution (data integration platform) from a number of tenders through a private contest. In order to enable the selection process a partnership between Galp and IST emerged as the scope of the present dissertation aiming towards the construction of a multicriteria evaluation model. This model would allow for the ranking of the available tending options (indirect-evaluation model) resorting to the use of the additive aggregation model. This would then capacitate the selection of the best EMS solution, to be implemented in a subsequent process. A series of activities were accomplished for developing the required model. Despite the fact that some of these were of a collaborative nature between Galp and IST, generally each one of the involved parties had specific activities assigned for which they were both responsible and accountable for.

Methodologically the model building process used in this application can be described as social-technical, combining concepts from multicriteria value measurement with participatory methods to build the multicriteria evaluation model. From the technical side the MACBETH approach was used to construct the model within a hierarchical multicriteria model structure, whereas from the social side the application of MACBETH was supported by a combination of participatory methods including modified web-Delphi processes and decision conferences. This approach was implemented in favor of meeting the process' demands and it is important to acknowledge the constitution of two different groups of decision makers to develop the sequence of interconnected process activities predicted: a panel of participants in the web-Delphi processes and a strategic group. This was driven by the following needs:

- Panel of participants – having a multidisciplinary and large group with different perspectives and skills which can provide valuable insights to the construction of the model;
- Strategic group – having a holistic view of the model-building process, being representative and of an adequate size to allow face to face meetings, therefore enhancing the effectiveness of the process.

Having different specificities both groups were designed to participate in distinct formats in different parts of the model building process. The referred process activities to be developed with both groups, in the scope of both the social-technical approach and the preceding activities of criteria definition and operationalization, are displayed in Figure 3 into two many phases of analysis: structuring and evaluating. The scheme displayed (Figure 3) is a valuable tool to clarify and ease the perception of the workflow and of certain aspects regarding the process activities, mainly:

- Type of activity: independent, either on Galp or IST's behalf, or collaborative between both;
- Work developed in or outside of the scope of the partnership: activities carried out either in the scope of the present dissertation or complementary (pre or post).

Grasping some other working considerations associated with the information provided in the scheme but non-explicit, the typology of the activities is directly linked to the responsible and accountable entity (Galp or IST). Thus both parties are responsible and accountable for activities classified as collaborative, as it is the case at the end of the structuring and at the beginning of the evaluating phases. Also it is important to notice the distinct timeframes in which the activities took place: pre-dissertation, ongoing dissertation or post-dissertation (Figure 3). This is essential to highlight two facts:

- Upon the first engagement of IST with the project it had already begun;
- The partnership didn't see through the end of this project.

Ultimately, Figure 3 is meant to provide a visual representation of the way the process of model building unrolled as well as to tackle key working considerations, while providing the structure to this dissertation report. The present section, referring to the methodological issues, will be drawn up from the scheme.

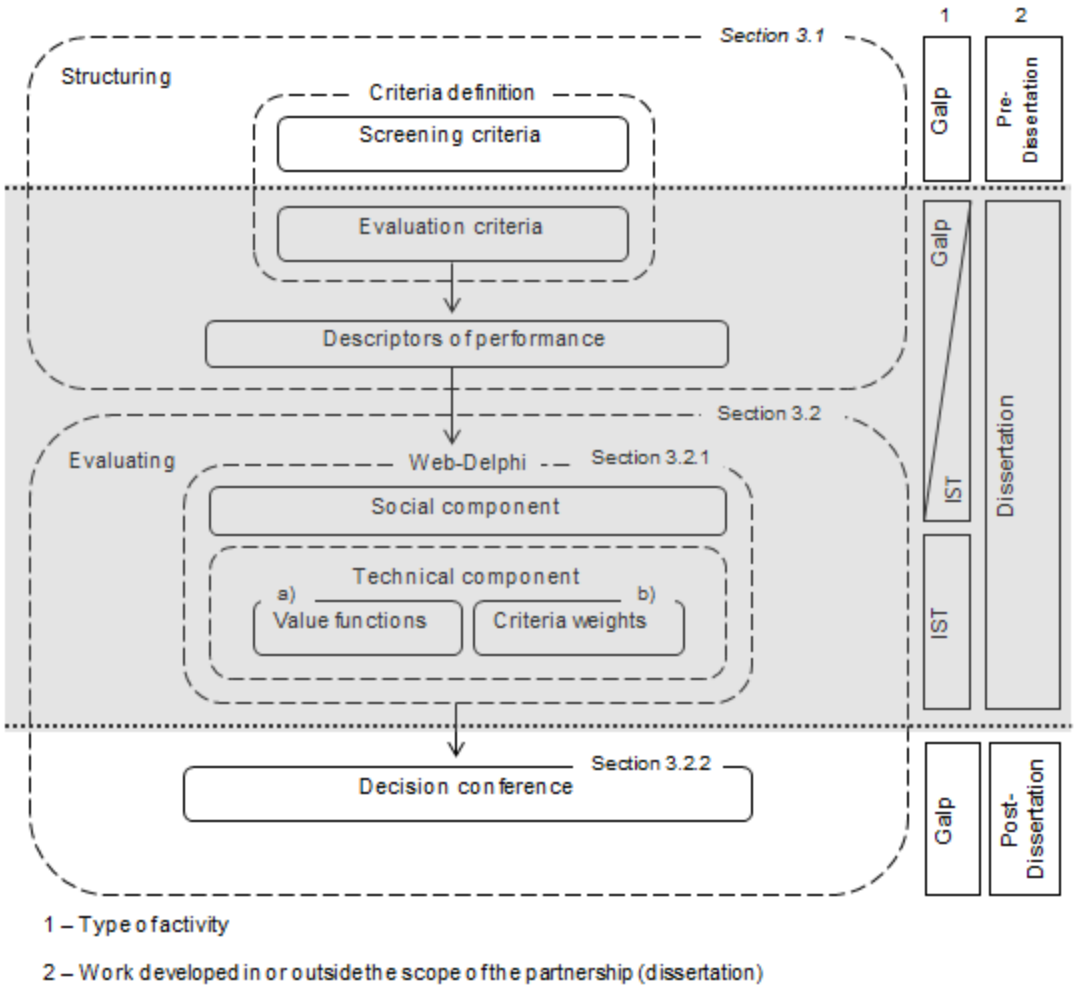


Figure 3. Model building activities. The section where each activity is presented in more detail is noted.

The methodological basis for the building of the aimed model is now presented in more detail.

3.1. Structuring activities: Identifying and operationalizing criteria

3.1.1. Criteria definition

During the structuring phase criteria were identified and operationalized. As introduced in the literature review, a criterion is a tool to evaluate a proposal in terms of a point of view or concern considered fundamental or key by the decision-making group. In the process of criteria identification, two types of criteria can be identified: screening or evaluation criteria. These have different functionalities in the process of model structuring making the distinction between them a task of major importance.

Screening criteria

Screening criteria are usually compulsory requisites to be respected by all proposals. These are focused on tenders' potential rather than on their specific tending proposal. Tending proposal screening should only be considered for prequalification or shortlisting of options. Fundamentally, screening criteria represent the deliberate intention to make vendors comply with thresholds of admissibility and to only proceed to comparative evaluation of proposals from vendor who do so. [23][22]

As a primary note in this subsection it is of worth stressing that upon the first engagement of IST in the project, time matching the emergence of the partnership, it had already started. That been said, the screening of the tending options was performed by Galp alone, more specifically by the strategic group. Regardless, the proceeding carried out in view of accomplishing this process activity will be briefly described hereinafter as it is part of the effort towards the model's development.

From the start of the project seven openings were available for seven tending proposals in the evaluation phase yet to come. However 15 tenders responded to the call upon the opening of the contest, which implied there were not seven but 15 tending proposals available at that point. This implied a screening action in order to shortlist the tending proposals to the target seven, enabling them to migrate to the evaluating phase later on. In order to accomplish this, screening criteria were established.

Screening criteria were settled through an interaction amongst the strategic group members, assuring these encompassed all software and vendor requirements necessary to meet the company's needs of an EMS solution (Annex A). A total of 12 screening criteria where identified, with respect to either the IT solution itself or the services associated with its implementation (clarifying, the latter are in relation to the tender proposing the IT solution in question rather than to the IT solution itself). These where then grouped into families of as follows:

i. Functional requirements;
ii. Technical requirements;
iii. Credentials;
iv. Partners.

Evaluation criteria

Evaluation criteria are meant to evaluate proposals as the denomination itself suggests and should be carefully selected. Furthermore in the case in which tending options will be compared and scored in terms of their relative attractiveness with respect to each criterion individually, each of them must be an independent axis of comparative evaluation. [23]

The definition of the evaluation criteria marks the first activity developed in the scope of the partnership between Galp and IST. At this point IST was fully involved in the project. The previous considerations imply that this is also the first activity developed in the scope of the present dissertation and according to Figure 3 can be defined as a collaborative activity between both parties.

In order to evaluate the seven tending options which were able to pre-qualify from the screening action, it was necessary to set the evaluation criteria. Instead of coming up with a brand new set of criteria, it was the company's decision to establish the evaluation criteria based in the previously considered screening criteria. This was due to the fact that the screening criteria were found to roughly cover all the necessary characteristics regarding the optimal EMS solution. Thus as part of the procedure for accomplishing the evaluation criteria the previously considered screening criteria underwent a refinement and adjustment procedure to enable tending options' evaluation.

Prior to this refinement and adjustment proceeding, the settlement of the evaluation criteria began with an analysis of the whole screening criteria set. Criteria found to be related to tenders rather than their tending options, thus relevant for screening but not for evaluating the options, were eliminated. Recalling, the screening criteria were set with based on the IT solution and the implementation services associated with it. Criteria with respect to the first were kept for evaluating the options, whilst the later were disregarded. As a result of this exercise two out of four previously considered families, and respective criteria sorted into them, were considered for evaluating the tending options: i) Functional requirements and ii) Technical requirements. The set of evaluation criteria was now ready to be refined and adjusted.

Being this a collaborative process activity, IST provided the guidelines empowering the strategic group (Galp) to successfully perform the refinement and adjustment procedure. These guidelines were with respect to the reassessment of the criteria to make sure they respected the necessary conditions that make them qualify as so hereinafter:

- Be intelligible;
- Be consensual;
- Be isolable;
- Be operational.

According to the above, criteria's denomination refinement was in place in an effort to make them more self-explanatory as was the inclusion of corresponding descriptions with each one of them. This was due to the required intelligibility of the criteria; this is due to the need to make criteria understandable or comprehensible avoiding subjective interpretations from third parties, e.g. vendors. The consensually of

the criteria was reassured through a constructive, iterative process intending to stage the diverse components of the decision problem. The value system of the actors engaging in the process was made explicit resorting to stimulating thinking, promoting an interactive reflection mechanism making sure all criteria were progressively identified and resettled. This process also served for assuring that the criteria were isolable making them able to stage as independent axis of evaluation in the process activities to follow. In addition the pre-requisites which enable the criteria were also reassured in the previously described procedure as follows: be complete (exhaustive), be non-redundant and concise (minimallity), be decomposable (from the interdependency property of each criteria) and be consensual (from the intelligibility and consensually properties of each criteria). Operationalization of the criteria was also assured through this practice. Time was not an evaluation concern in this project because Galp imposed a compulsory deadline from the start that tenders were fully aware. The set of evaluation criteria, resulting from the described refinement and adjustment procedure, is much more concise relatively to the previously considered screening criteria. The cost-benefit tree shown in Figure 4 shows the ten benefit criteria (evaluation criteria set) materialized over this entire process following the company's own interpretation as follows:

- 'Capture' - Capture data from different data sources systems and different data types, providing validation and cleansing capabilities, and keeping track of all versions.
- 'Storage' - Store different data types and frequencies, with definition of data imperativeness and owners, ensuring its quality and proper governance.
- 'Display' – Analyze and compare data sets within the platform, given a set of predefined charts and reports and allowing user made reporting.
- 'Assess' – Calculation engine and definition of workflows in order to improve collaboration between areas and the flow of data, allowing the quick identification of bottlenecks and critical paths.
- 'Alert' – Notification of relevant events, providing KPIs and dashboard to keep an up-to-date view of the critical processes' variables in the value chain.
- 'Distribute' – Mechanisms to access raw and aggregated data, automatizing its extraction on multiple formats, and enabling ad-hoc queries within the platform or through an Excel add-in.
- 'General' – User-friendly platform, with customizable Graphical User Interface and managing different time zones.
- 'Integration' – Bidirectional integration with the different systems supporting the Oil Value Chain and logging capacity.
- 'Security' – Definition of user profiles and permissions on the different levels, with full user and activity log, and providing database encryption.

• ‘Mobility’ – Access to the platform in remote using a browser enabled client and/or a mobile application.

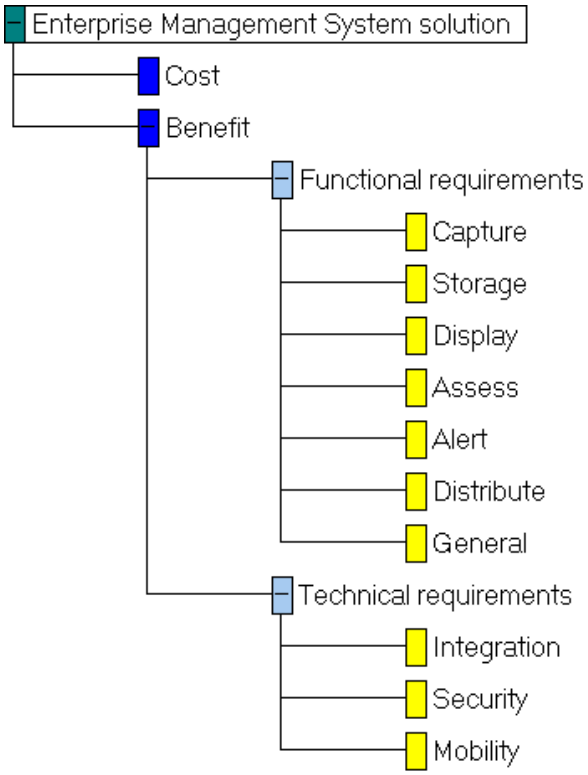


Figure 4. Evaluation criteria of tending options regarding the selection of the EMS solution.

Summing up there are ten criteria grouped into two families up to consideration in the evaluating phase.
It is not an easy task to appraise the ‘cost’ criterion when dealing with software applications. Estimates are made resorting to other indicators rather than just the financial. The performance of any option on the ‘cost’ criterion was thus defined as the balance of the cost of acquisition of the application and the expected financial benefits and others associated with it.

3.1.2. Descriptors of performance

A key task in building an indirect-evaluation model consists of associating with each of the considered criteria a descriptor of performance. Descriptors of performance measure the extent to which the criteria can be satisfied, while making them operationalized. The development of these is directly linked with the construction of scales, which enable the ranking of the multiple criteria [23]. Following the process activities until this point, next due in the order of work was the conception of these.
Resembling the settlement of the evaluation criteria, this process activity is also of a collaborative nature in the scope of the partnership involving IST and Galp. Yet in a previous instance the strategic group (Galp) had already started to work on the descriptors of performance to associate with the criteria. However some problems were identified in that work. Therefore before moving any forward in this final

structuring activity these problems had to be solved to accurately achieve the latest structuring components towards the model's construction.

In order to ease the perception of the problems encountered and associated with the early development of the descriptors of performance, Table 2 is presented featuring the criterion 'capture' as an example. To establish a parallelism with what has been found as a proper accomplishment of descriptors of performance and the pinpointed problems Table 3 is also presented, displaying a summarized procedure allowing for the accurate establishment of descriptors of performance.

Table 2. Early development of the descriptor of performance for 'capture'.

Capture	
0	Does not meet any of the other criteria.
2	Barely supports Galp's needs: capability to collect batch data from multiples sources.
3	Fully supports Galp's needs: a set of validation functionalities to ensure complete and accurate data is added to above functionalities.
4	Extensive functionalities: capability to collect real-time data is added to above functionalities.

Table 3. A procedure to develop a multidimensional constructed scale (source: Adapted from Bana e Costa and Beinat 2005, p.23).

Basic steps	**What to do**
Step 1	Define a discrete set of performance levels in terms of each of the component dimensions.
Step 2	Compare the desirability of the feasible combinations and group those that are judged to be indifferent in terms of the criterion; each group of profiles form an equally plausible performance level of the scale (if convenient, give a label to each level). Rank the plausible levels by decreasing relative attractiveness in terms of the criterion.
Step 3	Make a textual description of each plausible performance level, as detailed as possible appropriate and as objective as possible.

Analyzing both the tables displayed above (Table 2 and Table 3) the so referred problems associated with what can be called a "prime version" of the descriptors of performance are as follows:

- The presented groups of profiles do not form equally plausible performance levels of the scale (incompliant with Step 2, *Table 3*);

- The textual descriptions of each plausible performance level is very poorly defined, being the descriptions of different levels dependent on each other (incompliant with Step 3, *Table 3*).

In addition, non-desirable performance levels which are defined in the scope of screening the tending options are featured and incorporated in the set of performance descriptors (level 0). This doesn't comply with the plausible restriction of the performance range (implausible performance). Furthermore an exclusion factor can never be an integrating level of a scale giving the context we are inserted in, in which the use of the additive aggregation model is predicted, constituting a technical problem. Finally, while mentioning the use of the additive aggregation model as predicted it is relevant to note that although not constituting a problem when addressing the specific task of developing criteria's performance descriptors, the definition of two reference levels is missing in scope of its employment. This is of extreme importance in order to address the task of criteria weighting further ahead in this report.

Addressing the ill-definition of the descriptors of performance as above, achieving their proper accomplishment is of paramount importance. Here is why: the more objectively the performance is appraised, the better understood (less ambiguous) and therefore more accepted (less controversial) the evaluation model will be. Furthermore in the specific methodological framework of this dissertation these structuring components will be the object of study of Delphi processes. Thus their proper accomplishment also serves the purpose of increasing the acceptance and reliability of the processes results.

The procedure presented next was employed under IST guidelines by the strategic group (Galp) to perform the necessary adjustments on the performance descriptors, according to the information in Table 3, which allowed for the construction of multidimensional scales for the criteria that clustered several intertwined dimensions.

Constructed scales were developed making use of qualitative, constructed and discrete descriptors of performance, which enabled criteria operationalization, for each one of the benefit criteria according to the following ordinated steps:

- Two reference levels, good and neutral, were defined;
- More levels were added to cover the plausible range of performances;
- Each level of performance descriptor was carefully described to ensure a clear and unambiguous interpretation of its meaning.

Considering the 'capture' criterion, first was defined a neutral level for the criterion, i.e., defined a performance on the criterion that would neither be attractive nor unattractive: 'Capture all required batch data with different granularity (yearly, monthly, etc.) and providing validation capabilities, but without out-of-the-box connectors to Galp's architecture. Capability to define "data owners" (data governance functionalities) is also required'. Then was defined a good level, i.e., a performance on this criterion that would be substantially attractive: 'Most of the batch data can be captured on-demand and through an out-of-the-box connector and a validation workflow for data correction along with data cleansing capabilities is

provided'. Next two more levels were added in order to cover the plausible range of performance needed. Labels were given to this two remaining levels as follows, 'bad' and 'very good'. The developed range of plausible impact levels was then sorted in decreasing order of attractiveness. As was to be expected, 'very good' was chosen to be the most attractive level of performance because it presents extensive functionalities regarding Galp's functionality needs and 'bad' to be the least attractive level since it barely supports Galp's functionality needs. The remaining step was to carefully describe each level to ensure a clear and unambiguous interpretation of its meaning. The final constructed scale regarding 'capture' is shown in Table 4.

Table 4. Constructed performance scale for 'capture' (functional criterion).

Capture	
Bad	There are no validation capabilities or data governance functionalities.
Neutral	Capture all required batch data with different granularity (yearly, monthly, etc.) and providing validation capabilities, but without out-of-the-box connectors to Galp's architecture. Capability to define "data owners" (data governance functionalities) is also required.
Good	Most of the batch data can be captured on-demand and through an out-of-the-box connector and a validation workflow for data correction along with data cleansing capabilities is provided.
Very Good	Near real-time out-of-the-box connectors that replicate the data model of Galp's architecture, reducing the maintenance effort for major upgrades or new systems implementation.

Thus, as it is possible to observe in the above table 'capture' becomes operational based on a constructed scale of four ordered performance levels within the range of plausible impacts, presented in decreasing order of attractiveness according to Galp's view.

Through a similar process were constructed the remaining performance descriptors correspondent to the nine remaining benefit criteria. These are shown in tables 5 through 13. All levels of performance are presented in decreasing order of attractiveness.

Table 5. Constructed performance scale for 'storage' (functional criterion).

Storage	
Bad	No units conversion management (e.g. ton/bbl/m3).
Neutral	Stores high volumes of data, providing fast access to individual or aggregated data, and being capable of making data in different units comparable.
Good	Stores different versions of the data (original, recaptured, manually corrected, etc.) along with its change record (source, user or rule that modified the data, etc.). Sources' data model can be enriched with user defined fields, and any data can be flagged as "mandatory" to force it to be populated by the user if not provided by the system.
Very Good	Capable of automatically aggregate data with different granularity (yearly, monthly, daily, hourly, etc.).

Table 6. Constructed performance scale for 'display' (functional criterion).

Display

Bad	Displays current and historical data but does not provide data filtering functionalities.
Neutral	Displays current and historical data available within the platform database, providing data filtering functionalities.
Good	Compare data sets (i.e. forecasts vs. actuals) within the platform, providing a set of predefine charts to graphically display the selected data sets. Capability to export the view to Excel.
Very Good	Displays also up-to-date information directly from the original source (not stored in the platform).

Table 7. Constructed performance scale for 'assess' (functional criterion).

Assess	
Bad	No calculation capabilities.
Neutral	Calculations for secondary data with a pre-defined library of basic functions. Definition of workflows to complete a set of tasks, specifying the owner for each task and its due date, and the trigger of the workflow (i.e. modifications in the data).
Good	Out-of-the-box horizontal and vertical KPIs and dashboards.
Very Good	Capability to extend calculations library.

Table 8. Constructed performance scale for 'alert' (functional criterion).

Alert	
Bad	Only provides alerts on a reduced set of events.
Neutral	Notify the user when a specific event occurs, with a description of the event and the status. The notifications must contain an easy access to the task that created the alerts.
Good	Notifications also when a workflow requires the user's action, and when the time to execute a determined action is about to expire.
Very Good	Messaging between users to solve alerts or assigned tasks.

Table 9. Constructed performance scale for 'distribute (functional criterion).

Distribute	
Bad	No search engine.
Neutral	Access to raw and aggregated data within the platform and export to standard formats (i.e. XML, CSV, etc.). Provides a search engine to help users find specific data.
Good	Provides a report builder to define template reports (ready for use) that can be viewed on the platform and/or exported to standard file formats.
Very Good	Excel Add-in is available to query the data without login into the platform. All data required for reports or visualization is automatically converted into the desired query unit of measure.

Table 10. Constructed performance scale for 'general' (functional criterion).

General	
Bad	No multi-language support.
Neutral	User-friendly platform and with multi-language support.
Good	Capability to personalize the graphical interface (menus, predefined queries, etc.) depending on the user logged in.

Table 11. Constructed performance scale for 'integration' (technical criterion).

Integration	
Bad	Can only develop integrations with core systems using TIBCO and Informatica PowerCenter.
Neutral	Can develop a bidirectional integration with all Galp's systems using TIBCO and Informatica PowerCenter.
Good	Out-of-the-box integration with all core Galp's systems being capable of developing the remaining ones using TIBCO and Informatica PowerCenter.
Very Good	Provides integration with external calculation software (i.e Matlab, R, SAS, etc.) and capability to upload data through files in shared folders.

Table 12. Constructed performance scale for 'security (technical criterion).

Security	
Bad	Insufficient detail on activity log.
Neutral	Security based on groups and profiles at different levels of the platform (fields, functionalities, etc.), providing a detailed activity log.
Good	Provides single sign-on functionality, and database's encryption ensures the protection of the data both in transit and at rest.
Very Good	Integration of the activity log with a centralized repository for business activity monitoring.

Table 13. Constructed performance scale for 'mobility' (technical criterion).

Mobility	
Bad	No mobile capabilities.
Neutral	Provides access to the platform in remote using a browser enabled client.
Good	Solution provides access through mobile applications (smartphones, tablets, etc.).
Very Good	Provides mobile notifications (SMS or push notifications in mobile applications).

3.2. Evaluation activities: Assessing value functions and weighting the benefit criteria

The start of the evaluating activities described in this section marks the employment of the earlier mentioned social-technical approach. Reaffirming, this approach comprises two participatory processes: Delphi (non face-to-face) developed with the panel o participants; and decision conferencing (face-to-face) developed with the strategic group. In the specific context in which this dissertation is inserted the Delphi processes are meant for the extraction of valuable input from a large number of participants, concerning their judgments regarding a potential EMS solution. This information attained from the processes is meant to feed in the decision conferencing process helping the strategic group to make final decisions, as informed as possible, aiming at the multicriteria evaluation model's construction.

Despite the fact that the referred social-technical approach was adopted as a working outline in the present dissertation, only one of the integrating participatory processes was carried out as work developed in the present dissertation on IST's behalf – the Delphi participatory process. The participatory process concerning decision conferences were carried out by Galp alone in a post-dissertation activity in order to enable the model's construction. Nevertheless, the way the remaining of the processes activities was carried out is known and will be addressed in their respective sections ahead.

3.2.1. Web-Delphi processes

Delphi participatory processes intake two entities: the facilitating team and the panel of participants in the process. The facilitating team is in charge of managing of the group processes' dynamics whilst the participants of the processes give their input regarding the decision problem at hands. The facilitating team sets up and controls the processes while implementing the required procedures. Two Delphi processes were conducted on IST's behalf as playing the part of the facilitating team. Although Galp had what can be called a hybrid part to play with IST concerning the social component of the process, this process activity was entirely up to IST in what respects the technical aspects of the processes.
Two web-Delphi processes were developed aiming at the collection of valuable information in order to help the strategic group to construct the value model. This information would help to determine both the added and the partial value of the evaluation criteria through the assessment of both the criteria's value functions and weights, both required in the scope of the additive aggregation model employment as predicted. These were developed according to the following order and objectives:

a) 1st web-Delphi – Value functions: Collect qualitative pairwise comparison judgments between performance scale levels on each one of the multiple pre-defined criteria.
b) 2nd web-Delphi – Weighting criteria: Collect qualitative judgments of importance of swinging between least and most preferred performance levels on the criteria.

To enable the extraction of the intended information in either one of the cases through a panel of participants to be selected to engage in the process, two modified web-Delphi processes were designed. These are named modified web-Delphi processes since they frame a Delphi process with a MACBETH multicriteria approach. Both modified web-Delphi processes, with respect to value functions and weighting criteria, were developed in three sequential rounds where the main goal was not to reach consensus but to acquire the opinion of the panel through a structured process. Therefore participants in these processes were consulted three times in each one of them. This provided the panel with the opportunity to reconsider their answers given in previous rounds, aided by the information they receive from the other participants engaging in the process. In the three rounds a description of each one of the considered criteria was always available for consult as were the correspondent levels of performance to be considered along with their conforming description. The facilitating team in the process (IST) provided controlled feedback, informing the group members of the opinions of their anonymous colleagues. The design of both web-

Delphi questionnaires was accomplished resorting to an online platform specially developed for the purpose of carrying out web-Delphi processes: the Welphi platform (www.welphi.com).

After implementing the design of the process on the web platform for both web-Delphi processes, with respect to value functions and weighting criteria, it was possible to launch the Delphi processes that were both generally organized as described below:

- Through a briefing document internally disclosed at Galp via e-mail by the responsible member of the strategic group to the panel of participants, the modified Delphi processes were explained in detail resorting to a script. Also explained in the document were the questioning procedure and how the questionnaires would be used to either:

  a) Determine the added value from a set of performance levels in their respective categories, i.e. within each criterion (Value functions).
  b) Determine the partial value of each criterion considered in the model (Weighting criteria).

The provision of the information with regard to both the criteria and their descriptors of performance was not necessary as the questionnaires to be made available on the online platform where exhaustively detailed with respect to that information (available either directly in the questionnaires' layout or by pressing the 'eye' button in the questionnaires' layout).

- Each panel member then received an invitational e-mail generally describing the processes and the way these would be conducted, containing their username and instructions to access the online platform were they were required to set their password in order to assess the questionnaire (being this their first interaction with Welphi); in this platform each participant answered to the questionnaires using the MACBETH qualitative scale in both Delphi processes. In addition a 'don't know/don't want to answer' option was available to be selected and participants could provide any comments they saw fit (by pressing the 'balloon' button in the questionnaires' layout). Once the participants had given their answers the 1st round was closed
- In the 2nd round, feedback concerning the results of the 1st round was provided to each of the panel members which successfully engaged in the previous round, thus enabling their continuous participation in the processes. An invitation to take part in this 2nd round was sent by e-mail enabling their access to the questionnaire. Along with the supplied feedback participants were also reminded of their individual answers given in the 1st round. Participants now had the opportunity to revise their answers either keeping or changing them. A justification regarding a change in the answers was neither required nor compulsory although participants could provide any comments they saw fit as in the 1st round. This ended the 2nd round of the Delphi processes.
- In the 3rd round, updated feedback concerning the panel's answers was provided along the same lines as the ones considered in the 2nd round. Similarly participants still engaging in the process were invited to revise their previously given answers in the 2nd round. Once more, an invitation to take part in

this 3rd round was sent by e-mail enabling their access to the questionnaire. Again comments could be provided whenever participants saw fit. This ended the 3rd round. A sequence of these invitational e-mails through rounds is presented in the annexes section (annex B).

- Finally, after the three processes' rounds, a final report with the results of the modified Delphi processes was elaborated and sent to all the original members of the panel, regardless of their participation through rounds. This report contained the answers provided from all the participants in the processes in the 3rd and final round as well as a summary of the participants' comments if there were any. Through this the Delphi processes were at last finished (annex C).

Panel of participants

In order to enable the web-Delphi participatory processes a panel of participants was formed given the specificities of the evaluation criteria included in the model. Panel members were selected by Galp, being these future users of the platform and experts. The panel was composed by a total of 68 members divided into two smaller groups according to their expertise and skills regarding either the functional or technical requirements. These smaller groups had 61 and 12 participants, respectively assigned to carry out activities in the scope of the functional and technical requirements. Each of the groups was responsible of providing judgments for a set of criteria related with their area of knowledge and experience (functional or technical). All the participants in the process were either employees at Galp or were collaborating with the company in the scope of the selection and implementation of the EMS solution. Considering the previously mentioned, it is of worth noting for further analysis and discussion of the processes' results that panel members were selected from district working areas within the company, as illustrated in Figure 5.

Time requirements

Tables Table ***14*** and Table ***15*** present the start, duration and end of the three rounds associated with both web-Delphi processes, value functions and weighting criteria respectively. Time extensions regarding the duration of the rounds were in place in an effort to promote the panel's response adherence, giving participants more time to engage in the processes that are also included in the tables. Weekend days were not included in neither the duration nor the time extensions since they are not considered working days for the participants.

Table 14. Time requirements for the web-Delphi for value functions.

	Start	End	Duration	Time extension
1st round	26th July 2017	31st July 2017	4 days	1 day
2nd round	2nd August 2017	10th August 2017	7 days	3 days
3rd round	11th August 2017	6th September 2017	19 days	2 days

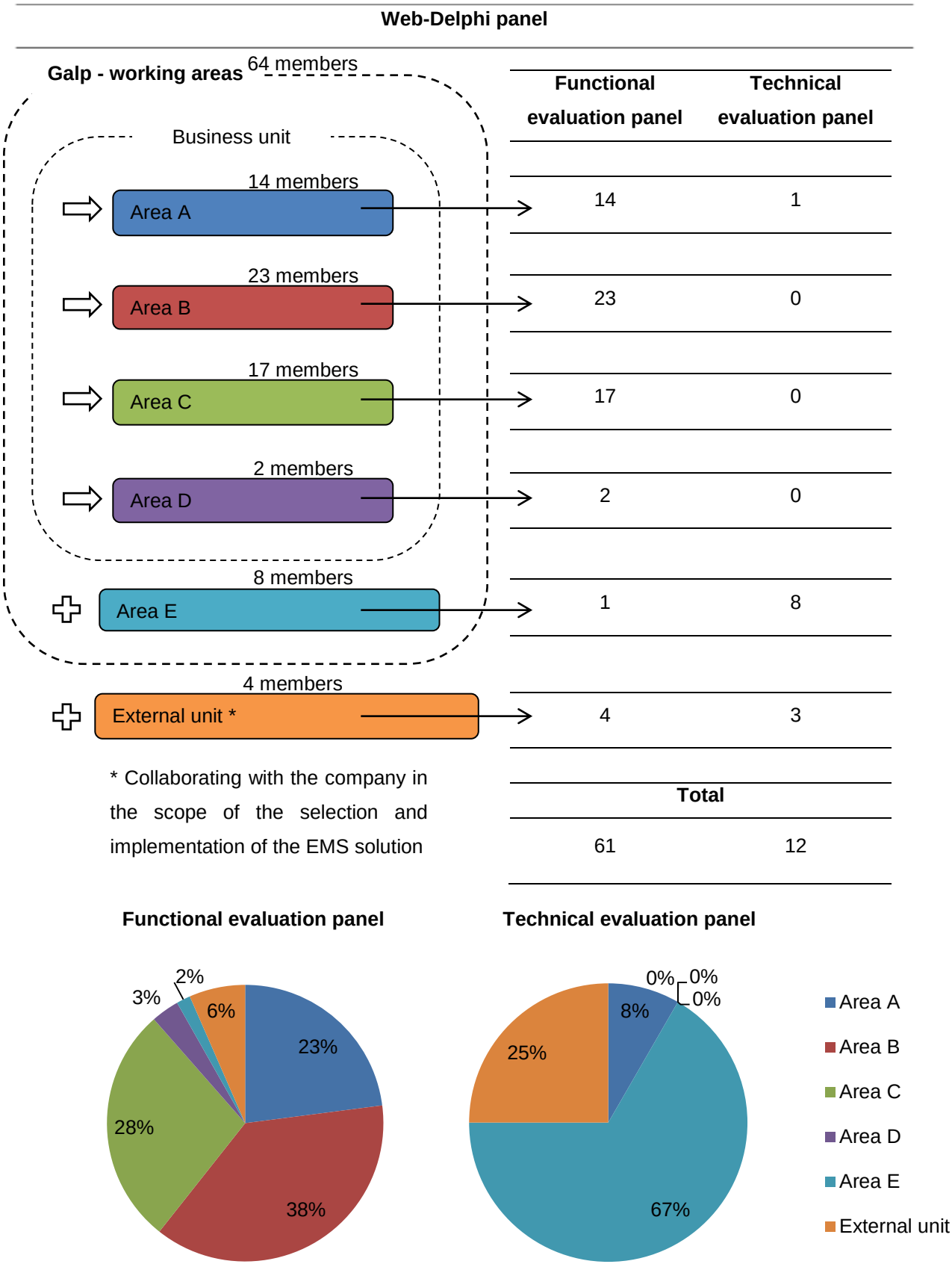


Figure 5. Web-Delphi panel's constitution.

Table 15. Time requirements for the web-Delphi for weighting criteria.

	Start	End	Duration	Time extension
1st round	7th September 2017	15th September 2017	9 days	1 day
2nd round	18th September 2017	20th September 2017	3 days	1 day
3rd round	21st September 2017	25th September 2017	5 days	3 days

Social component

Both the web-Delphi processes had the same social approach. As mentioned through a briefing document internally disclosed at Galp via e-mail by the responsible member of the strategic group to the panel of participants, the modified Delphi processes were explained in detail resorting to a script. Also explained in the document were the questioning procedure and how the questionnaires would be used to either:

a) Determine the added value from a set of performance levels in their respective categories, i.e. within each criterion (Value functions).
b) Determine the partial value of each criterion considered in the model (Weighting criteria).

In addition, resorting the Welphi's functionalities 'reminder' and 'last-reminder' e-mails were sent to the participants in the processes whenever the previously established deadlines for closing the processes' rounds were approaching and participants hadn't manage to engage in the processes. These normally would either encourage them to participate in the round before it finished or inform them that time extensions were being employed and rounds would remain further active, respectively (annexes D and E).

Technical component

a) Value functions

In the context of evaluating an EMS solution, a value function captures how changes in performance considering each evaluation criterion impact the quality of the EMS solution. In order to assess the value functions corresponding to each one of the considered evaluation criteria regarding the EMS solution's appraisal, a single question was developed. This was done exploiting the use of MACBETH regarding qualitative increases in preference between each two consecutive levels of performance, considering the criteria one by one. Upon the accomplishment of the questionnaire through the use of Welphi it was possible to launch the process. Participants were able to access the questionnaire that would allow determining their main concerns on each criterion regarding the increase in preference between each two levels of performance. The questioning procedure featured in the questionnaire and drawn upon the defined question was carried out through three rounds according to a specified layout hereinafter:

- 1st round: Participants in the process were presented with welcome message in the platform explaining the questionnaire's layout and functioning, which also reminded them of the time requirements

of the round (annex F). Next, after pressing the 'Continue' button, was featured the questionnaire that had as many pages as the considered evaluation criteria of each panel; seven pages and three pages in the case of the functional and technical panels respectively. Each one of the considered criteria in the process was presented in an individual page. In each page the criterion's performance intervals were displayed, each one representing an increase in performance. The participants were asked to answer the following question: "With regard to this criterion, which do you consider to be the increase in preference between each two levels of performance?" Answers were provided according to the MACBETH qualitative judgment scale through the selection of one of the following alternatives: 'no increase', 'very weak increase', 'weak increase', 'moderate increase', 'strong increase', 'very strong increase' and 'extreme increase'. In addition a 'don't know/don't want to answer' option was also available for selection and comments could be provided. Hence the participants were asked to answer three questions for each evaluation criteria. Figure 6 illustrates the layout of the questionnaire in this 1st round.

The sequence of the participants' answers to the three questions regarding each criteria, enabled to extract their implicit main concerns for each criterion. Seven main concerns were set as it follows:

Table 16. Sequence of answers and corresponding implicit main concerns.

Sequence of answers	Implicit main concern
When the participant gave equal qualitative answers to evaluate the three consecutive increases from one performance to the next.	*The increase in preference is constant (from worst to best performance)*
When the participant evaluated as the highest the increase from BAD to NEUTRAL.	*The main concern is to avoid bad performance*
When the participant evaluated as the highest the increase from NEUTRAL to GOOD.	*The main concern is to achieve a good performance*
When the participant evaluated equally and as the highest the increase from GOOD to VERY GOOD.	*The main concern is to achieve a very good performance*
When the participant evaluated equally and as the highest the two increases from BAD to NEUTRAL and from NEUTRAL to GOOD	*The main concern is both to avoid bad and achieve good*
When the participant evaluated equally and as the highest the two increases from BAD to NEUTRAL and from GOOD to VERY GOOD	*The main concern is both to avoid bad and achieve very good*

When the participant evaluated equally and as the highest the two increases from NEUTRAL to GOOD and from GOOD to VERY GOOD.	*The main concern is both to achieve good and very good*

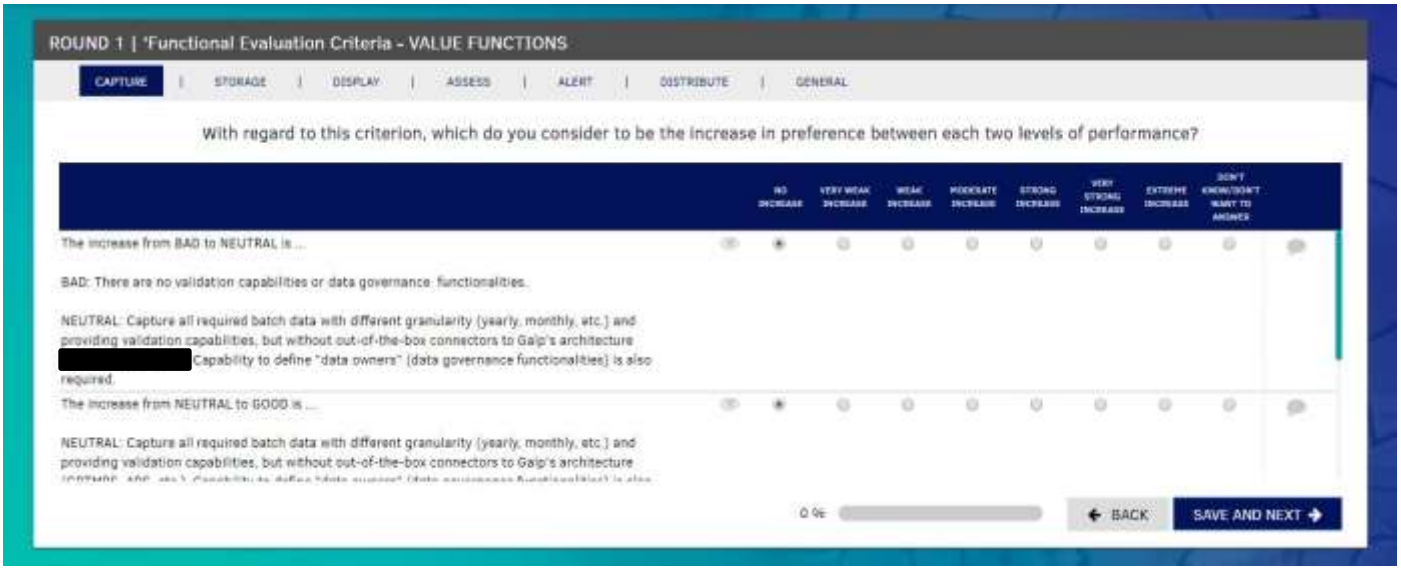


Figure 6. Screenshot 1st round (web-Delphi for value functions, functional evaluation panel).

- 2nd round: Participants were again presented with a welcome message resembling the one of the 1st round and were next presented with a one-page questionnaire with all the panel's criteria listed at the left of the table. Each cell of the table displayed the percentage of participants corresponding with each criterion and each one of the seven main concerns. Additionally any comments provided in the previous round were made available anonymously. Each participant's individual pre-selected main concern appeared highlighted in a dark-grey cell. Aiming at the collection of the participants' views regarding the main evaluation concerns on the several criteria, set from their answers in the 1st round, in this 2nd round these were invited to either keep or change each pre-selected main concern at the light of the group information (percentages) shown in the table. Figure 7 illustrates the layout of the questionnaire in this 2nd round.
- 3rd round: Finally after being presented with the last welcome message of the process participants access a questionnaire page resembling the one displayed in the 2nd round, concerning the layout. In this was featured the distribution of the panel's main concerns selection in the previous round. Feedback with the results of the 2nd round was updated on each criterion: percentages of respondents that selected each main concern and the comments made. Participants could maintain or change the main concern selected in the 2nd round at the light of the group information provided. The layout of this questionnaire was identical to the one of the 2nd round, depicted in Figure 7.

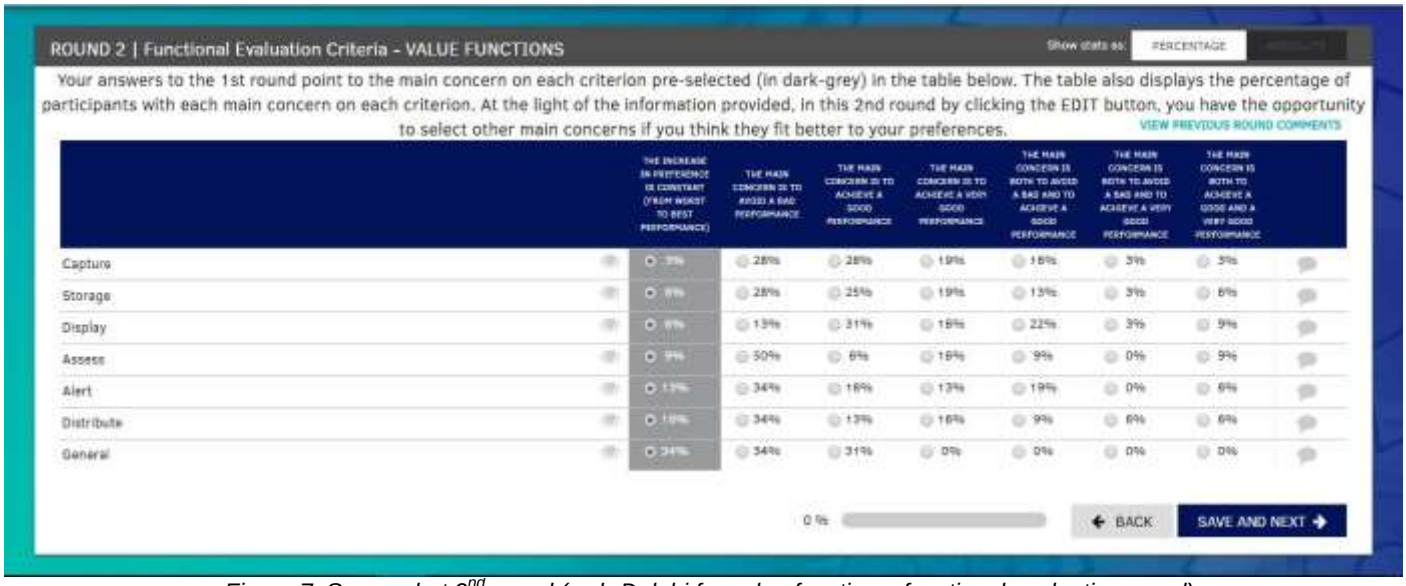


Figure 7. Screenshot 2nd round (web-Delphi for value functions, functional evaluation panel).

b) Weighting criteria

In order to assess the criteria weights corresponding to each one of the considered evaluation criteria regarding the EMS solution's appraisal, a single question was developed as for the case of the modified Delphi for value function. Similarly this was done exploiting the use of MACBETH, this time regarding qualitative swings in performance from neutral to good performances considering each of the criteria separately, departing from neutral levels in all the criteria (bottom up procedure). Upon the accomplishment of the questionnaire through the use of Welphi it was possible to launch the process. Participants were able to access the questionnaire that would allow for the collection of their value trade-off judgments regarding each of the considered evaluation criteria. The questioning procedure featured in the questionnaire and drawn upon the defined single question was carried out through three rounds according to the specific layout that hereinafter:

- 1st round: Participants in the process were presented with welcome message in the platform explaining the questionnaire's layout and functioning, which also reminded them of the time requirements of the round. Next, after pressing the 'Continue' button, was featured a one-page questionnaire with all the panel's criteria listed at the left of the table. The participants were asked to answer the following question: "Regarding the selection of the proposal for an [redacted] integration platform that best meets Galp's needs, suppose there is a proposal with neutral performances in all criteria. What would be the importance of improving it from neutral to good on each of the criteria?" Answers were provided with the MACBETH qualitative judgment scale through the selection of one of the following alternatives: 'no importance', 'very weak importance', 'weak importance', 'moderate importance', 'strong importance', 'very strong importance' and 'extreme importance'. In addition a 'don't know/don't want to answer' option was also available for selection and comments could be provided. Hence the participants were asked to answer seven or three

questions, considering the functional or technical evaluation criteria respectively. Figure 8 illustrates the layout of the questionnaire in this 1st round.

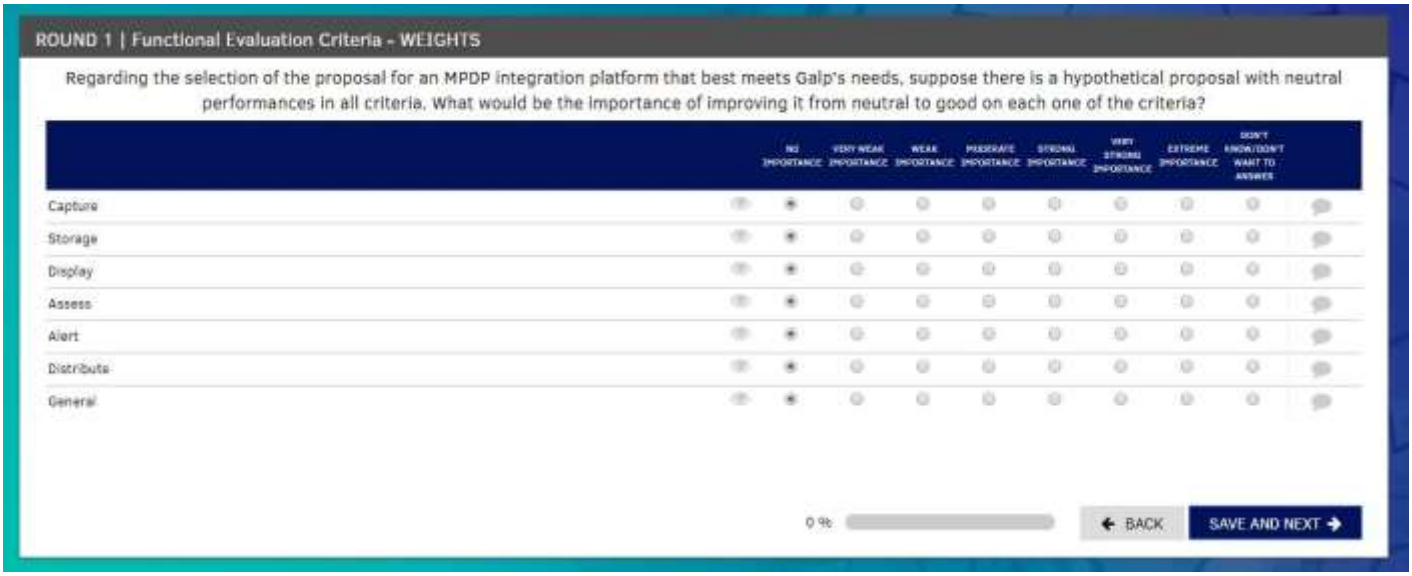


Figure 8. Screenshot 1st round (web-Delphi for weighting criteria, functional evaluation panel).

- 2nd round: Participants were again presented with a welcome message resembling the one of the 1st round and were next presented with a questionnaire page resembling the one displayed in the previous round, concerning the layout. Each cell of the table displayed the percentage of participants corresponding with each criterion and each one of the seven available judgments. Additionally any comments provided in the previous rounds were made available anonymously. The individual answers provided by each of the participants appeared highlighted in a dark-grey cell in their own questionnaire page. Participants were now invited to either keep or change they're previously provided judgments at the light of the group information (percentages) shown in the table. The layout of this questionnaire was identical to the one of the 1st round, depicted in Figure 8.
- 3rd round: Finally after being presented with the last welcome message of the process participants access a questionnaire page again resembling the one displayed in the previous rounds concerning the layout for the last time. Feedback with the results of the 2nd round was updated on each criterion: percentages of respondents that selected each judgment and the comments made. Participants could maintain or change the main concern selected in the 2nd round at the light of the group information provided. Once more the layout of this questionnaire was identical to the one of the 1st round, depicted in Figure 8.

3.2.2. Decision conferences processes

The final process activities predicted in the methodological framework respecting the decision conferencing processes for the model's construction were developed by Galp alone. At this point IST was no longer actively involved in the project having given its final contributions by concluding the web-Delphi

modified processes. A report meant for the strategic group providing feed in information for the model's construction processes was drawn up in the conclusion these. This report included a brief description of the two web-Delphi processes and presented their summary results as well as a preliminary analysis of these. The contents of this report are not presented in this dissertation since results and analyses concerning both web-Delphi processes are presented in further detail in the next section (section 5). As a final note, feedback from Galp was reported to IST informing that outcomes of the Delphi processes presented in the report were used as expected to construct the multicriteria evaluation model. The strategic group made final decisions regarding the provided compilation of the participants' judgments, which enabled the multicriteria evaluation model's construction resorting to the M-MACBETH software assessing criteria's value functions and weights in the framework of the additive aggregation model.

4. Results and analysis of the web-Delphi processes

This section presents the outcomes of both web-Delphi processes implemented according to the methodology described in section 3 (sub-section 3.2.1.) These respect the processes' selected results and analysis which were found to best fit Galp information needs. The outcomes of each web-Delphi (value functions and weighting criteria) are presented separately and aggregated by evaluation panel (functional or technical) in the following sub-sections. Results and analysis are always conducted following the same method, described in 4.a.

4.a. Web-Delphi for value functions

The objective of this web-Delphi process was to enable the determination of the added value of a set of performance levels in their respective category, i.e. criterion. Each participant evaluated the increase in preference between each two consecutive levels of performance, considering the evaluation criteria one by one.

4.a.1. Functional evaluation panel

1. Results

Two results were selected to be presented: the panel's adherence and their provided answers in the processes (sub-sections 1.1. and 1.2. respectively). Panel's adhesion results are presented both clustered and fragmented; this is considering the different working areas into which the participants are sorted that constitute the panel. The clustered panel's adhesion is presented featuring the invited participants, respondents and non-respondents through rounds. Following is presented the fragmented panel's adhesion as complementary information linked to the clustered adhesion, distributing the respondents into their respective working areas through rounds. Finally are presented the results with respect to the participants' answers in the processes. Following the above reasoning, only the clustered answers of the panel were selected for presentation since the fragmented were found to be of little significance (given the verified low fragmented adhesion of the panel through rounds). Accordingly, analyses of the panel's clustered answers are presented next.

1.1. Panel's adhesion through rounds

Clustered adhesion – Invited participants, respondents and non-respondents

In the 1st round, a total of 61 participants were invited to engage in the process. From the 61 invited participants a total of 31 participants concluded the questionnaire (51% adherence corresponding to a dropout rate of 49% among panel members). The 31 respondents from the 1st round were invited to take part in the 2nd round of the process. Of these 31 invited participants, a total of 26 participants concluded the questionnaire (84% adherence corresponding to a dropout rate of 16% among panel members). Finally, these 26 respondents were then invited to participate in the 3rd and final round, having 24 of them

concluded the final questionnaire (92% adherence corresponding to a dropout rate of 8% among panel members). Figure 9 illustrates the respective percentages of respondents and non-respondents in each one of the three rounds of the process, considering the total number of participants associated with each round.

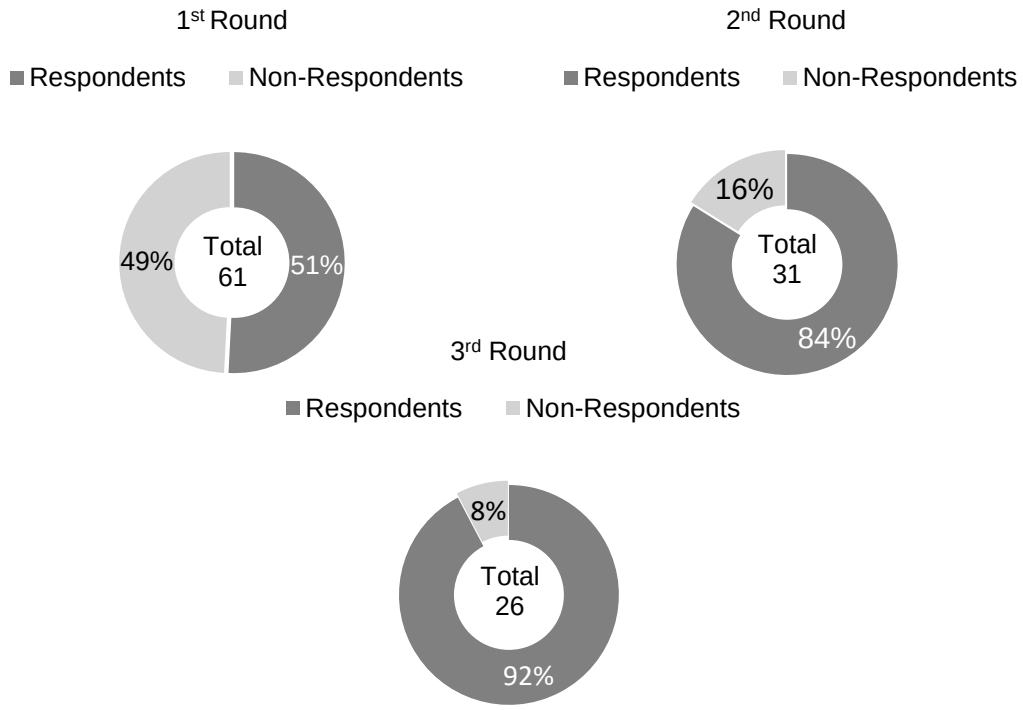


Figure 9. Diagrams representing the clustered percentages of responses through rounds (Web-Delphi for value functions; Functional evaluation panel).

Fragmented adhesion – Respondents associated with each working area

Complementary information linked to the results previously presented with respect to the panel's adhesion, is now provided in the below chart (Figure 10). The chart illustrates the percentages of respondents among the invited participants in each of the three rounds, which corresponds to the distinct working areas that form the panel of participants (internal or external). Note that detailed information regarding the panel's constitution was provided in section 3 (Figure 5) which includes the percentages of the panel members associated with each of the considered working areas at the start of the Delphi process. The functional panel had assigned to it members of all six working areas. 'Area D' had a percentage of 0% of respondents associated to it from the begging of the process (1st round) and consequently through the rest of the process (2nd and 3rd rounds) and will thus be disregarded in the following breakdown of the information provided in the chart. Having a total of 51% of respondents in the 1st round the percentages associated with each area are the following: 'Area A' 10% (6 respondents); 'Area B' 20% (12 respondents); 'Area C' 15% (9 respondents); 'Area E' 2% (1 respondent); and finally 'External unit' 5% (3 respondents). Keeping in mind the same reasoning, in the 2nd round the clustered sum of 84% is divided by the same areas considered in the 1st round respectively ordered as follows:

19%(6 respondents); 29% (9 respondents); 23% (7 respondents); 3% (1 respondent); and 10% (3 respondents). Finally in the 3rd round the 92% adhesion of the participants is again divided by the same areas considered in the previous rounds respectively ordered next: 23% (6 respondents); 35% (8 respondents); 23% (6 respondents); 4% (1 respondent); and 12% (3 respondents).

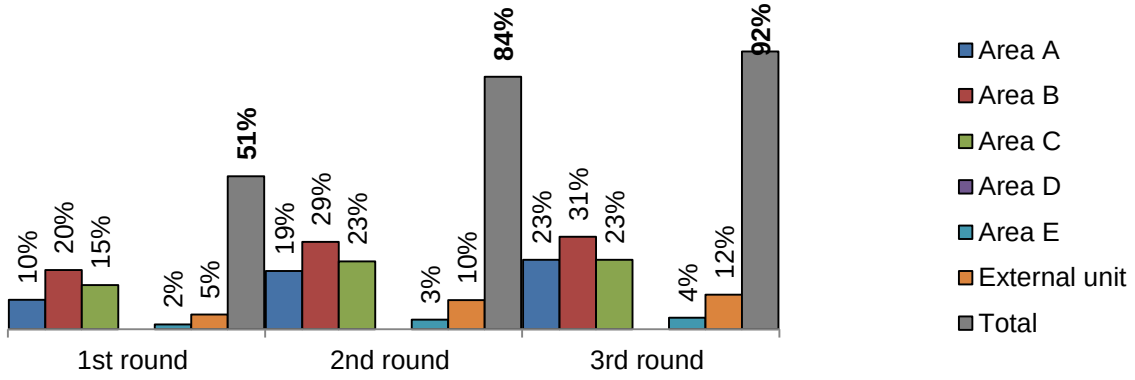


Figure 10. Diagram representing the fragmented percentages of responses associated with each business unit that forms the panel of participants through rounds (Web-Delphi for value functions; Functional evaluation panel).

1.2. Panel's answers trough rounds

Table 17. Clustered results of the process through rounds (Web-Delphi for value functions; Functional evaluation panel).

Functional evaluation criteria panel

	Criterion	The increase in preference is constant (from worst to best performance)	The main concern is … performance: to avoid a bad	to achieve a good	to achieve a very good	to avoid a bad and to achieve a good	to avoid a bad and to achieve a very good	to both achieve a good and a very good	Don't know/don't want to answer
Main concerns set on the 1st round	Capture	0%	29%	29%	19%	16%	3%	3%	0%
	Storage	3%	29%	26%	19%	13%	3%	6%	0%
	Display	3%	13%	32%	16%	23%	3%	10%	0%
	Assess	6%	52%	6%	16%	10%	0%	10%	0%
	Alert	10%	35%	16%	13%	19%	0%	6%	0%
	Distribute	13%	35%	13%	16%	10%	6%	6%	0%
	General	32%	35%	32%	*N.A**	*N.A**	*N.A**	*N.A**	0%

Answers in the 2nd round	Capture	0%	4%	23%	73%	0%	0%	0%	0%
	Storage	0%	8%	15%	77%	0%	0%	0%	0%
	Display	0%	4%	96%	0%	0%	0%	0%	0%
	Assess	0%	19%	0%	81%	0%	0%	0%	0%
	Alert	0%	12%	85%	0%	4%	0%	0%	0%
	Distribute	0%	12%	8%	81%	0%	0%	0%	0%
	General	92%	8%	0%	*N.A**	*N.A**	*N.A**	*N.A**	0%

Answers in the 3rd round	Capture	0%	0%	13%	88%	0%	0%	0%	0%
	Storage	0%	0%	4%	96%	0%	0%	0%	0%
	Display	0%	0%	100%	0%	0%	0%	0%	0%
	Assess	0%	4%	0%	96%	0%	0%	0%	0%
	Alert	0%	0%	100%	0%	0%	0%	0%	0%
	Distribute	0%	0%	4%	96%	0%	0%	0%	0%
	General	100%	0%	0%	*N.A**	*N.A**	*N.A**	*N.A**	0%

**N.A*- Non applicable; 'General' only possesses 3 levels of performance in its constructed scale thus invalidating the applicability of "labeled" the main concerns.

The web-Delphi proceeding for value functions concerning the functional evaluation panel produced information for each criterion in the form despised in the table above. Table 17 presents the distribution (in percentages) of the participants' main concerns through rounds. These main concerns were drawn implicitly from the participants' answers in the first round. They were then presented to the participants in the 2nd round, enabling them to either keep the pre-selected main concerns or change them. The 3rd round was meant to set the participants' final selection. No comments were provided by any of the participants in any of the rounds.

2. Analysis

For analyzing the clustered results attained for each criterion in the Delphi process the main concerns through rounds were screened to detect the existence, or not, of a majority within the panel regarding one of the seven main concerns set previously. By group majority main concern, it is meant at least 51% of the participants selected that main concern.

2.1. Main concerns; stability of the answers

Table 18 presents the majority analysis through rounds. For each criterion of the panel, the group majority main concern is shown or the message "No majority found" is displayed. The distribution (in percentage) of the participants' main concern selection (through rounds) is also presented.

Table 18. Group majority main concerns analysis through rounds (Web-Delphi for value functions; Functional evaluation panel).

Functional evaluation criteria panel			
Criterion	**1st round**	**2nd round**	**3rd round**
Capture	No majority found	***Achieve very good (73%)***	***Achieve very good (88%)***
Storage	No majority found	***Achieve very good (77%)***	***Achieve very good (96%)***
Display	No majority found	***Achieve good (96%)***	***Achieve good (100%)***
Assess	***Avoid bad (52%)***	***Achieve very good (81%)***	***Achieve very good (96%)***
Alert	No majority found	***Achieve good (85%)***	***Achieve good (100%)***
Distribute	No majority found	***Achieve very good (81%)***	***Achieve very good (96%)***
General	No majority found	***Constant (92%)***	***Constant (100%)***

As shown by the results presented in Table 18, the 2nd and 3rd rounds present group majority main concerns regarding all the criteria. Being that from the 2nd to the 3rd round all the group majority main concerns present themselves stable, in terms of the selected group majority main concern, while slightly increasing the percentage of selection by the participants. It should also be noted that some of these increases lead to a group consensus (100%), as is the case of 'display', 'alert' and 'general'. Another point of focus is the particular case of the assess criterion. This presents group majority main concerns in all three rounds. Nevertheless, it can be seen that the group majority main concern implicit in the participants' answers in the 1st round is not the same as the group majority main concern selected in both the 2nd and 3rd rounds.

4.a.2. Technical evaluation panel

1. Results

The presentation of the results follows in the same way as previously presented for the functional evaluation panel and under the same considerations.

1.1. Panel's adhesion through rounds

Clustered adhesion - Invited participants, respondents and non-respondents

In the 1st round, a total of 12 participants were invited to engage in the process. From the 12 invited participants a total of 10 participants concluded the questionnaire (83% adherence corresponding to a dropout rate of 17% among panel members). The 10 respondents from the 1st round were invited to take part in the 2nd round of the process. In this 2nd round all of the 10 invited participants completed the

questionnaire (100% adherence corresponding to a zero dropout rate among panel members). Finally, these same 10 respondents were then invited to participate in the 3rd and final round, having 8 of them concluded the final questionnaire (80% adherence corresponding to a dropout rate of 20% among panel members). Figure 11 illustrates the respective percentages of respondents and non-respondents in each one of the three rounds of the process.

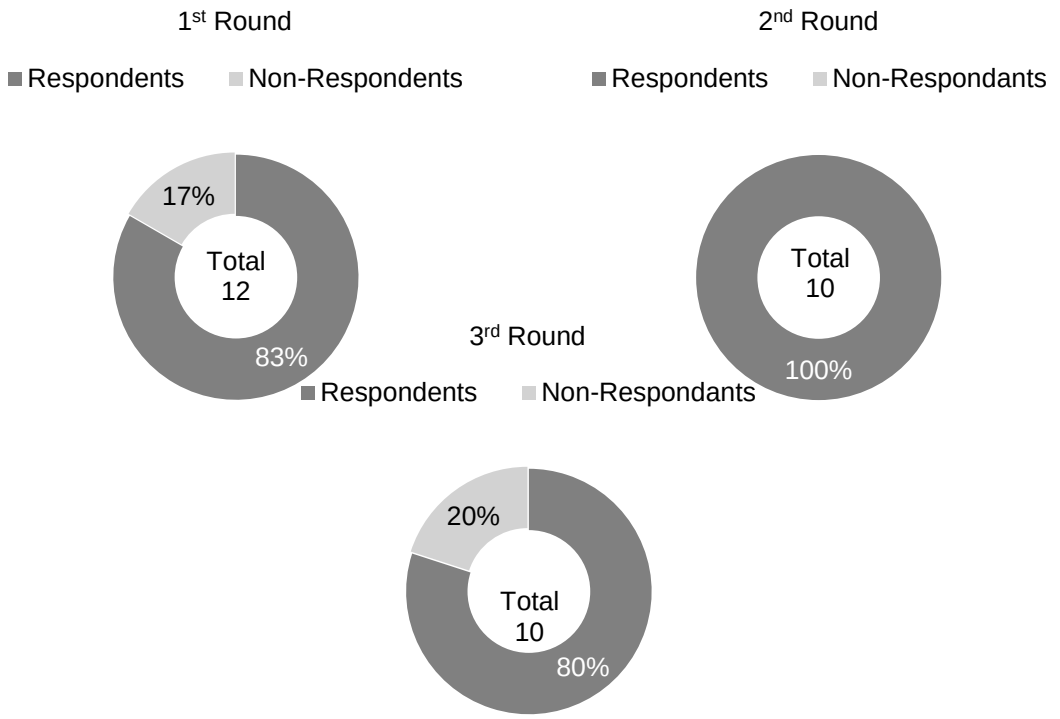


Figure 11. Diagrams representing the percentages of responses through rounds (Web-Delphi for value functions; Technical evaluation panel).

Fragmented adhesion – Respondents associated with each working area

Complementary information linked to the results previously presented with respect to the panel's adhesion is now provided in the chart below (Figure 12). Similarly to the given information for the functional evaluation panel, the chart illustrates the percentages of respondents among the invited participants in each of the three rounds, which corresponds to the distinct working areas that form the panel of participants (internal or external). Note that detailed information regarding the panel's constitution was provided in section 3 (Figure 5) which includes the percentages of the panel members associated with each of the considered working units at the start of the Delphi process.

The technical panel had only assigned to it members of three out of the six working areas previously considered in the functional evaluation panel (2 internal and the external one). Left out of the technical panel were the 'Area B', 'Area C' and 'Area D' areas. Considering the three remaining areas that form the technical panel following is the breakdown of the information provided in the chart by these. Having a total of 83% of respondents in the 1st round the percentages associated with each unit are the following: 'Area

A' 8% (1 respondent); 'Area E' 50% (6 respondents); and 'External unit' 25% (3 respondents). Keeping in mind the same reasoning and given the zero dropout rate of the panel members, in the 2nd round the clustered sum of 100% is divided equally by same units considered as in the 1st round. Finally in the 3rd round the 80% adhesion of the participants is again divided by the same units considered in the previous rounds respectively ordered next: 10% (1 respondent); 50% (5 respondents); and 20% (2 respondents).

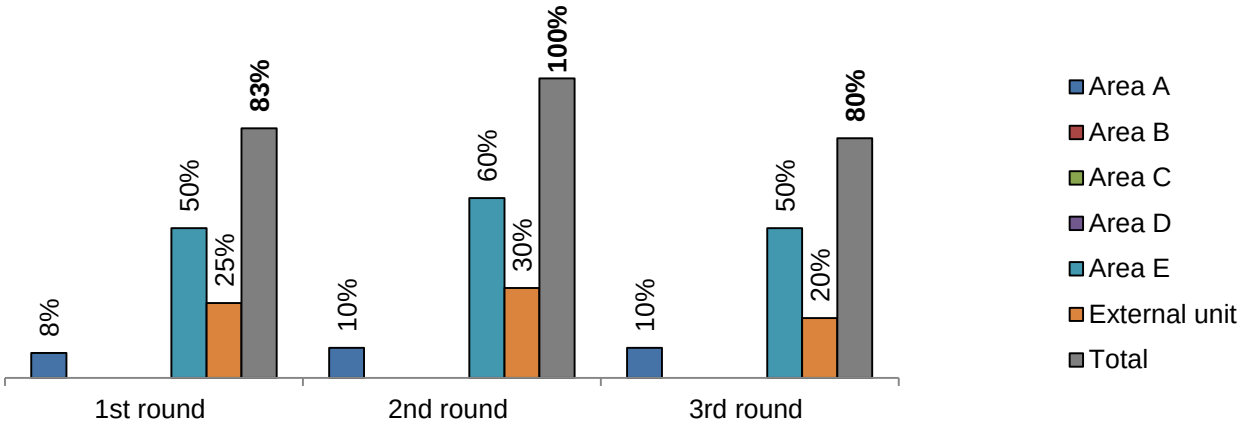


Figure 12. Diagram representing the fragmented percentages of responses associated with each business unit that forms the panel of participants through rounds (Web-Delphi for value functions; Technical evaluation panel).

1.2. Panel's answers through rounds

Table 19. Clustered results of the process through rounds (Web-Delphi for value functions; Technical evaluation panel).

Technical evaluation criteria panel

	Criterion	The increase in preference is constant (from worst to best performance)	The main concern is … performance: to avoid a bad	to achieve a good	to achieve a very good	to avoid a bad and to achieve a good	to avoid a bad and to achieve a very good	to both achieve a good and a very good	Don't know/don't want to answer
Main concerns set on the 1st round	Integration	0%	30%	50%	0%	20%	0%	0%	0%
	Security	20%	30%	20%	20%	10%	0%	0%	0%
	Mobility	10%	30%	10%	0%	30%	20%	0%	0%

Answers in the 2nd round	Integration	0%	0%	100%	0%	0%	0%	0%	0%
	Security	0%	90%	0%	0%	10%	0%	0%	0%
	Mobility	0%	10%	0%	0%	90%	0%	0%	0%

Answers in the 3rd round	Integration	0%	0%	100%	0%	0%	0%	0%	0%
	Security	0%	100%	0%	0%	0%	0%	0%	0%
	Mobility	0%	90%	0%	0%	10%	0%	0%	0%

The web-Delphi proceeding for value functions concerning the technical evaluation panel produced information for each criterion in the form despised in the table above. Table 19 presents the distribution (in percentages) of the participants' main concerns through rounds. These main concerns were drawn implicitly from the participants' answers in the first round. They were then presented to the participants in the 2nd round, enabling them to either keep the pre-selected main concerns or change them. The 3rd round was meant to set the participants' final selection. No comments were provided by any of the participants in any of the rounds.

2. Analysis

The analysis of the clustered results for each criterion follows in the same way as previously presented for the functional evaluation panel and under the same considerations.

2.1. Main concerns; stability of the answers

Table 20 below presents the majority analysis through rounds. For each criterion of the panel, the group majority main concern is shown or the message "No majority found" is displayed. The distribution (in percentage) of the participants' main concern implicit to the participants' answers in the 1st round (through rounds) is also presented.

Similarly to the functional criteria panel, looking at Table 20 it can be seen that group majority main concerns were reached in both the 2nd and the 3rd round. These majorities are stable and all of them present an increase in the percentage of participants that selected the main concerns in question, going from the 2nd to the 3rd round, reaching consensus in the 3rd and final round regarding all the criteria.

Table 20. Group majority main concerns analysis through rounds (Web-Delphi for value functions; Technical evaluation panel).

Technical evaluation criteria panel			
Criterion	**1st round**	**2nd round**	**3rd round**
Integration	No majority found	***Achieve good (100%)***	***Achieve good (100%)***
Security	No majority found	***Avoid bad (96%)***	***Avoid bad (100%)***
Mobility	No majority found	***Avoid bad and achieve good (96%)***	***Avoid bad and achieve good (100%)***

3. Overview of the clustered results of the Web-Delphi for value functions

Table 21 summarizes the results of the group majority main concerns, in the 3rd round treated in until this point. With respect the functional criteria panel, the three criteria that reached group consensus were: 'display', 'alert' and 'general'. Still regarding the functional criteria panel, in one criterion ('general') the selected group majority main concern was a constant increase in preference (from worst to best performance), while in other two criteria ('display' and 'alert') the selected group majority main concern was achieve a good performance and for another four criteria ('capture', 'storage', 'assess' and 'distribute') it was to achieve a very good performance.

Table 21. Clustered results per panel (web-Delphi for value functions).

Web-Delphi for value functions										
		Constant	***Avoid bad***	***Achieve good***	***Achieve very good***	***Avoid bad and achieve good***	***achieve very good***	***Achieve good and very good***		
Web-Delphi panel	**Total number of criteria**								**No group majority main concern**	**Group consensus reach**
Functional criteria	7	1	-	2	4	-	-	-	-	3

Technical criteria	3	-	1	1	-	1	-	-	-	3

Considering the technical criteria panel, all of the three criteria achieved group consensus. Each one of the three criterion of the panel had different selected group majority main concern; in one criterion (’integration’) the selected group majority main concern was to achieve a very good performance, in another (’security’) it was to avoid a bad performance and finally to avoid a bad and achieve a good performance in the other (’mobility’).

4.b. Web-Delphi for weighting criteria

The objective of this web-Delphi process was to enable the collection of qualitative judgments on the preferences between the criteria. Each participant evaluated the importance of an improvement in performance from a neutral to good performance in each one of the criteria separately, departing from neutral levels in all criteria.

4.b.1. Functional evaluation panel

1. Results

The presentation of the results follows in the same way as previously presented for the web-Delphi for value functions.

1.1. Panel’s adhesion through rounds

Clustered adhesion - Invited participants, respondents and non-respondents

In the 1st round, a total of 61 participants were invited to engage in the process. From the invited participants a total of 37 concluded the questionnaire (61% adherence corresponding to a dropout rate of 39% among panel members). The respondents from the 1st round were invited to take part in the 2nd round of the process. Of these a total of 26 concluded the questionnaire (70% adherence corresponding to a dropout rate of 30% among panel members). Finally, these 26 respondents were then invited to participate in the 3rd and final round, having 20 of them concluded the final questionnaire (77% adherence corresponding to a dropout rate of 23% among panel members). Finally, these 26 respondents were then invited to participate in the 3rd and final round, having 20 of them concluded the final questionnaire (77% adherence corresponding to a dropout rate of 23% among panel members). Figure 13, illustrates the respective percentages of respondents and non-respondents in each one of the three rounds of the process.

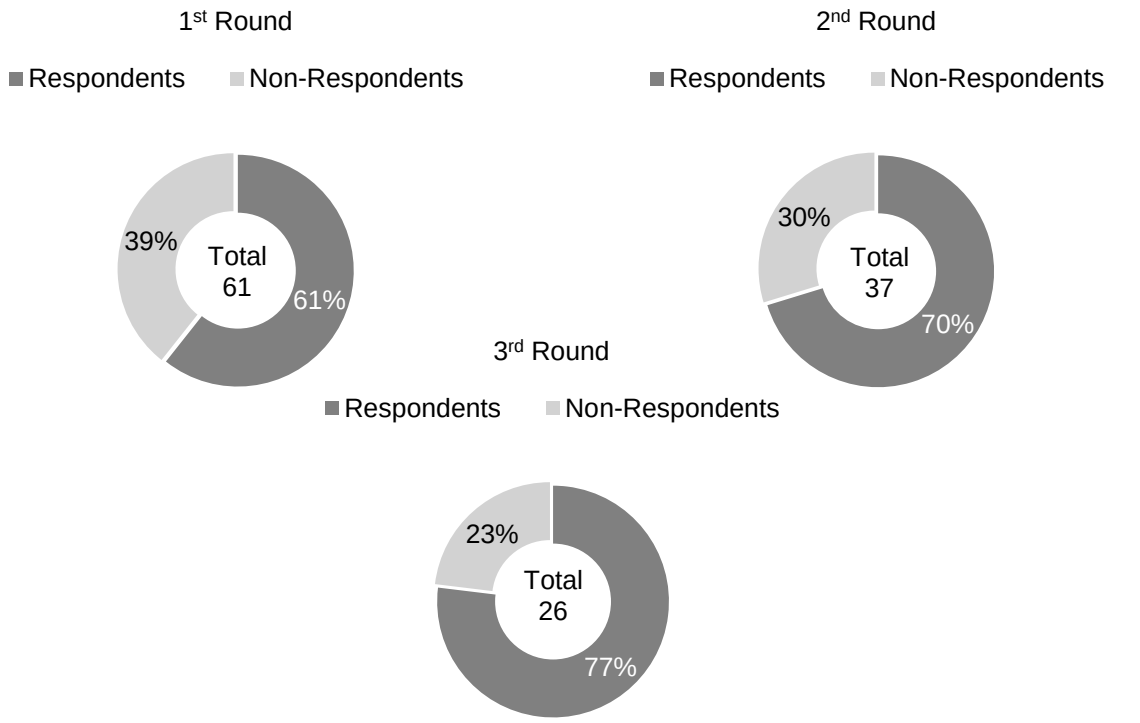


Figure 13. Diagrams representing the percentages of responses through the three rounds (Web-Delphi for weighting criteria; Functional evaluation panel).

Fragmented adhesion – Respondents associated with each working area

Complementary information linked to the results previously presented with respect to the panel's adhesion, is now provided in the chart (Figure 14).

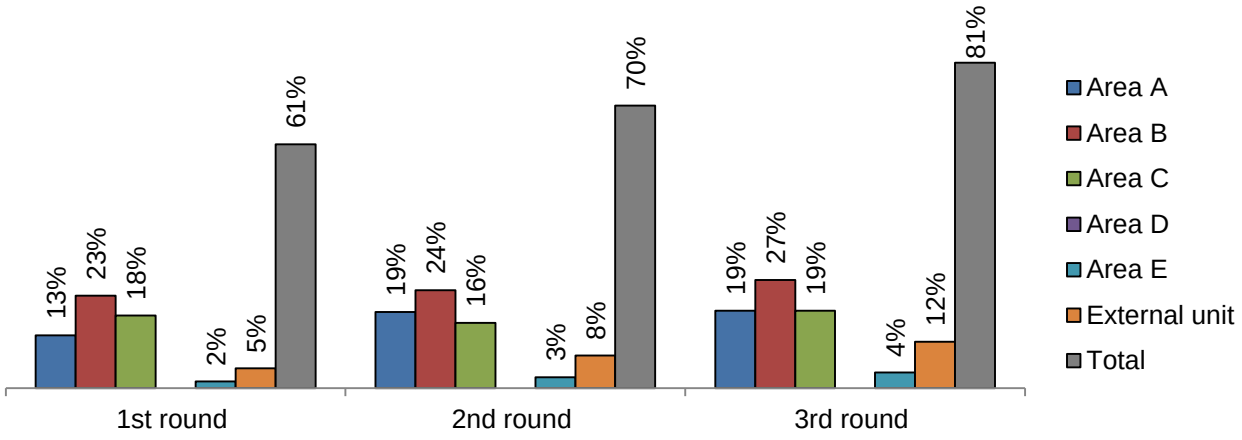


Figure 14. Diagram representing the fragmented percentages of responses associated with each business unit that forms the panel of participants through the three rounds (Web-Delphi for weighting criteria; Functional evaluation panel).

Similarly to the occurred in the web-Delphi for value functions the 'Area D' had a percentage of 0% of respondents associated to it from the begging of the process (1st round) and consequently through the rest of the process (2nd and 3rd rounds) and will thus be disregarded in the following breakdown of the information provided in the chart. Having a total of 61% of respondents in the 1st round the percentages

associated with each unit are the following: 'Area A' 13% (8 respondents); 'Area B' 23% (14 respondents); 'Area C' 18% (11 respondents); 'Area D' 2% (1 respondent); and finally 'External unit' 5% (3 respondents). Keeping in mind the same reasoning, in the 2nd round the clustered sum of 70% is divided by the same areas considered in the 1st round respectively ordered as follows: 19%(7 respondents); 24% (9 respondents); 16% (6 respondents); 3% (1 respondent); and 8% (3 respondents). Finally in the 3rd round the 81% adhesion of the participants is again divided by the same areas considered in the previous rounds respectively ordered next: 19% (5 respondents); 27% (7 respondents); 19% (5 respondents); 4% (1 respondent); and 12% (3 respondents).

1.2. Panel's answers through rounds

Table 22. Clustered results of the process through rounds (Web-Delphi for weighting criteria; Functional evaluation panel).

		Functional evaluation criteria panel							
	Criterion	No importance	Very weak importance	Weak importance	Moderate importance	Strong importance	Very strong importance	Extreme importance	Don't know/don't want to answer
Answers in the 1st round	Capture	0%	0%	19%	11%	24%	27%	14%	5%
	Storage	0%	0%	0%	32%	32%	24%	11%	0%
	Display	0%	0%	3%	11%	51%	24%	8%	3%
	Assess	0%	3%	14%	27%	22%	16%	16%	3%
	Alert	0%	0%	5%	35%	38%	14%	5%	3%
	Distribute	0%	0%	0%	30%	49%	16%	5%	0%
	General	0%	3%	19%	30%	24%	14%	5%	5%
Answers in the 2nd round	Capture	0%	0%	12%	0%	19%	65%	4%	0%
	Storage	0%	0%	0%	23%	62%	12%	4%	0%
	Display	0%	0%	0%	4%	85%	12%	0%	0%
	Assess	0%	0%	12%	23%	62%	4%	0%	0%
	Alert	0%	0%	0%	19%	58%	23%	0%	0%
	Distribute	0%	0%	0%	15%	50%	27%	8%	0%
	General	0%	0%	12%	23%	50%	8%	0%	8%

Answers in the 3rd round									
	Capture	0%	0%	5%	0%	15%	80%	0%	0%
	Storage	0%	0%	0%	20%	60%	15%	5%	0%
	Display	0%	0%	0%	0%	90%	10%	0%	0%
	Assess	0%	0%	10%	10%	80%	0%	0%	0%
	Alert	0%	0%	0%	15%	60%	25%	0%	0%
	Distribute	0%	0%	0%	5%	55%	30%	10%	0%
	General	0%	0%	5%	*30%*	*50%*	*10%*	*0%*	5%

The web-Delphi proceeding for weighting criteria concerning the functional evaluation panel produced information for each criterion in the form despised in the table above. Table 22 presents the distribution (in percentages) of the participants' answers through the three rounds. No comments were provided by any of the participants in any of the rounds.

2. Analysis

The analysis of the clustered results follows in the same way as previously presented for the web-Delphi for value functions.

2.1. Main concerns; stability of the answers

Table 23 presents the majority analysis through rounds.

Table 23. Group majority main concerns analysis through rounds (Web-Delphi for weighting criteria; Functional evaluation panel).

Functional evaluation criteria panel			
Criterion	**1st round**	**2nd round**	**3rd round**
Capture	No majority found	***Very strong importance (65%)***	***Very strong importance (80%)***
Storage	No majority found	***Strong importance (62%)***	***Strong importance (90%)***
Display	***Strong importance (51%)***	***Strong importance (85%)***	***Strong importance (90%)***
Assess	No majority found	***Strong importance (62%)***	***Very strong importance (80%)***
Alert	No majority found	***Strong importance (58%)***	***Strong importance (60%)***
Distribute	No majority found	No majority found	***Strong importance (55%)***
General	No majority found	No majority found	No majority found

For each criterion of the panel, the group majority judgment is shown or the message “No majority found” is displayed. The distribution (in percentage) of the participants’ judgment selection (through rounds) is also presented. As shown by Table 23 in the 1st round only the ‘display’ criteria achieved a group majority judgment. This particular group majority judgment was stable through the three rounds, having an increase in the percentage of selection by the participants in both the 2nd and 3rd rounds. In the 2nd round five out of the seven panel criteria manage to achieve group majority judgment and in the 3rd round, six out of the seven criteria achieve the group majority judgment. Regarding the stability of the group majority judgment through the 2nd and 3rd rounds, all of the considered criteria maintained a stable selected group majority judgment, with the exception of the ‘assess’ criterion which suffered a change in the selected group majority judgment going from the 2nd to the 3rd round.

4.b.2. Technical evaluation panel

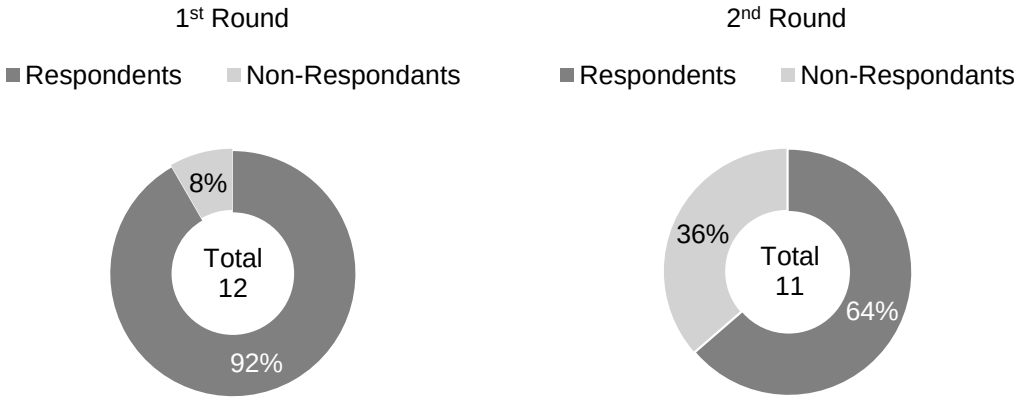
1. Results

The presentation of the results follows in the same way as previously presented for the web-Delphi for value functions.

1.1. Panel’s adhesion through rounds

Clustered adhesion - Invited participants, respondents and non-respondents

In the 1st round, a total of 12 participants were invited to engage in the process. From the invited participants a total of 11 concluded the questionnaire (92% adherence corresponding to a dropout rate of 8% among panel members). The 11 respondents from the 1st round were invited to take part in the 2nd round of the process. Of these a total of 7 concluded the questionnaire (64% adherence corresponding to a dropout rate of 36% among panel members). Finally, these 7 respondents were then invited to participate in the 3rd and final round, having 6 of them concluded the final questionnaire (86% adherence corresponding to a dropout rate of 14% among panel members). Figure 15 illustrates the respective percentages of respondents and non-respondents in each one of the three rounds of the process.



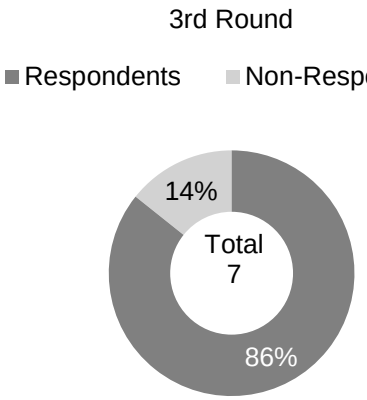


Figure 15. Diagrams representing the percentages of responses through rounds (Web-Delphi for weighting criteria; Technical evaluation panel).

Fragmented adhesion – Respondents associated with each business unit

Complementary information linked to the results previously presented with respect to the panel's adhesion, is now provided in the chart (Figure 16).

Having a total of 92% of respondents in the 1st round the percentages associated with each area are the following: 'Area A' 8% (1 respondent); 'Area D' 58% (7 respondents); and 'External unit' 25% (3 respondents). Keeping in mind the same reasoning in the 2nd round the clustered sum of 64% is divided equally by same areas considered as in the 1st round respectively ordered as follows: 'Area A' 9% (1 respondent); 'Area D' 27% (3 respondents); and 'External unit' 27% (3 respondents). Finally in the 3rd round the 86% adhesion of the participants is again divided by the same areas considered in the previous rounds respectively ordered next: 14% (1 respondent); 43% (3 respondents); and 29% (2 respondents).

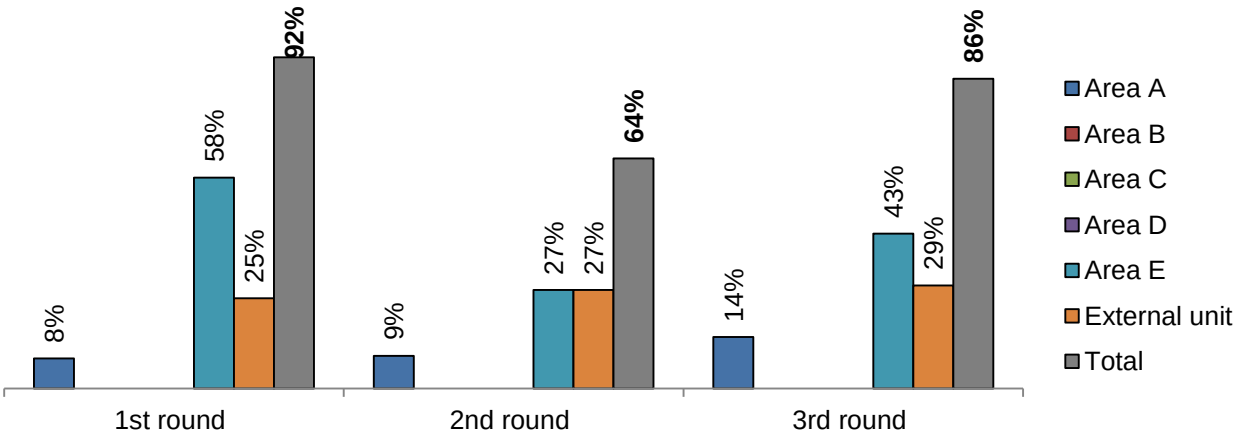


Figure 16. Diagram representing the fragmented percentages of responses associated with each business unit that forms the panel of participants through rounds (Web-Delphi for weighting criteria; Technical evaluation panel).

1.2. Panel's answers through rounds

The web-Delphi proceeding for weighting criteria concerning the technical evaluation panel produced information for each criterion in the form despised in the table below. Table 24 below presents the distribution (in percentages) of the participants' answers through the three rounds. No comments were provided by any of the participants in any of the rounds.

Table 24. Clustered results of the process through rounds (Web-Delphi for weighting criteria; Technical evaluation panel).

		Technical evaluation criteria panel							
		No importance	Very weak importance	Weak importance	Moderate importance	Strong importance	Very strong importance	Extreme importance	Don't know/don't want to answer
	Criterion								
Answers in the 1st round	Integration	0%	0%	0%	0%	9%	45%	45%	0%
	Security	0%	0%	0%	9%	27%	45%	18%	0%
	Mobility	0%	0%	9%	55%	36%	0%	0%	0%
Answers in the 2nd round	Integration	0%	0%	0%	0%	14%	86%	0%	0%
	Security	0%	0%	0%	0%	14%	71%	14%	0%
	Mobility	0%	0%	0%	43%	57%	0%	0%	0%
Answers in the 3rd round	Integration	0%	0%	0%	0%	17%	83%	0%	0%
	Security	0%	0%	0%	0%	0%	100%	0%	0%
	Mobility	0%	0%	0%	67%	33%	0%	0%	0%

2. Analysis

The analysis of the clustered results follows in the same way as previously presented for the web-Delphi for value functions.

2.1. Main concerns; Stability of the answers

Table 25 presents the majority analysis through rounds. For each criterion of the panel, the group majority judgment is shown or the message “No majority found” is displayed. The distribution (in percentage) of the participants’ judgment selection (through rounds) is also presented.

Table 25. Group majority main concerns analysis through rounds (Web-Delphi for value functions; Technical evaluation panel).

Technical evaluation criteria panel			
Criterion	**1st round**	**2nd round**	**3rd round**
Integration	No majority found	***Very strong importance (86%)***	***Very strong importance (83%)***
Security	No majority found	***Very strong importance (71%)***	***Very strong importance (100%)***
Mobility	***Moderate importance (55%)***	***Strong importance (57%)***	***Moderate importance (67%)***

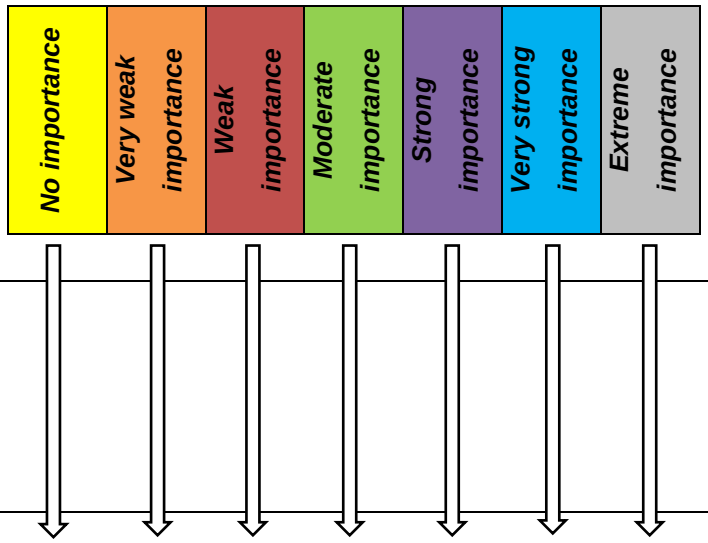
As shown in Table 25 it can be seen that group majority judgment was reached in both the 2nd and the 3rd rounds regarding the ’integration’ and ‘security’ criterion. Both this criteria present stable selected group majorities, going from the 2nd to the 3rd round , while slightly increasing the percentage of selection by the participants. In the case of the ‘security’ criterion the referred increase leads to a group consensus (100% of the participants selected that main concern). In the particular case of ’mobility’, the selected group majority judgments sifted between a moderate importance judgment, in the 1st and 3rd rounds, and a strong importance judgment in the 2nd round.

3. Overview of the clustered results of the Web-Delphi for weighting criteria

Table 26 summarizes the results of the group majority judgments, in the 3rd round treated until this point.
With respect the functional criteria panel, the General criterion didn’t reach a group majority judgment. Still regarding the functional criteria panel, in four criteria (‘storage’, ’display’, ‘alert’ and ‘distribute’) the selected group majority judgment was a judgment of strong importance and for another two criteria (’capture’ and ‘assess’) it was a judgment of very strong importance.
Considering the technical criteria panel, ’security’ reached group consensus judgment. Two (’integration’ and ’security’) out of the three panel criteria achieved a very strong importance group majority judgment, while the other criterion remaining (’mobility’) achieved a moderate group majority judgment.

Table 26. Clustered results per panel (web-Delphi for weighting criteria).

Web-Delphi for value functions



Web-Delphi panel	Total number of criteria								No group majority main concern	Group consensus reach
Functional criteria	7	-	-	-	-	-	4	2	1	-
Technical criteria	3	-	-	-	1	-	2	-	-	1

5. Discussion

The results and subsequent analysis of both web-Delphi participatory processes developed in the scope of this dissertation, to collect the judgments of a panel of participants constituted by future users of an EMS solution (data integration platform) and experts, will be discussed under two views: i) contributions to Galp's decision problem and ii) contributions to the literature.

i) Contributions to Galp's decision problem

This study contributed to aid the solving of Galp's decision problem through the employment of two web-Delphi participatory processes designed to collect the judgments of a panel of participants. The results of these processes are meant to feed in the construction process of the evaluation model to select de EMS solution by a designated strategic group, in charge of making decisions based on the completion of the group judgments. Key components to a Delphi process, including anonymity, interaction, controlled acquisition of feedback and analytic aggregation of responses, were followed. Some aspects regarding the unwinding of both the implemented Delphi processes deserve special attention as follows.

Delphi in web-based environment

Resorting to a web friendly environment for the development of the Delphi questionnaires through Welphi proved to have very positive outcomes. The management of responses and nonresponses is a critical aspect in all Delphi studies [43]. The facilitation team is responsible for the administration of the Delphi process's playing a fundamental role in its success. The use of the Welphi platform to deliver the questionnaires and to follow-up on the processes increased the efficiency of the process and Delphi procedures, easing data entry, responses and analysis. It simplified the process of gathering information from the panel, and enhanced the controlled opinion feedback and communication across rounds. The Welphi platform allowed monitoring the participation, which was important to reduce drop-out. Welphi proved to be an extremely good tool in this process being very intuitive to use and user-friendly both from the participants' and from the facilitator's perspective. Regardless some aspects can be appointed for future consideration when upgrading the platform. To ease even more the task of data entry, the platform should allow the upload of excel files containing all the data instead of requiring single manual data entry as was the case in this study. Yet another feature that Welphi would benefit from would be a system of organizing folders for the facilitators to organize themselves better in this process which is not available at the time being.

Delphi in a corporate environment

Corporate utilization of Delphi is perhaps one of the least-known aspects of the technique's application. This is a result of corporations regarding the products of their Delphi exercises as proprietary and, hence, restricting their distribution or description in professional literature. A review of the long-term planning and futurist literature has revealed that few of the corporate efforts in this field have been documented in any

detail making it hard to examine this variable's contribution to the attained outcomes of both Delphi processes [44].

Balancing the validity of the Delphi processes' resulting outcomes

Validity refers to the confidence placed in cause effect relationship [26]. In this context validity of resulting outcomes of the Delphi processes developed in this dissertation is placed in the attained results for measuring the value system of the actors regarding the appraisal of an EMS solution.

The structuring components of the multicriteria evaluation model, which would be the object of study of both Delphi processes, suffered adjustments and refinements to accurately accomplished. This was done with the goal of increasing the validity and acceptance of the Delphi's results which would feed in the model's construction process, consequently increasing the model's validity and acceptance. However some unexpected outcomes regarding both the implemented Delphi processes contributed against the effort aimed at increasing the validity of the results, namely the verified dropout/response rates and response bias as addressed next.

Iteration being the most distinctive characteristic of the Delphi technic requires the continuous participation of a stable group of participants to provide their opinions in sequential rounds, with each round presenting group feedback from the previous [31]. For this reason, the panelists who did not respond to the 1st round were not invited to take part of further rounds. This allowed the participants' responses to be continuously assessed and integrated into the group feedback from the 1st to the last round. The "retention" and commitment of participants through the consecutive rounds are key for the success of a Delphi. Yet, these processes could be much time consuming and require much effort from the participants. The literature shows that there are many reasons for abandoning a Delphi process: lack of time; strong deviation between individual and group opinion; uncertainty or perception of incompetency to answer to the topic, etc [45].

Care was taken as an attempt to mitigate the time consuming factor and the effort required on the participants' behalf to maximize the panel's the response rates in the Delphi processes, exploring the technicalities of Delphi. The use of simple and clear questioning procedures combined with a friendly web-platform, Welphi, to collect the participants' judgments was the first effort aiming at high adherence from the panel. By avoiding the need for having a consensus in the Delphi processes – through the use of a strategic group to make final decisions regarding the collection of judgments to aid the model's construction -, there was no need to force experts to have middle-of-the round opinions (avoiding what the literature describes as conformity pressure) [35]. The level of agreement was used rather than consensus concept because it is less strict and easily interpretable, being consensus therefore a special case of agreement (perfect agreement) [46]. Group agreement was quantified by percentage and defined as being of majority considering a level of 51% of agreement as clear evidence of a majority opinion. Both Delphi processes were carried out in three rounds in view of achieving reliable results. Literature states that the number of rounds in a Delphi process is variable but it rarely goes beyond one or two iterations

(two or three rounds) [35]. It may be arguable that the number of iterations could have been reduced from two to one avoiding the feeling of fatigue among experts, as group majorities for the criteria with few exceptions were achieved in the 2nd round of the processes. Regardless the employment of two interactions was justifiable in both Delphi processes. On the one hand, the Delphi for value functions, in which it was actually verified a group majority for all criteria in the first interaction, falls into the conceptualization of an enchained Delphi with two sub-processes rather that a single process associated with it (the 2nd round of the first sub-process was simultaneously the 1st round of the second sub-process). The 1st round judgments enabled for the settlement of participants' main concerns with which they were presented in the 2nd round along with the panels aggregated response sorted by each of the seven main concerns assessed. Participants were given the opportunity to either keep the pre-selected main concern selected based on their judgments from the 1st round or to select one of the other main concerns set that would best fit their judgments. Hence a 3rd round was justifiable in order to assess the stability of the results. Furthermore on the other hand, the Delphi for weighting criteria although falling into the concept of a simple modified Delphi did not produce the most reliable results at the end of the 2nd round since the presence of majorities was not detected for all the criteria. Thus the employment of a 3rd round was justifiable in order to try and achieve this, attaining reliable outcomes for all the criteria. The employment of three rounds in each process is also justifiable given the fact that for both processes stability of the answers wouldn't be appraised otherwise. In addition to all this an effort was also put in the way the results of the enchained Delphi were presented to the participants from the first sub-process to the second sub-process to ease participants' perception of these. The provision of the results through different forms was considered going from color schemes resembling classical temperature scales, emotion icons expressing their views or even the value function shape which could be assessed from the provided judgments. In the end sentences describing participants main concerns based on their judgments was found to be the most complete and simple option to present to the participants. In a final effort to increase response rates, during the whole participatory process six reminders (two per round) were sent to participants who did not complete the questionnaire in the previously specified time allotted and deadlines were extended in some cases. This measure reduced the occurrence of high drop-out rates. As can be seen in section 4 round-to-round response increased decreased as the Delphi processes progressed, with the sole exception of the Delphi for weighting the technical evaluation criteria which experienced a decrease in the response rates from the 1st to the 2nd round. Although no specific guidelines can be found in the literature for an acceptable response rate a number of authors recommend a 70% rate as necessary for each round to maintain rigor [47]. Considering both the implemented Delphi processes response rates ranged within the interval of 51% to 100%. Thus although not necessary high the verified dropout rates through rounds were found significant enough to detect the existence of issues along the accomplishment of the Delphi processes. Hereinafter are addressed the reasons, mainly focused in the social component of Delphi, that might have been the root of the verified significant dropout rates.

Firstly, the approach taken to brief the panel members explaining the processes and how these would be conducted through the disclosure of an internal e-mail by the responsible member of the strategic group at

Galp might not have been the most effective. Literature suggests that the realization of a face-to-face meeting with the panel members is critical to explain and discuss the whole process. This approach would allow for clarifying the value of the project, to the company and to the panel members as most of them are future users of the platform, and explaining the way the process would be conducted. It would enable an iterative process of sharing the panelist's doubts through a questioning session with the facilitating team and the accomplishment of a pilot test of how to interact with Welphi showing the participants how easy, simple, intuitive and not at all time consuming it would be to engage in the web-questionnaire. Secondly, it wasn't until the implementation and start of the 1st round of the first Delphi process for value functions that the time allocation of the processes was found to be inappropriate. Many of the panel members had vacations scheduled to that period in time and were thus unavailable to engage in the processes. Upon this realization previously established dead lines were extended regarding all three rounds of the already ongoing Delphi process, having the 3rd round of this processes remain active for a considerable amount of time, contrary to what was planned. This was done in an effort to get as many participants to engage in the last round allowing for their judgments to be considered, provided their continuous engagement in the process until this point, by giving them time to return from their vacations period. As a consequence of the significant time extension employed in the 3rd round of the Delphi for value functions, the remaining Delphi process for weighting criteria, started at the end of the Delphi process for value functions as predicted, experienced an increase in the response rates as participants in the processes were no longer in their vacation period in their majority. Again and time extensions regarding the duration of the three rounds were also employed in an effort to increase response rates. Finally, the literature suggests that the nature of the panel of participants is of paramount importance. Feedback from some of the members that were not engaging in the process reported that they found themselves to be uncertain about their competency to answer to the topic and thus opted to no engage in the processes making this a determinant factor in some of the obtained dropout rates.

Directly linked to the significant verified dropout rates is the effect of non-response bias. The effect of non-response bias recognizes that if the systematic dropout of a certain sub-group of participants occurs, it compromises the quality of the results and the representativeness of all points of view. However, this only contributed further for the already existent risk of response bias effect linked to the Delphi panel composition, since it fail to include a homogenous distribution of members through the areas from which they were allocated in or outside the company. Practically speaking the involvement of members of a heterogeneous panel in a homogenous way is directly dependent of the resources available, in this case human resources. In the case in which these Delphi processes are inserted, the strategic group indicated those who should make up the panel based on their interest of achieving the study purpose based on human resources availability. This led to a potential impact on the areas representativeness, since not all the areas were represented in equal percentages in the panel. The presence of different sources of panel members could've potentiate further differentiation in the analysis and the quality of the results, leading to the verification of differences in opinion varied as a function of these characteristics. The multivariate analysis of variance could've revealed or not perceptions about the relevance of each criterion varying as

a function of the type of panelist. However this analysis was not carried out given the fact that both the addressed bias effects led to having areas with no representation by panel members at all at the end of the processes (3rd round) or of little significance representation (often 1 member).

Regardless of all the discussed above, on the one hand validity of the resulting outcomes of both implemented Delphi processes was attained considering the value system of the participants involved in a general way, even if it indisputably it could've been higher (provided a higher response rates). On the other hand, the assessment of the validity concerning the value systems of the participants through the district working areas of the company is not possible manly due to bias in the process as explained above leading to low representativeness of the different working areas in the results (also not assured at the start of the processes as addressed above). Having said this, the assessed validity is expected to contribute to a high general acceptability of the EMS solution in the company, when implemented.

ii) Contributions to the literature

This study contributes to the literature by exploring the use of Delphi in corporate environments to assess the value system of the actors in a top bottom approach to inform a decision conferencing process in the context of developing a multicriteria evaluation model to solve a decision problem at Galp. This study adds to the literature namely by: 1) from the practical viewpoint, promoting a level of agreement among a range of participants from different areas of knowledge on which criteria are most relevant for appraising an EMS solution in a corporate environment. 2) from a methodological perspective, by employing participatory Delphi processes and applying statistical analysis of responses that can be used in the multicriteria evaluation model's construction to evaluate potential EMS solutions. 3) and from the technology side, by presenting an innovative web-platform that enables the use of participatory processes and its monitoring.

6. Conclusions and future work

The presented work was framed in the scope industrial processes integration in the Portuguese oil & gas company, Galp. The activity in Galp goes through a transformational era that requires actions with structural impact in the Information Systems (IT) infrastructure and in the way they support the respective business processes. Currently business processes at Galp with regard to the oil management are handled in an inefficient way regarding data and information sharing. In this context, Galp intends to implement an integration platform aiming at higher integration, flexibility, coordination and efficiency, easing the access to information so as to support better decision making and improve the capacity to respond to market moves.

This dissertation fulfilled its initially proposed objective by generally assessing the value system of an enlarged group of actors regarding the appraisal of an EMS solution to be implemented at Galp. Normally this type of corporate decisions intake a more centralized approach where only the value systems of e.g. head board members are taken into consideration. Thus this is a most valuable study emphasizing the potential of developing Delphi processes in corporate environments in the context of decision making.

Concerning the work developed for this dissertation in a primary instance, the scope of the project was assessed. A literature review was presented with the purpose of framing the project in a theoretically context and to configure an approach for the decision problem at hand, referring enterprise management systems' selection criteria reported in previously documented case studies, multi-criteria decision analysis systems where the MACBETH approach was highlighted and the additive aggregation model was introduced and finally were addressed participatory methods giving special emphasis to Delphi.

After, in the scope of the employed partnership between Galp and IST the structuring phase of the multicriteria evaluation model building was addressed. Recalling this phase had already started prior to IST's engagement in the project for the selection of the EMS solution and screening of the tending options was already finalized. Next was due the settlement of the evaluation criteria through adjustment and refining actions having the screening criteria as a base. The correction of some of the structuring components was also in place in order to increase the validity and acceptance of the Delphi processes in which these would be the object of study, and consequently increase the final evaluation multicriteria model's validity and acceptance, still to be constructed.

Having concluded the structuring phase of the model building were started the participatory Delphi processes aiming at the collection of judgments from and enlarged group of participants in order to posteriorly feed in the decision conferencing sessions in which the model was to be constructed. Two web-Delphi processes were implemented with regard to value functions and weighting criteria respectively. The Delphi for value functions objective was to collect qualitative pairwise comparison judgments between performance scale levels on each one of the multiple pre-defined evaluation criteria whereas the objective of the Delphi for weighting criteria was also to collect judgments but this time with respect to the importance of swinging between good and neutral performance levels on the criteria, departing from neutral levels in all the criteria. To our knowledge the outcomes of these processes were

used as expected to construct the model in the previously way outlined (Having the strategic group make final decisions regarding the provided compilation of judgments from the Delphi processes which enabled the model's building resorting to the M-MACBETH software assessing criteria's value functions and weights in the framework of the additive aggregation model).

Next were presented the selected results and corresponding analysis according to the company's information needs. The outcomes of both Delphi processes were then discussed in two strands: Galp's decision problem and literature contributions. Regarding contributes for the project, Delphi results proven to be very useful in the model's construction and a valuable asset to the strategic group when the time came to build the model. The benefits of using a web-based environment to conduct the processes were emphasized. The most distinct variant of these processes being the corporate environment in which they were inserted did not suffer much discussion as literature to base this discussion on is vary scare due to the proprietary nature of the Delphi processes outcomes developed in these environments which makes them little or not at all published. The balance of the outcomes was done in which the response rates on the participants' behalf could've been higher and the response bias could've been eliminated contributing to a higher validity of the processes outcomes and a richer analysis of these through the participants allocation areas. Regardless were presented the ensured and implemented measures adopted in an effort to prevent the occurrence of these outcomes, and reasons that might have been the roots to these were also discussed. Contributions to the literature were addressed in the scope of the practical view, the methodological perspective and finally from the technological side.

Ultimately this study provides a comprehensive and sound analysis of the application of Delphi processes to inform the construction of a multicriteria evaluation model for the selection of and EMS solution, data integration platform, to be implemented in an oil & gas company. Furthermore, this study highlighted the usefulness of relevant use of future users of the platform and experts involvement, showing their existent view points and perceptions. The findings can inform future research on Delphi processes developed in corporate environments.

Future research should be enhance regarding the panel of participants since participatory processes' inclusion in decision-making studies is increasing, namely to inform the dimension and composition of Delphi panels according to the topic and objective, in order to assure the representativeness of their values and goals enabling the enrichment of possible analysis cutting off the effect of response bias of any nature. Also several "blind spots" remain regarding Delphi's implementation in corporate environment which require enlightenment in order to implement these in the best possible and adapted way as to increase even further the reliability of the outcomes.

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Annexes

Annex A – Screening criteria set

Figure 17. Screening criteria set.

Annex B – Example of the sequence of invitational e-mails sent through Welphi at the start of each round.

welphi

26th of July 2017

Dear participants,

Galp is currently conducting a project, in collaboration with Management Solutions, which intends to select and implement an integration platform hereafter named [redacted]

In addition to the above mentioned collaboration, a partnership with IST (Instituto Superior Técnico) is also in course. This partnership envisions the employment of a methodology to design a multicriteria decision support model.

This model aims to assess vendors' proposals, aiding the platform selection according to Galp's preferences.

The model design will include two main phases, as follows:

1st Phase - Value functions: Added value of a set of performance levels in their respective category.

2nd Phase - Criteria weights: Collect qualitative judgments on the preferences between the criteria.

Both phases will be implemented through a Web-based Delphi approach with three rounds for each, with the purpose to include Galp group expert's preferences, for which you are invited.

The achieved results for the 1st Round will be presented at the beginning of the 2nd round, giving you the opportunity to maintain or revise your answers for each criterion, considering all the others participants' responses. Afterwards a similar 3rd and final round will take place, with the same approach.

In each round you will have the opportunity to provide optional comments associated with your answers for each criterion (by pressing "Add/Edit comment"). All answers and comments will be treated anonymously.

Please be aware that to get reliable results it is mandatory to reply to the questionnaires on the 3 rounds. Moreover, all questionnaires will be conducted on-line through a web-based solution, outside Galp's network, thus facilitating the access, and it cannot be conducted through Internet Explorer.

Rounds description

1st Round

After logging in, a welcome message with some instructions will show up on your screen and, after pressing "Continue", you will be directed to the questionnaire. Each of the considered criteria will be presented in one individual page.

In each page the criterion performance gaps will be presented requesting to answer the following question: *With regard to this criterion, which do you consider to be the increase in preference between each two levels of performance? You must* choose one of the eight options: "No increase", "Very weak increase", "Weak increase", "Moderate increase", "Strong increase", "Very strong increase", "Extreme increase" or "Don't know/Don't want to answer". When clicking on "SAVE AND NEXT" your answers will be registered and you will be moved to the second criterion, and so on.

2nd and 3rd Rounds

The extracted results of the 1st Round will be presented at the beginning of the 2nd round, allowing you to maintain or revise your answers for each set of questions. At the beginning of the 3rd round, you will again receive information synthesizing the answers of the panel after the 2nd round. Accordingly, you will have the opportunity to maintain or revise your answers.

Agenda

Please note the schedule, which concerns the start, duration and end of the rounds, hereinafter:

1st Phase: Value functions

1st Round: 26th of July – 28th of July

2nd Round: 2nd of August – 3rd of August

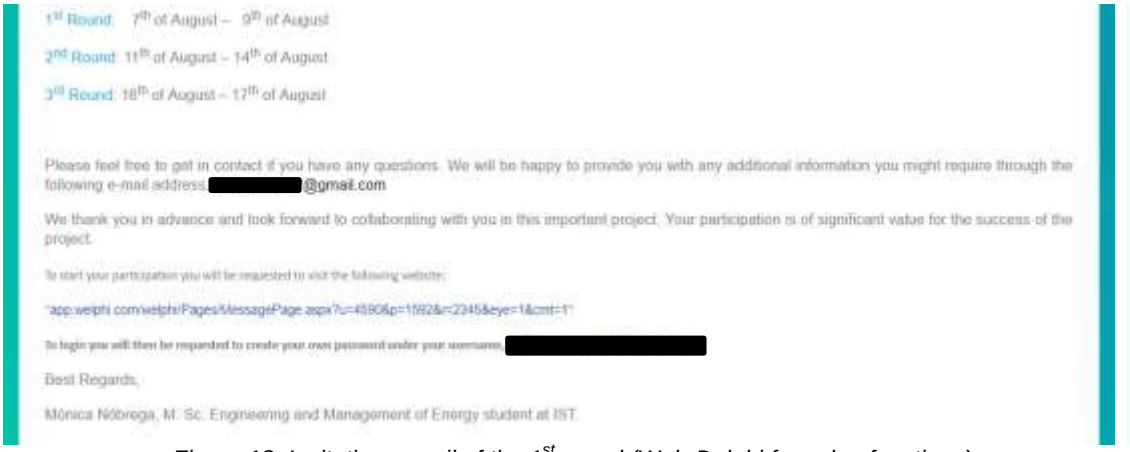
3rd Round: 7th of August – 8th of August

2nd Phase: Criteria weights

1st Round: 7th of August – 9th of August

2nd Round: 11th of August – 14th of August

3rd Round: 16th of August – 17th of August



1st Round: 7th of August – 9th of August

2nd Round: 11th of August – 14th of August

3rd Round: 16th of August – 17th of August

Please feel free to get in contact if you have any questions. We will be happy to provide you with any additional information you might require through the following e-mail address: [redacted]@gmail.com

We thank you in advance and look forward to collaborating with you in this important project. Your participation is of significant value for the success of the project.

To start your participation you will be requested to visit the following website:

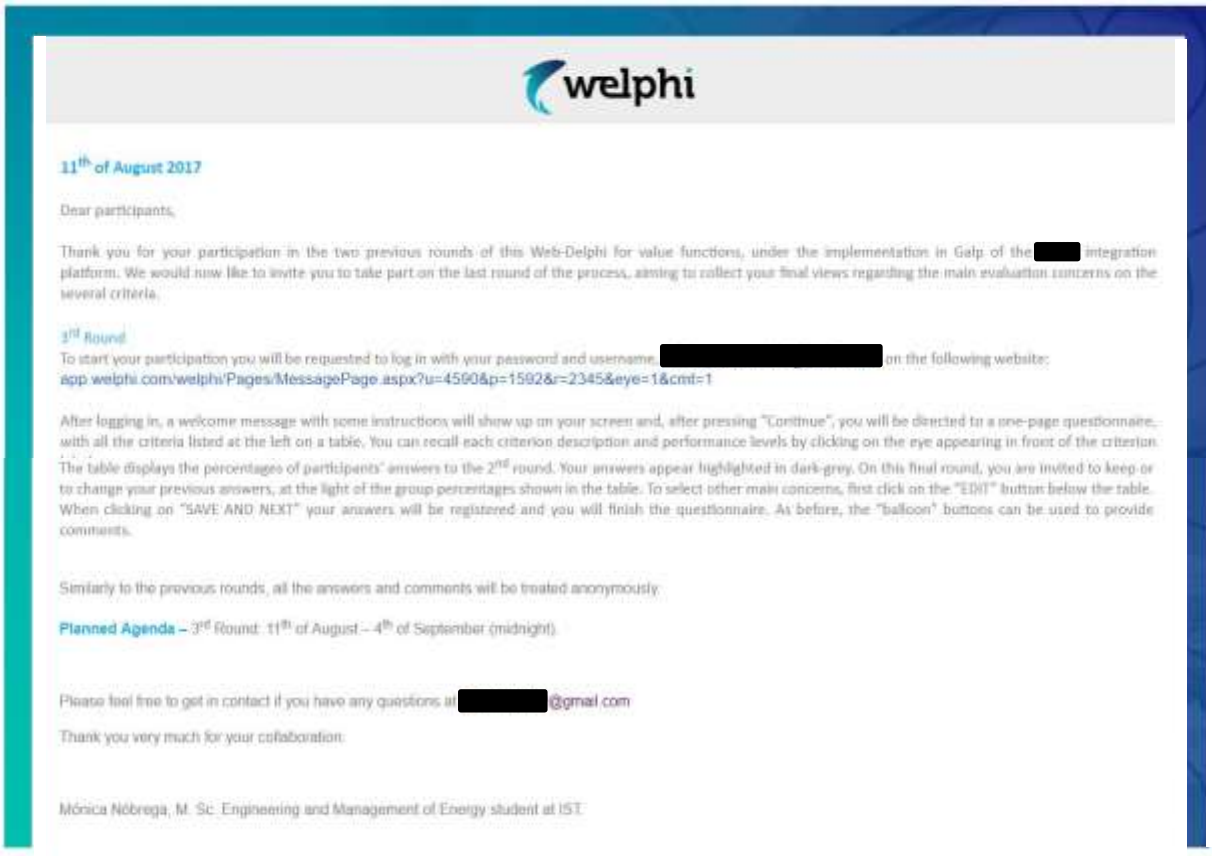
"app.welphi.com/welphi/Pages/MessagePage.aspx?u=4590&p=1592&r=2345&eye=1&cmt=1"

To login you will then be requested to create your own password under your username: [redacted]

Best Regards,

Mónica Nóbrega, M. Sc. Engineering and Management of Energy student at IST

Figure 18. Invitation e-mail of the 1st round (Web-Delphi for value functions)



welphi

11th of August 2017

Dear participants,

Thank you for your participation in the two previous rounds of this Web-Delphi for value functions, under the implementation in Galp of the [redacted] integration platform. We would now like to invite you to take part on the last round of the process, aiming to collect your final views regarding the main evaluation concerns on the several criteria.

3rd Round

To start your participation you will be requested to log in with your password and username: [redacted] on the following website:
app.welphi.com/welphi/Pages/MessagePage.aspx?u=4590&p=1592&r=2345&eye=1&cmt=1

After logging in, a welcome message with some instructions will show up on your screen and, after pressing "Continue", you will be directed to a one-page questionnaire, with all the criteria listed at the left on a table. You can recall each criterion description and performance levels by clicking on the eye appearing in front of the criterion.
The table displays the percentages of participants' answers to the 2nd round. Your answers appear highlighted in dark-grey. On this final round, you are invited to keep or to change your previous answers, at the light of the group percentages shown in the table. To select other main concerns, first click on the "EDIT" button below the table. When clicking on "SAVE AND NEXT" your answers will be registered and you will finish the questionnaire. As before, the "balloon" buttons can be used to provide comments.

Similarly to the previous rounds, all the answers and comments will be treated anonymously.

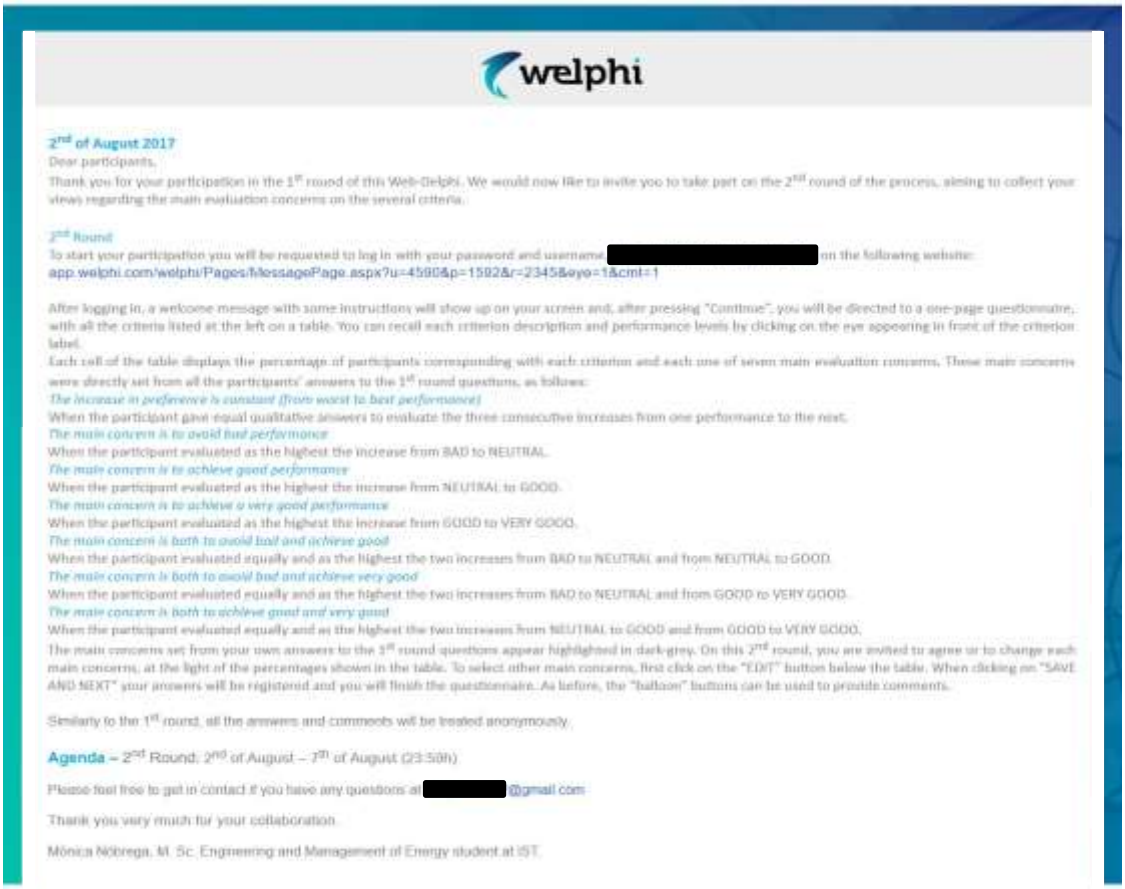
Planned Agenda – 3rd Round: 11th of August – 4th of September (midnight).

Please feel free to get in contact if you have any questions at [redacted]@gmail.com

Thank you very much for your collaboration.

Mónica Nóbrega, M. Sc. Engineering and Management of Energy student at IST

Figure 19. Invitation e-mail of the 3rd round (Web-Delphi for value functions)



welphi

2nd of August 2017

Dear participants,

Thank you for your participation in the 1st round of this Web-Delphi. We would now like to invite you to take part on the 2nd round of the process, aiming to collect your views regarding the main evaluation concerns on the several criteria.

2nd Round

To start your participation you will be requested to log in with your password and username [redacted] on the following website:
app.welphi.com/welphi/Pages/MessagePage.aspx?u=4590&p=1592&r=2345&eyo=1&cmt=1

After logging in, a welcome message with some instructions will show up on your screen and, after pressing "Continue", you will be directed to a one-page questionnaire, with all the criteria listed at the left on a table. You can recall each criterion description and performance levels by clicking on the eye appearing in front of the criterion label.

Each cell of the table displays the percentage of participants corresponding with each criterion and each one of seven main evaluation concerns. These main concerns were directly set from all the participants' answers to the 1st round questions, as follows:

The increase in preference is constant (from worst to best performance)
When the participant gave equal qualitative answers to evaluate the three consecutive increases from one performance to the next.
The main concern is to avoid bad performance
When the participant evaluated as the highest the increase from BAD to NEUTRAL.
The main concern is to achieve good performance
When the participant evaluated as the highest the increase from NEUTRAL to GOOD.
The main concern is to achieve a very good performance
When the participant evaluated as the highest the increase from GOOD to VERY GOOD.
The main concern is both to avoid bad and achieve good
When the participant evaluated equally and as the highest the two increases from BAD to NEUTRAL and from NEUTRAL to GOOD.
The main concern is both to avoid bad and achieve very good
When the participant evaluated equally and as the highest the two increases from BAD to NEUTRAL and from GOOD to VERY GOOD.
The main concern is both to achieve good and very good
When the participant evaluated equally and as the highest the two increases from NEUTRAL to GOOD and from GOOD to VERY GOOD.

The main concerns set from your own answers to the 1st round questions appear highlighted in dark-grey. On this 2nd round, you are invited to agree or to change each main concerns, at the light of the percentages shown in the table. To select other main concerns, first click on the "EDIT" button below the table. When clicking on "SAVE AND NEXT" your answers will be registered and you will finish the questionnaire. As before, the "balloon" buttons can be used to provide comments.

Similarly to the 1st round, all the answers and comments will be treated anonymously.

Agenda – 2nd Round: 2nd of August – 7th of August (23:59h)

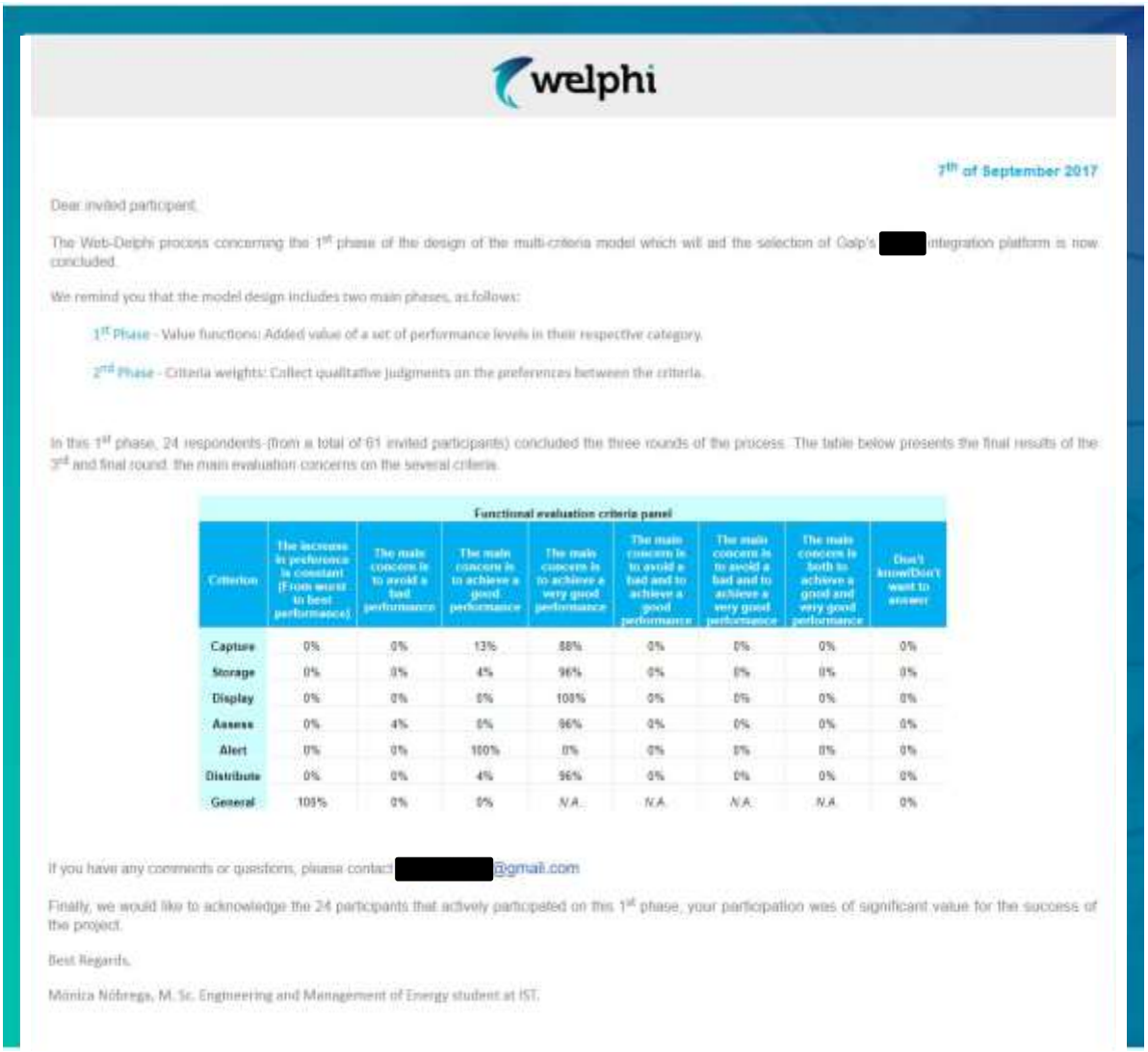
Please feel free to get in contact if you have any questions at [redacted]@gmail.com

Thank you very much for your collaboration.

Mónica Nóbrega, M. Sc. Engineering and Management of Energy student at IST.

Figure 20. Invitation e-mail of the 2nd round (Web-Delphi for value functions)

Annex C – Final report sent by e-mail sent through Welphi for closing the Delphi process



welphi

7th of September 2017

Dear invited participant,

The Web-Delphi process concerning the 1st phase of the design of the multi-criteria model which will aid the selection of Galp's [redacted] integration platform is now concluded.

We remind you that the model design includes two main phases, as follows:

1st Phase - Value functions: Added value of a set of performance levels in their respective category.

2nd Phase - Criteria weights: Collect qualitative judgments on the preferences between the criteria.

In this 1st phase, 24 respondents (from a total of 61 invited participants) concluded the three rounds of the process. The table below presents the final results of the 3rd and final round, the main evaluation concerns on the several criteria.

Functional evaluation criteria panel

Criterion	The increase in performance is constant (From worst to best performance)	The main concern is to avoid a bad performance	The main concern is to achieve a good performance	The main concern is to achieve a very good performance	The main concern is to avoid a bad and to achieve a good performance	The main concern is to avoid a bad and to achieve a very good performance	The main concern is both to achieve a good and very good performance	Don't know/Don't want to answer
Capture	0%	0%	13%	88%	0%	0%	0%	0%
Storage	0%	0%	4%	96%	0%	0%	0%	0%
Display	0%	0%	0%	100%	0%	0%	0%	0%
Assess	0%	4%	0%	96%	0%	0%	0%	0%
Alert	0%	0%	100%	0%	0%	0%	0%	0%
Distribute	0%	0%	4%	96%	0%	0%	0%	0%
General	100%	0%	0%	N.A.	N.A.	N.A.	N.A.	0%

If you have any comments or questions, please contact [redacted]@gmail.com

Finally, we would like to acknowledge the 24 participants that actively participated on this 1st phase, your participation was of significant value for the success of the project.

Best Regards,

Mónica Nóbrega, M. Sc. Engineering and Management of Energy student at IST.

Figure 21. Final report (Web-Delphi for value functions, Functional evaluation panel)

Annex D – E-mail ‘reminder’ sent through Welphi

welphi

Dear participant,

A few participants did not complete the questionnaire of the **first round of the Web-Delphi for Value Functions**, under the MPDP (Market/Production Data Platform) integration platform project.
We would like to inform you that the duration of this first round has been exceptionally extended and invite you to participate until Monday, the 31th of July 2017 (13:00), when the first round of the Web-Delphi for Value Functions will be definitely closed.

Your participation is paramount to the success of the project and very much appreciated.

Please log in the following link:

app.welphi.com/welphi/Pages/MessagePage.aspx?u=4590&p=1592&r=2345&eye=1&cmt=1

With the following information:

Username: nobregaccmonica@gmail.com
Password: Password

In case you have any doubts or questions, please contact: WelphiMPDP@gmail.com

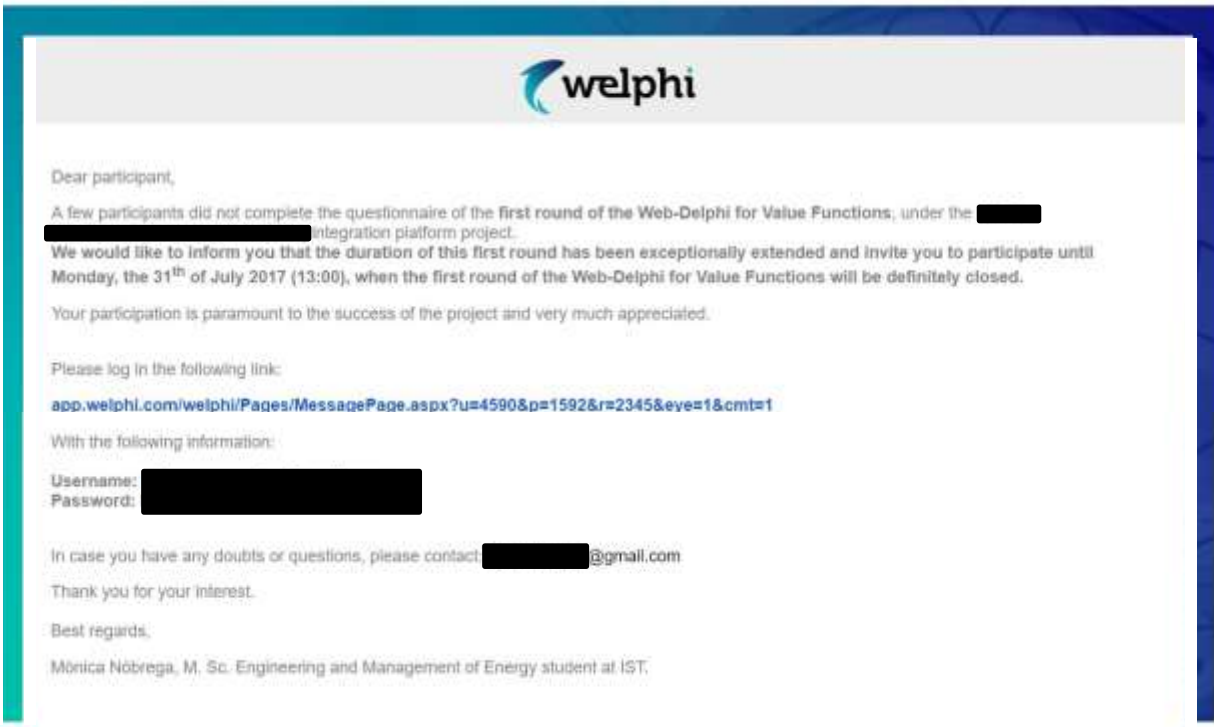
Thank you for your interest.

Best regards,

Mónica Nóbrega, M. Sc. Engineering and Management of Energy student at IST.

Figure 22. E-mail ‘reminder’ (Web-Delphi for value functions)

Annex E - E-mail 'last reminder' sent through Welphi



welphi

Dear participant,

A few participants did not complete the questionnaire of the **first round of the Web-Delphi for Value Functions**, under the [redacted] integration platform project.

We would like to inform you that the duration of this first round has been exceptionally extended and invite you to participate until Monday, the 31th of July 2017 (13:00), when the first round of the Web-Delphi for Value Functions will be definitely closed.

Your participation is paramount to the success of the project and very much appreciated.

Please log in the following link:

app.welphi.com/welphi/Pages/MessagePage.aspx?u=4590&p=1592&r=2345&eve=1&cmt=1

With the following information:

Username: [redacted]
Password:

In case you have any doubts or questions, please contact [redacted]@gmail.com

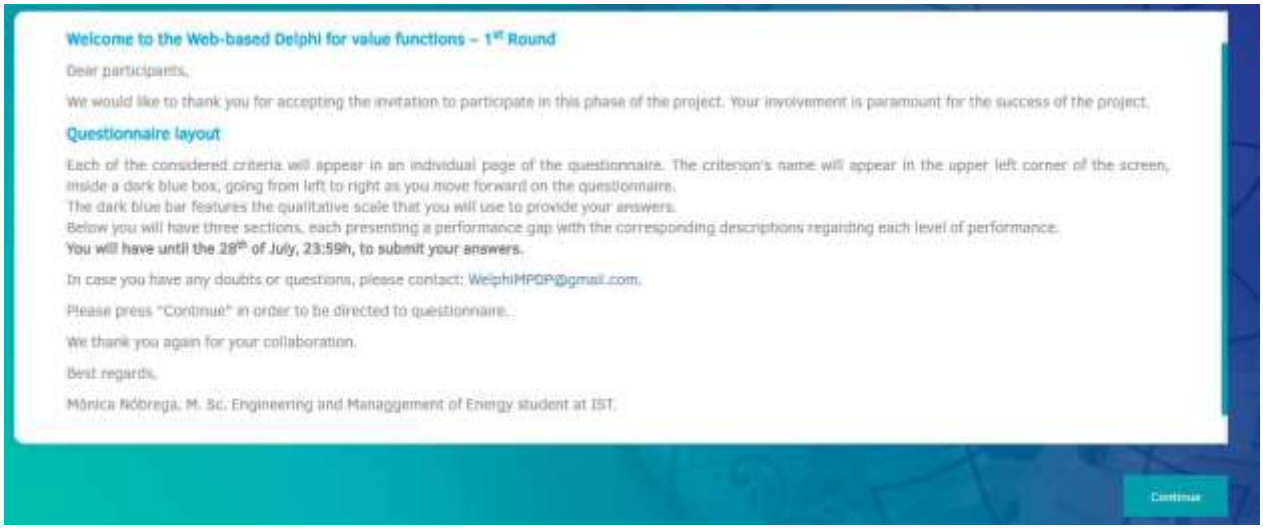
Thank you for your interest.

Best regards,

Mónica Nóbrega, M. Sc. Engineering and Management of Energy student at IST.

Figure 23. *E-mail ' last reminder' (Web-Delphi for value functions)*

Annex F – Welcome message displayed at the beginning of each Delphi round



Welcome to the Web-based Delphi for value functions – 1st Round

Dear participants,

We would like to thank you for accepting the invitation to participate in this phase of the project. Your involvement is paramount for the success of the project.

Questionnaire layout

Each of the considered criteria will appear in an individual page of the questionnaire. The criterion's name will appear in the upper left corner of the screen, inside a dark blue box, going from left to right as you move forward on the questionnaire.
The dark blue bar features the qualitative scale that you will use to provide your answers.
Below you will have three sections, each presenting a performance gap with the corresponding descriptions regarding each level of performance.
You will have until the 28th of July, 23:59h, to submit your answers.

In case you have any doubts or questions, please contact: WelphiMPDP@gmail.com.

Please press "Continue" in order to be directed to questionnaire.

We thank you again for your collaboration.

Best regards,

Mónica Nóbrega, M. Sc. Engineering and Management of Energy student at IST.

Continue

Figure 24. Welcome message (Web-Delphi for value functions)