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► **To cite this version:**

Elena Kornyshova, Rebecca Deneckere. Decision-Making Method Family MADISE: Validation within the Requirements Engineering Domain. Research Challenges in information Science (RCIS), 2012, Valencia, Spain. pp.120. hal-00704111

HAL Id: hal-00704111

<https://hal.science/hal-00704111>

Submitted on 4 Jun 2012

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Decision-Making Method Family MADISE: Validation within the Requirements Engineering Domain

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Abstract— Information Systems (IS) engineering (ISE) processes contain steps where decisions must be made. Moreover, the growing role of IS involves requirements for their engineering, such as quality, cost, time, and so on. On the one hand, considering these aspects implies that the number of researches dealing with decision-making (DM) in ISE increasingly grows. On the other hand, many DM methods exist and are applied in several fields of ISE. The main characteristic of these applications is that they resolve one DM problem at a time. We have developed a generic DM approach MADISE, which aims at guiding IS engineers through DM activities. The goal of this paper is to check the completeness and flexibility of MADISE by comparing it with the five well-known requirements prioritization approaches.

Keywords – *Method Family; Decision-making; Information System Engineering*

I. INTRODUCTION

Information system design, development, implementation, and every other process in IS engineering may be considered as a set of steps of two kinds: first, of decision-making (where a decision is made) and, second, of decision performing (when the previous choice is carried out and the result is obtained). We may say that each process contains steps where decisions must be made. Moreover, considering requirements as quality, cost, time, and so on implies that many decisions must be made for optimizing the result [1].

Regarding to DM in ISE three following findings can be made:

1. ISE processes are teleological by their nature [2]. That means they contain steps where decisions must be made. Number of researches dealing with DM in ISE increasingly grows (for instance, the multicriteria DM methods spread throughout Computer Science [3]).
2. Many DM methods exist. These methods have different nature and are more or less efficient in function of the situation in which they are applied.
3. There are many works in the ISE research dealing with DM (aiming at resolving DM problems). The main characteristic of these works is that they resolve

a DM problem each time. This finding concerns isolated and selective cases of DM methods application in ISE.

The lack of decision-making in IS engineering could be considered at three levels: (i) at the model level (decisions are not formalized in terms of alternatives and criteria, their consequences are not analyzed, decisions are not transparent), (ii) at the method level (intuitive and ad hoc decisions overshadow method-based ones), (iii) at the tool level (even if DM tools exist there is none with a complete DM process).

We have developed the MADISE (MAke Decisions in Information Systems Engineering) approach to deal with the two first kinds of difficulties. The goal of the MADISE approach is to guide IS engineers through DM activities.

The MADISE approach includes three elements: DM ontology, MADISE method family, and DM methodological repository.

- The DM ontology [4] is a representation, shared between researchers and practitioners, of DM concepts, which formalizes DM knowledge.
- The MADISE DM Method Family [5] is a set of DM method components representing main activities used for DM. It is modeled with MAP [6] and can be used each time a IS engineer meets a DM situation in ISE.
- The DM methodological repository provides a set of methodological guidelines for realizing DM activities.

This paper concentrates on the MADISE DM method family. The DM method family differs from other by its generic character, by flexibility of its execution and context-awareness. In this paper, our goal is to check the first two characteristics, that we call completeness and flexibility. For the first one, we analyze essential DM activities and for the second one, we investigate whether a DM process is predefined or adaptable. The two characteristics are organized into a comparison framework.

We compare the MADISE method family with several DM methods of the requirements engineering domain as it is a field of ISE, in which DM is widespread. For this purpose,

we have selected five approaches dealing with requirements prioritization, which are analyzed within the comparison framework.

Firstly, we present DM fundamentals (Section II). Secondly, we describe the DM method family (Section III). Our approach is then compared with the five DM methods of the requirements engineering field (Section IV). We conclude this paper by presenting the possible applications of the DM method family and our future works (Section V).

II. DECISION-MAKING FUNDAMENTALS

In this section, we introduce decision-making fundamentals (concepts and steps). A decision is an act of intellectual effort initiated for satisfying a purpose and allowing a judgment about the potential actions set in order to prescribe a final action. This prescription is based on the study of several aspects characterizing alternative actions. Decisions are made by actors, which can be assisted by DM methods and tools. Actors make decisions in order to satisfy a purpose. The decision concept is also closely related to the decision-making process [7]. In this section, we present the decision structure, the decision actors, and a basic DM process.

A. Decision Structure

Bernard Roy defines three basic concepts that play a fundamental role in analyzing and structuring decisions in close connection with the decision process itself [8]: decision problem, alternatives (potential actions), and criteria.

The decision problem [8] can be characterized by the result expected from a DM. When the result consists in a subset of potential alternatives (most often only one alternative) then it is a choice problem. When the result represents the potential alternative affectation to some predefined clusters, then it is a classification problem. When the result consists in a potential collection of ordered alternatives then it is a ranking problem. When a decision is highlighted only by a description of alternatives and of their impact using an appropriate language, it is a description problem. The last one is rarely used in DM processes.

The concept of alternative designates the decision object. Any decision involves at least two alternatives that must be well identified.

A criterion can be any type of information that enables the evaluation of alternatives and their comparison. There are many different kinds of criteria: intrinsic characteristics of artifacts or processes, stakeholders' opinions, potential consequences of alternatives etc. When dealing with criteria, the engineer must determine "preference rules", i.e. the wishful value of criterion (for example, max. or min. for numeric criterion) according to a given need.

B. Decision-making Actors

The first priority in a DM process is to assign actors. There are three main actors participating in DM activities: stakeholder, IS engineer and DM staff. Each typical actor has several roles in the DM process.

A Stakeholder defines the decision problem, sets goals, expresses preferences on alternatives and criteria [5] and validates the final decision. An IS engineer evaluates alternatives and makes a proposal for decision making to stakeholders. A DM staff is responsible for assisting stakeholders and IS engineers in all stages of the DM process [9]. Our methodological support aims at accomplishing functions of the DM staff.

Actors contribute to the DM process at different stages. It is obvious that the same actor can play different roles in a specific DM process.

C. Decision-making Process

Herbert Simon (1978 Nobel Prize in Economics) was the first to formalize the decision-making process. He suggested a model including three main phases: intelligence, design, and choice (I.D.C. model) [10]. Intelligence deals with investigating an environment for conditions that call for decisions. Design concerns inventing, developing, and analyzing possible decision alternatives. Choice calls for selecting an alternative from possible ones.

This process was modified and extended in different ways. Currently, the commonly agreed and used decision-making steps are defined as follows [9]:

- Define problem (necessity to define priorities),
- Identify problem parameters (for instance, alternatives and criteria),
- Establish evaluation matrix (estimate alternatives according to all criteria),
- Select method for decision making
- Aggregate evaluations (provide a final aggregated evaluation allowing decision).

III. MADISE DECISION-MAKING METHOD FAMILY

We propose the MADISE method family to deal with DM in ISE. MADISE is based on the main DM concepts and steps explained in the preceding section. This process can be used each time the engineer performs his process and meets a DM situation in ISE.

A. MADISE Method Family Definition

The MADISE method family was built based on the following methodology: (i) identification of DM method components and (ii) their further assembly into the DM method family using the MAP formalism.

The spectrum of the DM method used for identifying the DM method components includes Outranking methods, Analytic Hierarchy Process (AHP), Multi-Attribute Utility Theory, and Weighting methods. Then, we have completed them with a set of several additional activities (such as alternatives discovering, criteria definition etc.) in order to cover the complete DM process. The DM method components are identified from these methods (DM and others) by applying the following steps: highlight elementary

activities, group them with respect to several principles, and formalize method components.

The next step is to organize the identified DM method components within the method family. This is done using the assembly-based SME approach [11] using similarity measures. Two types of measures are distinguished: those which allow measuring the similarity of the elements of product models and those which allow to measure the closeness of process models elements. We apply these measures to identify common method components (that is to say similar to each other) and variable one. This methodology allows to have a generic DM process that covers essential DM activities without repeating the same DM steps and to organize these activities into a unique DM “multi-method”.

We use the MAP formalism [6] to model the MADISE process. This formalism allows specifying process models in a flexible way by focusing on the process intentions, and on the various ways to achieve each of these intentions. A map is presented as a graph where nodes are intentions and edges are strategies. The directed nature of the graph shows which intentions should precede which one. An edge enters a node if its associated strategy can be used to achieve the target intention. The selected modeling formalism (MAP) enables to guide users through this DM “multi-method” in a flexible and adaptable manner.

B. MADISE Method Family Description

The MADISE method family modeled with MAP is presented in Fig. 1.

The MADISE Map contains four main intentions: Define Alternatives, Define Criteria, Evaluate Alternatives, and Make Decision. The main element of a map is a section, which is a combination of three elements: <Source intention, Strategy, Target intention>. A section is associated to a guideline, which explains how to reach the target intention from the source one by performing the given strategy. Such a guideline can be (i) a simple description, (ii) a set of actions to execute, (iii) a choice between different actions, or (iv) be refined by another Map [12].

The MAP formalism helps to use the MADISE method family in a flexible manner. At each stage, the Map indicates all possible trajectories to go ahead and gives information about how to choose a trajectory, but does not impose any one. The engineer can select between different intentions or strategies which constitute possible trajectories. The MADISE Map contains a set of guidelines, which allow choosing between intentions and strategies in an exhaustive way. The engineer makes these choices and composes a set of Map sections that are executed consecutively. In this manner, he dynamically constructs a DM method suited to the given situation. For instance, one possible trajectory is to Define alternatives, Define criteria, Evaluate alternatives, Make decision by methods application (for instance multicriteria method AHP [13]). Another one is to Define alternatives and then Make decision directly (by ad hoc or by using arguments strategies) like in [14] [15]. Therefore, the MADISE Map provides the IS engineer with a complete set of guidelines for both trajectory selection and sections execution. By the lack of space, we do not present these guidelines in this paper.

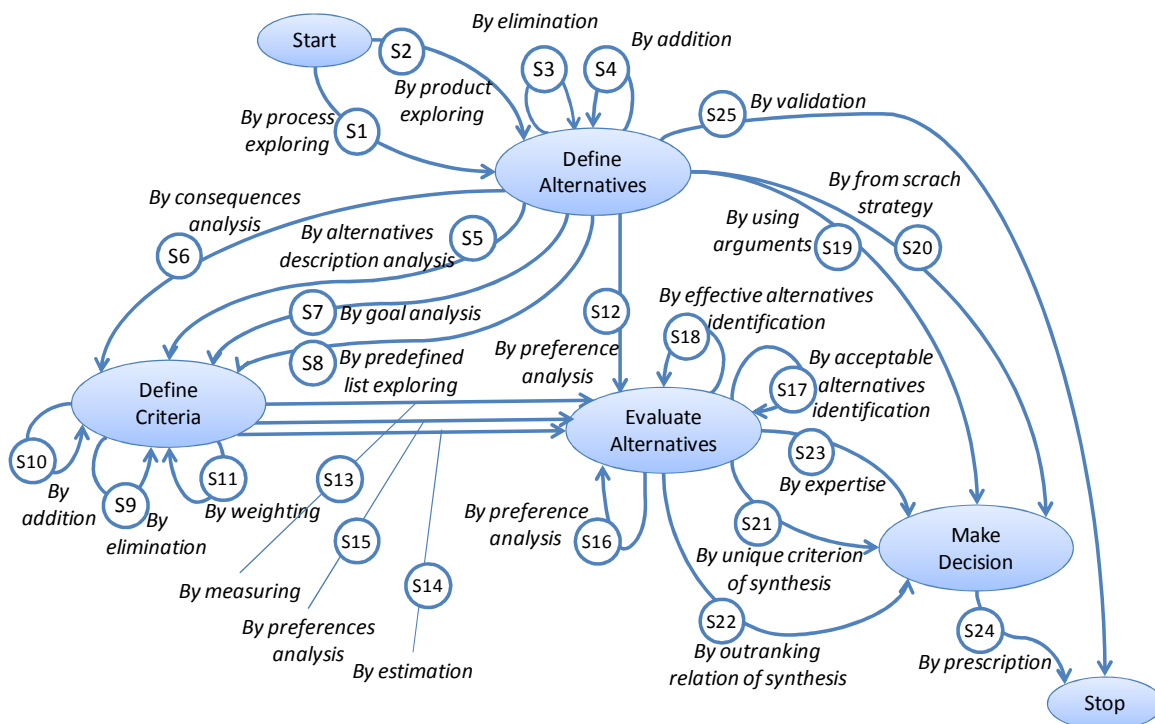


Figure 1. MADISE Map

1) *Define Alternatives*. The engineer starts the MADISE by reaching the *Define Alternatives* intention. At this stage, an alternative set (or alternative family) is generated.

As commonly accepted, IS engineering processes contain two parts: a process part and a product part [16]. The process part of methods captures their behavioral and procedural aspects (stages, tasks, activities, and schedules) [17]. The product part of a method takes into account its structural and static aspects (e.g., requirements documents, models, and other deliverables) [17]. The engineer could explore both process and product variability in order to find possible alternatives. He starts the DM process by choosing one of the following sections S1 and S2: (i) S1 allows to *Define alternatives list By process exploring*; for instance, this section is used in intention-based approaches (based on MAP formalism) in order to select a strategy which is an action, or a process part [18]. (ii) S2 allows to *Define alternatives list By product exploring*; a usual example is the requirements prioritization, in which requirements are the product parts [14] [15] [19] [20].

Alternatives can be complementary or exclusive to each other. Once the initial alternatives list is defined, it can be refined by the two following sections: The *By elimination* strategy is applied in S3 when one or more alternatives forming the initially defined set are evaluated by the engineer as non-realistic or non-feasible [7] [21]. In this case, they are removed from the set and not anymore studied. An example of this section is the requirements review before applying AHP in the cost-value approach of requirements prioritization [14]. The *By addition* strategy (section S4) is available when some alternatives could be added to the initial set by searching complementary alternatives. Such a strategy is used in [11]: the *Refinement* strategy proposes to search for another candidate method component within the assembly-based method engineering approach.

2) *Define Criteria*. The *Define Criteria* intention is not mandatory. The engineer selects it if he wants to arbitrate between alternatives based on multiple factors. At this stage, a set of criteria (at least one criterion) for alternatives evaluation is defined.

From the *Define Alternatives* intention, the intention *Define Criteria* can be achieved following four strategies. The *By alternatives description analysis* strategy (section S5) can be used in the case where alternatives have intrinsic characteristics, which can be considered as criteria. The engineer analyzes them in order to identify those that are important for arbitrating between alternatives. One example is the requirements characterization in [14]. The *By consequences analysis* strategy (section S6) deals with alternatives consequences, which are effects produced by alternatives if they are chosen. Future properties of alternatives and their effects on the decision problem are analyzed in order to identify possible criteria. The *By goal analysis* strategy (section S7) is applicable when an actor participating in the DM process has goals with regard to the decision problem. Each alternative can be measured according to its capability to contribute to these goals. In this case, goals become criteria. Goals as criteria are used in [22] for business processes prioritization and in [23] for

requirements prioritization. *By predefined list exploring* (section S8), engineers investigate the list of the project characteristics which are common in ISE and select the suitable ones.

Once the first set of criteria is selected, it can be refined with other strategies. The *By elimination strategy* (section S9) is used when elaborating the set of criteria, as the decision maker must comply with some rules to be coherent. For instance, in order to eliminate criteria, the IS engineer considers their set using the *SMART* method [24]. Criteria must be specific, measurable, actionable, relevant, and timely. An application of the *SMART* method to business processes is shown in [24]. The *By addition* strategy (section S10) is applied when criteria can complement each other. In this case, a criterion is added following the analysis of existing ones. The *By weighting* strategy (section S11) deals with weights assignment to the decision criteria. Weights are assigned when the engineer wants to define relative importance of criteria. The engineer can select one of the following techniques: (i) by simple attribution [25] [26], (ii) by indentifying the first criterion to enhance [27], (iii) by trade-off technique [27], (iv) by importance analysis [28], or by pair-wise comparison [13]. The last one is commonly used in the requirements prioritization within AHP [14] [23].

3) *Evaluate Alternatives*. The *Evaluate Alternatives* intention aims at constructing the evaluation matrix (or decision matrix) [7] [21]. There are several ways to evaluate alternatives:

From *Define Alternative*, alternatives can be evaluated using the *By preferences analysis* strategy (section S12). An engineer determines preferences between two alternatives a and b . [6] defines four elementary relations: (i) Indifference: $aIb - a$ and b are equivalent; (ii) Strict preference: $aPb - a$ is strictly preferred to b ; (iii) Weak preference: $aQb - a$ is weakly preferred to b ; (iv) Incomparability: $aRb - a$ and b are not comparable. For instance, a strict preference relation is present in AHP method applied for requirements prioritization [14] [23].

From the *Define Criteria* intention, alternatives may be evaluated following three strategies: by measuring, by estimation, and by preferences analysis.

By measuring (section S13). Measuring is an activity that uses a metric definition in order to produce a value [29]. A measure is a number assigned to a characteristic by making a measurement [29]. A measuring method is a logical sequence of operations allowing the alternative estimation. Measuring methods are objective as the evaluation is based on numerical rules [29].

By estimation (section S14). Alternatives could also be evaluated using heuristics. An actor evaluates alternatives according to subjective criteria, for instance based on his opinion. The estimation is subjective as the evaluation involves human judgment [29]. The evaluation method type (objective or subjective) that depends on the nature of the operations used to evaluate an alternative may be found in [30].

By preferences analysis (section S15). An actor determines preferences between two alternatives a and b according to a criterion. For instance, the engineer can compare two requirements according to the cost criterion.

Once the evaluation matrix is constructed, alternatives evaluations can be enhanced by the three following strategies.

The *By effective alternatives identification* strategy (section S18) allows removing dominated alternatives in order to keep “effective” ones. An alternative is *dominated* if its evaluations according to all criteria are worse or at least the same that those of another alternative [21] [31].

The *By acceptable alternatives identification* strategy (section S17) allows to qualify several alternatives as non-acceptable and to remove them from the alternative set. An acceptance threshold is established for a criterion. Such a technique is used in the WinWin method for requirements prioritization [20].

By using the *By preferences analysis* strategy (section S16), the engineer can enhance preferences analysis by defining complementary parameters such as preference threshold, indifference threshold, veto threshold [7] [21]. These parameters are used in outranking decision-making methods, for instance for business processes prioritization in [22].

4) *Make Decision*. At this stage, a prescription for a decision is made.

By using arguments (section S19). In several approaches, decisions are based on an argument set [6] [12] [18]. The decision-maker is guided between alternatives by arguments, which indicate the alternative to select depending on the given parameters.

By “From scratch” strategy (section S20). A decision can be made by a decision-maker ‘on the fly’ without using a DM method. This kind of decision, allowed with the “From scratch” strategy, is specific to each DM situation and highly depends on the decision-maker skills and experience.

The method-based approach deals with the transformation of partial values (alternatives values according to different criteria) into an aggregated one. There are two main aggregation approaches using two different strategies: unique criterion of synthesis and outranking relation of synthesis.

By unique criterion of synthesis (section S21). This approach consists of building a single criterion from a criteria set by using an aggregation function [7]. The aggregation function can be an addition or a multiplication function. The most known one is the method based on weighted sum. Weighting methods include SMART (Simple Multiattribute Technical Rating) [28], SWING [27], and Trade-off weighting [28]. Another MC method from this group is MAUT [32], proposed by H. Raiffa and R.L. Keeney. According to MAUT, a utility function is established for each criterion. Then, the partial utility functions are aggregated to a multiattribute utility function representing either an addition, or a multiplication of the partial functions. All alternatives are evaluated by using this function. The alternative, which maximizes the utility, is selected. These methods are available

for choice, ranking or classification decision problems. This component has a strategic guideline.

By outranking relation of synthesis (section S22). Outranking methods [6] are inspired by the theory of the Social Choice. The most known outranking method is ELECTRE (Elimination And Choice Corresponding to Reality). Outranking indicates the degree of dominance of one alternative over another. Outranking methods are based on step-by-step identification of decision makers' preferences. Decision makers formulate their preferences and then a detailed analysis allows decision-making for one of the base problems (choice, ranking or classification). Outranking methods are used for method components selection [33] and for business process prioritization [22].

By expertise (section S23). Experience may be sufficient to make decision, in particular if the exactly same situation has already been met. Then the *By expertise* strategy (section S24) can be used.

5) *Stop Decision-Making Process*. This stage deals with the validation of DM results.

Once a decision is made, the engineer generates a prescription for decision based on the usage of the DM Map (*By validation*). In this case, the DM process is stopped by validation. Some metrics (for instance, a consistency index in [14]) can be used to checking if the DM result is valid. Otherwise, the DM process continues by returning to the previous stages.

From *Define Alternative*, the DM process may be stopped when the number of identified alternatives is limited, for instance one. The engineer validates or does not the initially obtained alternative set as a decision.

C. MADISE Method Family Usage

The usage of the DM Method Family is characterized by data which are required for starting and finishing the corresponding process. This implies the identification of the Input and Output data.

Two kinds of information are required before beginning the use of the DM Map: the decision object and the decision problem which are Input data, as shown in Figure 2.

```

Input:
  DMObject.name: String
  DMObject.type: ENUM{product,process}
  Problem.type: ENUM{choice,ranking,
                    classification,description}
  
```

Figure 2. Input Data.

The Output data is a decision made according to the identified decision problem. The DM output could also have a NULL value if the decision is not made (for different reasons, such as a lack of information, not valid alternatives etc.). Figure 3 summarizes the Output Data.

Output:

Decision.validity: Boolean
Decision.type: ENUM{selected_alternative,
selected_alternatives, ranked_alternatives,
classified_alternatives,
described_alternatives, NULL}

Figure 3. Output Data.

Two kinds of users could use this approach. The first one is composed of DM method engineers who specify DM method components and organize them within the method family. DM engineers, possessing DM knowledge, represent it into DM method components. They use the DM ontology in order to represent DM knowledge and to specify DM methods as components. DM components are stored in a methodological library that we call the MADISE repository. These components are organized within the MADISE repository according to the intention-oriented MADISE process.

The second group represents IS engineers who need DM assistance. They specify their requirements for decision-making and select one or more DM method components in order to enhance their methodologies or to create a new DM application method. An IS engineer has one of the two following goals: (i) to construct a customized DM method or (ii) to extend an IS engineering method with DM components. In both cases, the process starts by specifying requirements for DM, namely the situation and the intention. For this purpose, the DM ontology is used. Then, the engineer selects one or more DM components adapted to the given situation. If DM components are numerous, they are assembled into a composite one. In this manner, the IS engineer obtains a customized DM method fitting the given DM problem (the first goal is reached). Then, if he wants to extend the IS engineering method (the second goal), he integrates the selected or composed component into the ISE method using of the available SME approaches. Thus, two main cases of the MADISE approach could be identified: improving an existing ISE method or creating a customized DM method.

IV. MADISE VALIDATION THROUGH A COMPARISON FRAMEWORK

This section aims at validating the MADISE process through its comparison with five requirements prioritization techniques: Cost-Value Approach (CVA) [14], Prioritization Matrix (PrMatrix) [15], Requirement Prioritization Tool (RPT) [34], WinWin [20], and REDEPEND [23]. The main goal of this comparison is to check whether the MADISE approach is complete and flexible. We have selected these five techniques as they are well-known, representative, and differ from each other. In this section, we present and motivate our comparison framework and after a brief description of the five above mentioned techniques, we use this framework in order to validate our approach.

A. Cost-Value Approach Expression through MADISE

In this section, our goal is to show that existing DM processes could be expressed through the MADISE DM method family. For doing this, a DM process must be represented as a MADISE application method (i.e. a sub-set of MADISE sections). In order to illustrate this, we have chosen an existing and well known DM process: the cost-value approach for requirements prioritization [14].

The cost-value requirements prioritization approach [14] aims at ranking requirements using the AHP DM method. The AHP (Analytic Hierarchy Process) was proposed by T.L. Saaty [13]. As a shot reminder, this method is based on pair-wise comparison between alternatives and/or criteria and aggregation of comparison results into a quantitative indicator (score).

Figure 4. shows the set of DM method components corresponding to the cost-value approach.

The cost-value approach trajectory through the MADISE Map is as follows. The product based strategy is available for identifying candidate requirements (the *By product exploring* strategy is selected). This approach suggests reviewing candidate requirements for ensuring their completeness and correctness. Therefore, requirements can be added to or removed from the initial set (The *By elimination* and *By addition* strategies are selected). The approach defines two criteria describing requirements: relative cost and relative value. These criteria are predefined by the cost-value approach (The *By predefined list exploring* strategy is selected). Actors (users and engineers) express their preferences by pair-wise comparison for defining the relative value and cost of candidate requirements (The *By preferences analysis* strategy is selected). The aggregated value obtained by AHP application is used for ranking requirement. The cost-value approach uses also a cost-value diagram in order to assist DM (The *By unique criterion of synthesis* strategy is selected). A consistency index is calculated in order to check the result validity (The *By validation* strategy is selected). The DM components used by the cost-value approach are given in Table I.

TABLE I. DM METHOD LINE OF THE COST-VALUE APPROACH: DM COMPONENTS LIST.

| <i>Section</i> | <i>Name</i> |
|----------------|--|
| S2 | Define alternatives list by product exploring |
| S3 | Refine alternative list by elimination |
| S4 | Refine alternative list by addition |
| S8 | Define criteria by predefined list exploring |
| S15 | Evaluate alternatives by preferences analysis according to a criterion |
| S21 | Make decision by unique criterion of synthesis |
| S24 | Prescribe decision |

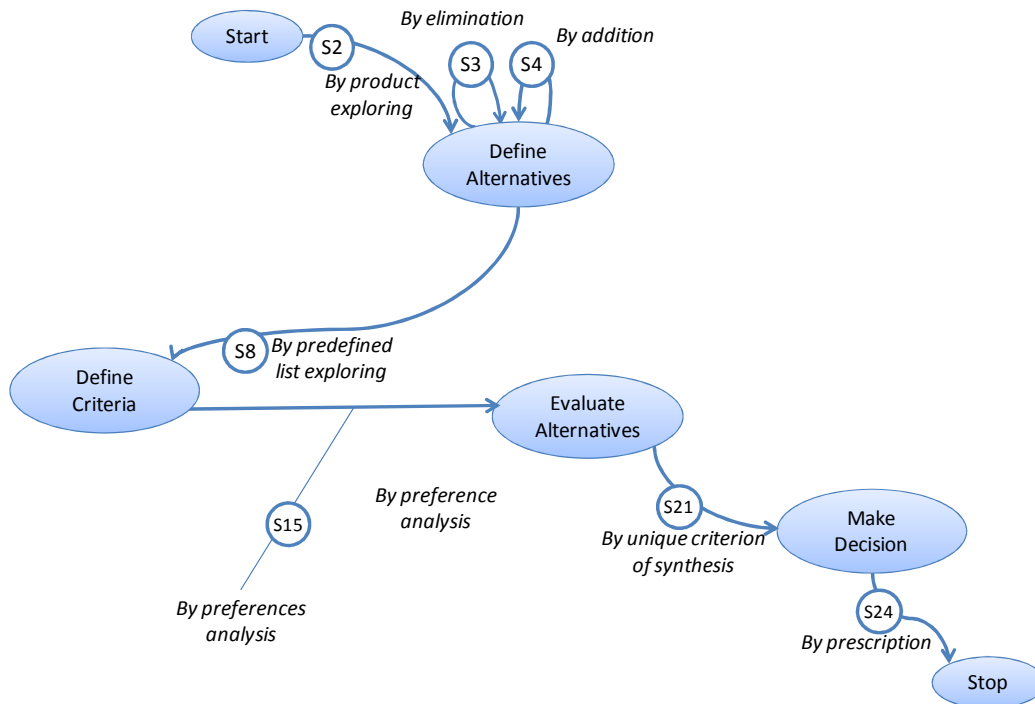


Figure 4. DM Application Method of the Cost-Value Requirements Prioritization Approach.

B. Comparison Framework

As mentioned in the introduction section, we compare our approach with existing requirements prioritization techniques according to two aspects: completeness and flexibility.

We consider a technique as complete if it is generic and covers all basic DM activities. We have detailed the main DM steps in order to distinguish the basic DM activities as follows:

- Requirements list identification;
- Requirements list refinement;
- Criteria list definition;
- Criteria list refinement;
- Criteria weighting;
- Requirements evaluation;
- Requirements evaluation refinement;
- Decision-Making;
- Validation;
- Execution.

Requirements list identification. This activity explains how to identify the initial set of requirements to be prioritized (for instance, in [6]).

Requirements list refinement. The initial requirements set may be refined as requirements can be complementary or exclusive to each other. They can be removed from the list as

non-realistic or non-feasible [7] or added to the initial set by searching complementary alternatives.

Criteria list definition. This activity explores how to identify criteria list for requirements comparing. Criteria can be deduced from requirements description, from consequences analysis of goal analysis. For instance, goals as criteria are used in [23] for requirements prioritization.

Criteria list refinement. Once the first set of criteria is selected, it can be refined. Criteria can be eliminated as not relevant or added when criteria can complement each other.

Criteria weighting. The By weighting strategy deals with weights assignment to the decision criteria. Weights are assigned when the engineer wants to define relative importance of criteria. For instance, weights can be assigned by pair-wise comparison [13]. The last one is commonly used in the requirements prioritization within AHP [20].

Requirements evaluation. Requirements must be evaluated according to the criteria list or compared between them. For instance, a pair-wise comparison is present in AHP method applied for requirements prioritization [14] [20].

Requirements evaluation refinement. Once the requirements are evaluated, their evaluations can be enhanced. For example, a domination analysis can be carried out. An acceptance threshold is established for each criterion. It allows to qualify several requirements as non-acceptable and to remove them from the list. Such a technique is used in the WinWin method for requirements prioritization [20].

Decision-Making. The decision is made when partial values (alternatives values according to different criteria) are transformed into an aggregated one. There are three main aggregation approaches: aggregation into a single criterion,

outranking approach and interactive approach. Multi-criteria DM method are used on this step [8].

Validation. A DM actor receives a prescription for decision. If he agrees with results, he validates them. Some metrics (for instance, a consistency index in [14]) can be used to check if the DM result is valid.

Execution. The execution activity deals with the available support for DM. This activity is present in a given requirement prioritization support if a support tool is available in a given approach.

We will use several criteria to compare the approaches. The *completeness* criterion is calculated as a percentage of the available activities composing a given DM method on the total number of the main DM activities. Flexibility is important when we investigate whether a DM process is predefined or adaptable. Processes must be flexible in order to match better a project following the situation [16]. Flexibility refers to two criteria: variation and iterativity, both are calculated based on the steps number: (i) Variation points number represents a number of steps where a choice can be made, (ii) Backward steps number is a number of steps where engineers can return in the requirements prioritization process, (iii) Number of steps is the total number of the main steps. The *variation* criterion shows the percentage of steps where a choice between some actions can be made. The *iterativity* criterion represents the percentage of steps where, a backward action can be undertaken.

C. Framework Application

The described frame is applied to the five selected requirements prioritization techniques and to MADISE. The six approaches are analyzed according to the ten identified activities (See Table II).

TABLE II. DM ACTIVITIES OF THE FIVE SELECTED REQUIREMENTS PRIORITIZATION TECHNIQUES.

| DM Activities | CVA [14] | PrMatrix [15] | RPT [34] | WinWin [20] | REDEPEND [23] | MADISE [5] |
|------------------------------------|----------|---------------|----------|-------------|---------------|------------|
| Requirements list identification | - | - | - | + | - | + |
| Requirements list refinement | + | + | - | + | - | + |
| Criteria list definition | - | - | - | - | - | + |
| Criteria list refinement | - | - | - | - | - | + |
| Criteria weighting | - | + | + | + | + | + |
| Requirements evaluation | + | + | + | + | + | + |
| Requirements evaluation refinement | - | - | + | + | - | + |
| Decision-Making | + | + | + | + | + | + |
| Validation | + | - | + | + | - | + |
| Execution | + | + | - | + | + | - |

The application of the criteria to the six approaches is given in Table III.

We show within the Cost-Value Approach (CVA), how these tables were fulfilled.

TABLE III. REQUIREMENTS PRIORITIZATION APPROACHES COMPARISON.

| Comparison criteria | CVA [14] | PrMatrix [15] | RPT [34] | WinWin [20] | REDEPEND [23] | MADISE [5] |
|-------------------------------|----------|---------------|----------|-------------|---------------|------------|
| Completeness criterion | | | | | | |
| Number of DM activities | 5 | 5 | 5 | 8 | 4 | 9 |
| Percentage | 50% | 50% | 50% | 80% | 40% | 90% |
| Flexibility criterion | | | | | | |
| Variation points number | 0 | 0 | 0 | 0 | 0 | 5 |
| Backward steps number | 0 | 1 | 0 | 3 | 0 | 3 |
| Number of steps | 5 | 8 | 6 | 7 | 3 | 6 |
| Variation | 0% | 0% | 0% | 0% | 0% | 83% |
| Iterativity | 0% | 13% | 0% | 43% | 0% | 50% |

The CVA contains four main DM activities:

- Requirements list refinement. This approach suggests reviewing candidate requirements for ensuring their completeness and correctness.
- Requirements evaluation. Actors (users and engineers) express their preferences by pair-wise comparison for defining the relative value and cost of candidate requirements.
- Decision-Making. The aggregated value is obtained by AHP application and is used for ranking requirement. The cost-value approach uses also a cost-value diagram in order to assist DM.
- Validation. A consistency index is calculated in order to check the result validity.
- Execution. A tool is suggested to support the Cost-Value approach.

As a result, the completeness criterion may be evaluated at 50%.

The CVA contains five steps:

1. Requirements review;
2. AHP's pair-wise comparison in order to assess the relative value of the candidate requirements;
3. AHP's pair-wise comparison in order to assess the relative cost of the candidate requirements;
4. Cost-Value diagram construction;
5. Requirements prioritization based on the Cost-Value diagram and with the stakeholders participation.

However, none of these steps contains any variation point or backward step. Therefore, the variation criterion is evaluated at 0%, as for the iterativity criterion.

As we can see, the MADISE approach contains all methodological DM activities but does not include the

execution of the DM methods. Between existing requirements prioritization techniques, the WinWin approach is more complete and covers 80% of the DM activities.

Dealing with the flexibility criteria, we can observe that none of the studied approach is completely flexible. All existing requirements prioritization techniques follow a predefined set of steps and, in this manner, do not provide a context-aware DM for prioritize requirements. However, the MADISE process suggests different actions for carrying out DM activities. Regarding the iterativity criterion, two existing requirements prioritization techniques (Prioritization Matrix and WinWin) allow to return back and to adapt DM process to the new circumstances. From this viewpoint, the WinWin approach is also flexible as it allows refining of prioritization results by realizing iterations.

Finally, according to the selected criteria, we can conclude that the MADISE approach is the most flexible one between the six studied approaches

V. CONCLUDING REMARKS

We have presented the MADISE DM method family representing a set of DM method components elaborated to guide IS engineers any time they need to make decisions. We have compared the MADISE process with the five existing requirements prioritization techniques.

According to the completeness criterion, this comparison demonstrates that the MADISE approach is almost complete. It does not include the execution activities, that is to say, it stays methodological. The associated support tool (the MADISE repository) allows to select the adapted to a given case DM method components and does not implement these components. Except, this aspect, the MADISE approach is the most complete one as it includes guidelines for identifying the alternatives list (requirements set in the given case), for identifying the criteria list (when the most requirements prioritization approaches have the limited list of possible criteria). Concerning the flexibility criterion, the MADISE approach is the most flexible one. This implies that it could be adapted to different situations in an easier manner.

Moreover, another application of the MADISE approach can be highlighted within the studied examples as it can contribute to improve existing DM models. For instance, the Cost-Value approach may be enhanced by the <Evaluate Alternatives, By elimination analysis, Evaluate Alternatives> section in order to eliminate dominated alternatives and, in this way, to simplify the AHP method application.

In this manner, the MADISE approach may be used in different ways. Firstly, it provides a complete and generic view on any DM process. However, its various elements (DM method components) could be used separately: for instance, alternatives' definition, consequences description, and so on. Secondly, MADISE can be connected to different engineering processes such as method engineering and IS engineering. Thirdly, it can be applied for both individual and group decisions. Fourthly, this approach can be used to create new DM methods or to enhance existing ones.

Our first future research aims at validating the context-awareness of the MADISE approach. Secondly, the DM method components of the MADISE approach could be implemented as executable services in order to provide the complete DM guidelines.

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