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A Methodology for the Selection of Multi-Criteria Decision Analysis Methods in Real Estate and Land Management Processes

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Received: 15 December 2017; Accepted: 10 February 2018; Published: 13 February 2018

Abstract: Real estate and land management are characterised by a complex, elaborate combination of technical, regulatory and governmental factors. In Europe, Public Administrators must address the complex decision-making problems that need to be resolved, while also acting in consideration of the expectations of the different stakeholders involved in settlement transformation. In complex situations (e.g., with different aspects to be considered and multilevel actors involved), decision-making processes are often used to solve multidisciplinary and multidimensional analyses, which support the choices of those who are making the decision. Multi-Criteria Decision Analysis (MCDA) methods are included among the examination and evaluation techniques considered useful by the European Community. Such analyses and techniques are performed using methods, which aim to reach a synthesis of the various forms of input data needed to define decision-making problems of a similar complexity. Thus, one or more of the conclusions reached allow for informed, well thought-out, strategic decisions. According to the technical literature on MCDA, numerous methods are applicable in different decision-making situations, however, advice for selecting the most appropriate for the specific field of application and problem have not been thoroughly investigated. In land and real estate management, numerous queries regarding evaluations often arise. In brief, the objective of this paper is to outline a procedure with which to select the method best suited to the specific queries of evaluation, which commonly arise while addressing decision-making problems. In particular issues of land and real estate management, representing the so-called "settlement sector". The procedure will follow a theoretical-methodological approach by formulating a taxonomy of the endogenous and exogenous variables of the multi-criteria analysis methods.

Keywords: Multi-Criteria Decision Analysis (MCDA); Decision Making (DM); life cycle management; decision-making

1. Introduction and Aims of the Work

Real estate and land management (including technical, regulatory and governmental aspects) are typically highly complex sectors. Decision-making problems of this type are defined by multidimensional objective profiles and by the multidisciplinary or multi-criteria nature of the factors needing to be evaluated [1]. During the different phases of the construction process, while managing these kinds of decision-making problems, evaluation methodologies have to be designed to interpret the objectives of the land transformation and to translate the premise of the intervention into real actions.

Strategic planning of the decisions executed through decision support systems, or DSS [2], have proven highly effective in the context of settlement transformations. DSS can also be utilised with computerised systems that allow for an interactive use of data and models to support those making decisions while problem solving [1]. In each of the iterative and interactive phases of the construction

process, the strategic planning of decisions is geared towards making informed choices based upon methods of evaluation. These methods need to be well suited to the purpose and to the agenda of needs and demands posed by the programs and projects being carried out in the geographical area.

Within DSS, the use of methods of Multi-criteria Decision Analysis (MCDA) can provide support for the multidisciplinary management of the factors, which need to be optimized in fulfillment of the objective being evaluated [3]. The literature regarding MCDA considers different schools of thought [4–7] and proposes an extensive number of methods with which to resolve decision-making problems in fields of application such as mathematics, management, information technology, psychology, the social sciences and economics. More specifically in the last decade, we find examples in real estate and land management, which demonstrate an increase of interest in the use of formalised analytical decision methods employing structured and comprehensive databases [8]. Several authors act as a reference source for describing the main MCDA methods, which have proven useful in different types of decision-making problems and the approaches taken to resolve them [5,9–17]. A helpful synthesis is provided by the contributions of, among others [18–21], Guitoni, Martel et Vincke (1999) [15], as well as of Roy et Bouyssou (1993) [16], all of which already demonstrate attempts at taking a systematic approach to the methods of MCDA. At the present moment (2018), about 100 different methods are in circulation [22]. Consulting Guitoni, Martel et Vincke [15] and Ishizaka and Nemery [9], it can be noted that the most frequently used and implemented are:

1. ELimination Et Choix Traduisant la REalitè (ELECTRE) [23];
2. Multi-attribute utility theory (MAUT) [24];
3. Analytic Network Process (ANP) [25];
4. Measuring Attractiveness by a Categorical Based Evaluation (MACBETH) [26];
5. Analytic Hierarchy Process (AHP) [27];
6. Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) [28];
7. Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE) [29].

A summary of the various contributions cited above [9,15,16] should include these points:

- No method can be considered perfect or applied to every type of problem [9].
- The range of available procedures offers many different operating opportunities, but also poses the risk of using methods that are not suited to the decision-making problem at hand [16].
- A conclusive analysis of decision-making procedures has yet to be carried out [9].

Even if the use of MCDA techniques is by now an established practice, there are no specific texts, either from Italy or from the rest of Europe, dealing with the exact procedures to be followed when selecting the MCDA method best suited to the contexts of real estate and land management. In particular when generally dealing with the settlement transformation processes and more specifically the design and planning of public and private projects.

As a rule, the choice of the MCDA method best suited to the objectives of the decision-making problem can significantly affect the efficiency of the procedure. Furthermore, it effects the proper formulation of the decisions that need to be made. For example, the expression of the elements that make up a multi-criteria decision-making problem reflects on the effectiveness of the different methods and on the strength of the results. It follows that the choices in question play a key role in arriving at a solution that provides an informed, suitable response to the needs and demands identified in the project.

In light of these considerations, the present work, that represents an in-depth study of a previous work [30], sets out to define a procedure which, taking into account the relevant factors when addressing decision-making problems, makes it possible to select the MCDA methods best suited to problems of real estate and land management, but which can also be employed in other decision-making contexts. In terms of settlement transformations, these methods can expand the

horizons of fact-finding and decision-making situations from a simple consideration of the financial requirements to the full range of relevant criteria (e.g., socio-economic, environmental etc.).

The proposed procedure serves as a useful tool, when added to the regulatory measures of the European Union governing public tenders. The most recent is Directive 2014/24/EU, which has been transposed into Italian laws regarding the Public Contracts Code (Codice dei Contratti Pubblici) via Legislative Decree 50/2016 (plus its subsequent modifications and additions—s.m.a.) as well as its regulations of implementation. These measures contemplate the use of MCDA in public tenders, particularly for the selection of the most economically advantageous bid. MCDA has been considered useful also in the context of planning and design choices for urban regeneration and or transformation as early as 2006. To this end, the European Commission has drawn up a manual with recommendations on systematic approaches to the use of MCDA in different fields of application, including real estate and land management [31].

After having introduced, in the current Section 1, the subject of this study, hereinafter: firstly, after the identification of the framework in which evaluation problems grow up in settlement transformation, it will be proposed a theoretical-methodological approach with a taxonomic catalogue of variables ('endogenous' and 'exogenous') that characterize MCDA and that must be considered during the selection of the most appropriate method among those most commonly carried out in literature (Section 2); afterwards, a procedure for selecting MCDA methods is built on the basis of proposed taxonomic catalogue (Section 3); finally, the proposed procedure, is applied to a case study in its widest form, taking into account a different points of view of stakeholders, and the results of this application are discussed (Section 4). The conclusions of this study are argued at the end of this work (Section 5).

2. MCDA: Structure, Endogenous Variables, Exogenous Variables

2.1. Framework

Any MCDA is generally structured in two macro-phases. The first one involves the construction and compilation, referring to the evaluation problem in question, of the evaluation matrix, which consists of the different alternatives and their performance, based on the various criteria and sub-criteria (and their weightings), plus their indicators of assessment. The second regards the processing of the data in the evaluation matrix used to evaluate the alternatives, on the basis of the objectives to be reached [30,32]. This operation is similar for all MCDA methods. The second phase involves processing (or aggregating) data via a variety of different procedures, depending on which method is being used, considering that each method comes with its own procedures of application (referred to as endogenous variables later on in this paper).

When selecting the method best suited to meet the objectives posed by the evaluation, it is necessary to take into account the context of the evaluation and that can give rise to many different decision-making problems attached to the phases of the settlement process. As presented by the literature on Life Cycle Management [33], the issues to be resolved during the different phases of the Life Cycle of a settlement process correspond to a variety of objectives [34].

In Italy, the Unique Construction Text ("Testo Unico dell'Edilizia") Presidential Decree 380/2001 (s.m.a.) and Public Contracts Code ("Codice dei Contratti Pubblici") Legislative Decree 50/2016 (s.m.a.) are the main laws that control the settlement transformation sector and its respective phases in both private and public works. Using these laws, we can establish categories related to the decision-making problems typical to different types of initiatives. The potential assessment questions and queries can be classified according to the phases of the settlement process and for which of these phases solutions are expected, based on the objectives of evaluation (Table 1).

Once the decision-making problem has been identified from among the possible assessment queries that present themselves during the settlement transformation process, it is necessary to address the evaluation question promptly, thus resolving the problem.

Table 1. Decision making problems in Life Cycle Management and action to solve them.

Phases of the Building Process		Valuable Question	Action Fields of Decision-Making Problems		Action to Be Taken to Solve the Valuable Question
Normative References (Italy)	- Presidential Decree 380/2001 s.m.a.; - D.lgs. 50/2016 s.m.a.	Leg. 50/2016 s.m.a.	D.L. 351/2001 s.m.a.; D.L. 112/2008 s.m.a., D.lgs. 42/2004 s.m.a., D.L. 85/2010 s.m.a.	Presidential Decree 380/2001 s.m.a.	-
Programming	Preliminary needs studies	Priority of needs identification	- Settlement development; - Redevelopment, recovery, reuse, urban regeneration; - Development of discarded areas/buildings; - Decision support in project management; - Valuation of public buildings (Legislative Decree 351/2001, Article 3-bis of Legislative Decree 112/2008, Article 58 of the Italian Civil Code); - Valorization of Cultural Heritage (D.L. 85/2010, Articles 5–7 s.m.a.); - Valorization of landscape-environmental assets (D.L. 85/2010, Articles 5–7 s.m.a.)	- Restoration and conservation interventions; [Article 3 par. 1(c)]; - Renovation of buildings; [Article 3 par. 1(d)]; - New construction works; [(Article 3, par. 1 (e1–e7)]; - Urban planning interventions; [(Article. 3 par. 1(f)]	Identify between a set of items, the most important ones based on a limited amount of information
	Designers and advisors selection	Identification of subjects to be included in Life Cycle Management			Identify decision-makers, their respective importance and their influence in decisions
	Economic technical feasibility project	Design solution that identifies the best relationship between cost and benefit for the community, in relation to the specific needs to be met and performance to be provided (Legislative Decree 50/2016, Article 23, paragraph 5)			Identify the best solution among different proposals based on an average number of information
Design	Definitive project	Best design solution in accordance with the requirements, criteria, constraints, addresses and indications set by the contracting authority and, where applicable, the feasibility project (Legislative Decree 50/2016, Article 23, paragraph 7)			Identify the best solution among different proposals based on a large amount of information
	Executive project	Best design solution in terms of form, type, quality, size and price and in relation to the solution proposed in the maintenance plan of the work and its parts in relation to the life cycle (Legislative Decree 50/2016, Article 23 par. 8)			
Work execution	Relocation of work	Finding the best deal (based on the most economically advantageous bid criterion)			Identify the best offer among different offers (of different numbers depending on the type of competition) on the basis of an average number of information
Management during exercise	Service delivery	Identify the most advantageous management solutions and/or the most suitable operator in accordance with the objectives			Building a set of possible solutions excluding hypotheses that can not be prosecuted
	Ordinary and extraordinary maintenance (Presidential Decree 380/2001 s.m.a., Article 3, paragraph 1, letter a, b)	Definition of the ordinary and extraordinary maintenance solution in relation to the modalities and times for the interventions			Identify all possible solutions in relation to specific factors

2.2. The Correlation between the Action to Be Taken and the Variables (Exogenous and Endogenous) of MCDA Methods

Each action can be related to exogenous variables (strictly related to decision problems and the context from which they arise) and endogenous ones (possible properties of MCDA methods). This is described in more detail respectively in Sections 2.3 and 2.4, where they are defined according to their taxonomic classification (Figure 1).

The Exogenous variables have been defined taking into consideration the 'external' context of the MCDA. They vary depending on the regulations and other measures in place in the relevant country in which evaluation process occurs.

The endogenous variables have been defined following an analysis of the specific literature regarding MCDA. Understandably, there is not one single definition, which can explain MCDA and many 'endogenous variables' can thus be created. Concisely, Roy [10] has suggested that decision-making situations can be categorized on the basis of decision problematics [11]. Different kinds of compensation logic are examined by Vincke [12] and shared by Colson and De Bruyn [13] and further studies [14,35], for example Guitony et al. [15] and Huang et al. [8] who investigated the required input information. In this paper, a set of endogenous variables is defined as that which best represents the most useful occurring in the related literature and according to the survey performed by Ishizaka et Nemery P. [9].

Each variable (exogenous or endogenous) represents the qualifications and properties that exemplify the various forms that the variable can take. Each method retains specific properties, in terms of how successfully it can be implemented. These properties are tied to the qualities of the variables.

In this study, the ensemble of exogenous and endogenous variables has been taken as a starting point on which to structure the selection procedure for the proposed MCDA method (see Section 3) intended for use in the settlement transformation process sector.

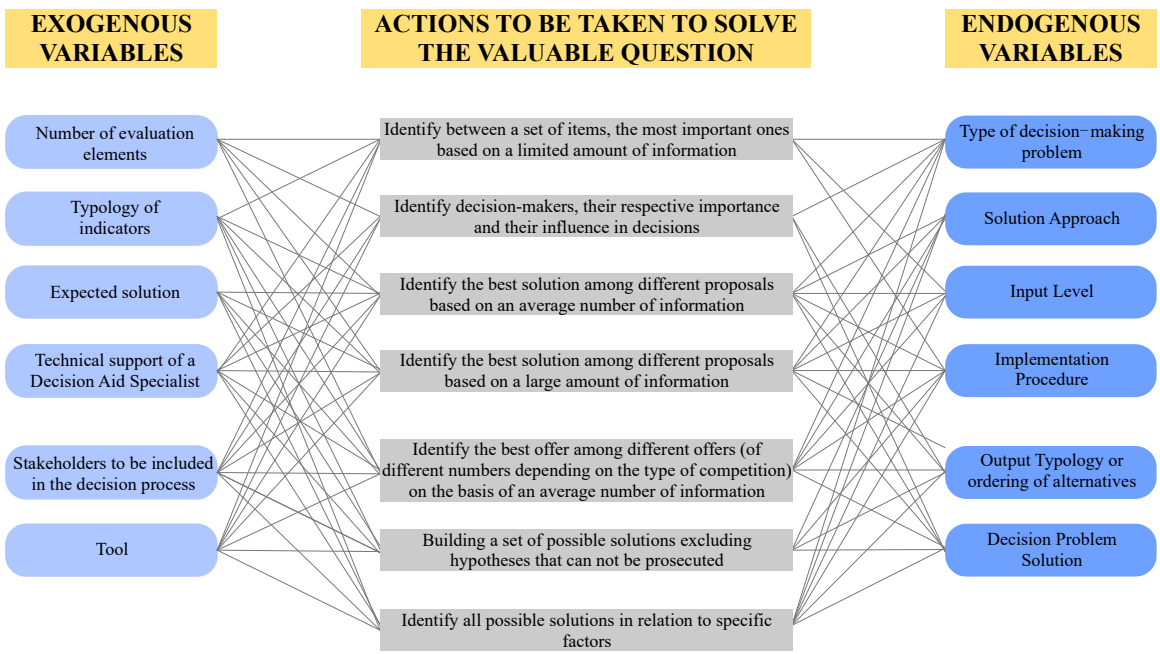

Figure 1. Action to be taken with exogenous and endogenous variables.

2.3. Exogenous Variables

In this section, exogenous variables will be examined: (i) By the number of evaluation elements; (ii) By the typology of the indicators; (iii) The stakeholders involved in the decision process;

(iv) The typology of the expected solution; (v) The presence of technical support from a Decision Aid Specialist during the implementation of the procedure. In the settlement transformation process, the number of evaluation elements (criteria, sub-criteria and alternatives) depends on the nature of the different decision-making problems [8,30,36–40].

The numeric configuration of evaluation elements (Table 2) is generally decided by the person responsible for the evaluation process before the selecting the most suitable MCDA method with reference to the specific problem in hand. In the case of settlement transformation processes, which are generally rather complex, the number of criteria and sub-criteria are defined by the process manager (Responsabile del Procedimento), role regulated by the Legislative Decree 50/2016 Article 31. This is the individual who "provides the authority offering the contract with the data and information regarding the main stages of the intervention, necessary for the coordination, guidance and checks of the correct implementation, and oversees the economic management of the intervention" (Legislative Decree 50/2016 Article 31, par. 4, point f). This kind of activity has been present since the definition of administrative acts relating to settlement process initiation. The person responsible for the evaluation process must attempt to construct the set of evaluation elements without allowing the potential repercussions to overly influence the selection of an MCDA method. Although the creation of the set of variables must of course represent the maximum number of requirements with the minimum number of possible elements [35,41,42]. The number of alternatives can be deduced by taking into account what has happened in the past in similar settlement proceedings in the same or in other administrative contexts [43,44]. The typology of the indicators (Table 3) varies in accordance with the decision-making problem to be resolved and the context in which it arises.

Table 2. Numeric configuration of evaluation elements.

Numeric Configuration of Evaluation Elements
Limited number of criteria and sub-criteria and a small number of alternatives
Limited number of criteria and sub-criteria and a large number of alternatives
Large number of criteria and sub-criteria and a small number of alternatives
Large number of criteria and sub-criteria and a large number of alternatives

Table 3. Typology of the indicators.

Typology of the Indicators	Features of Indicators
Quantitative	Measurable in specific units
Qualitative	Not measurable but subject to judgments of merit that may also employ specially designed scales of measurement (ordinal, cardinal or mixed)
Mixed	Both quantitative and qualitative

The number of stakeholders involved in the decision-making process may vary depending on the different assessment questions that the MCDA needs to answer and from the decision maker's management related to the activation (or not) of Participatory Processes (P.P.) also deciding the number of stakeholders to be considered (Table 4).

Table 4. Number of stakeholders.

Participatory Process	Number of Stakeholders
Not activated	Zero
Actived with a limited and specific number of stakeholders	Narrow
Activated with a high number of stakeholders, if possible organised into categories	Large

The involvement of stakeholders in the decision-making process aims to keep the decision-maker informed as to the opinions of those who may be interested or influenced by the effects of the

decision. The types of stakeholders to be included in the participatory process [45,46] can be classified into the following: (i) standard stakeholders "who have the legitimate responsibility to participate in the process" [47], including all those who could be impacted by the results of the program (e.g., beneficiaries or those who have suffered damage), design engineers and public administration officials, etc. [31]; (ii) interest groups, stakeholders selected from local or professional representatives, leaders of non-governmental organizations (such as stakeholder or environmental protection, consumers and women's rights), public sector bodies the representatives of financial donors, etc. [31]. In short, interest groups are often political parties, civic organizations, or residents of the impact area [47]. Each interest group, as well as the standard stakeholder, has their own motives when evaluating the potential alternatives and often has different relational systems of preference. The process manager, influenced by his own knowledge of the context from which the decision-making arises, identifies the stakeholders to be included in the process. After attributing indices of importance to each stakeholder, the process manager can select the solution (MCDA method) that is generally best for them, for example the wishes of a simple majority (a solution that is preferred by stakeholders whose added indices of importance is greater than 50%) [30].

The type of solution proposed for the decision-making problem in question depends on the selection criterion sought during the evaluation process (Table 5).

Table 5. Type of solution.

Type of Solution	Selection Criterion
Valid alternatives	Based on the aims of the objective
Best alternative	Based on the objective
Coherent alternative	Closest to the objective itself

The technical support of a Decision Aid Specialist during the execution of the process is one of the variables that must be considered. As has been noted by the European Commission [31], the management of the multi-criteria evaluation processes can prove anything but simple. Therefore, another factor influencing the selection of the most suitable method is the availability or non-availability of a Decision Aid Specialist who can put into action the MCDA procedure (Table 6).

Table 6. The presence of technical support from a Decision Aid Specialist.

Role of the Decision Aid Specialist	The Presence of Technical Support from a Decision Aid Specialist
Only technical manager of the MCDA method used to respond to the problem under evaluation	Yes
Only facilitator for understanding the decision-making phase(s) of the process	Yes
Both technical and facilitator roles	Yes
No role for the Decision Aid Specialist	No

The Decision Aid Specialist deals with the technical implementation of the MCDA by making use of the various software available. In other studies, a wide variety of MCDA software has been described, some of which is commercially available, discussing different kinds of packages that have been developed to facilitate MCDA methods [9,48,49]. They involve several processes to give structure to decision-making problems including the exploration of the situation and a formulation and breaking down of the solution [48] by using mathematical algorithms. In reference to the MCDA methods mentioned above (Section 1), a review of the literature draws attention to some of the software available, which is easy to use and free to access or trial. Examples include MakeItRational [49,50] or ExpertChoice [51] for AHP, SuperDecision [52] for ANP, RightChoice [53] for MAUT, M-MACBETH [54] for MACBETH, SmartPickerPro [55] for PROMETHEE, Electre III–IV

software [56] for ELECTRE and Topsis [57] for TOPSIS. The Decision Aid Specialist in his position as "technical" manager needs to have specific knowledge of programming and query languages in order to perform MCDA using this kind of software. Acting as a "facilitator", the Decision Aid Specialist as a has the task of making the stages of the MCDA clear to non-specialist stakeholders; their presence also increases the level of transparency in the evaluation process allowing for informed decisions to be taken.

Table 7 summarizes the features of the exogenous variables.

Table 7. Features of exogenous variables.

Number of Evaluation Elements	Typology of Indicators	Expected Solution	Technical support of a Decision Aid Specialist	Stakeholders to Be Included in the Decision Process	Tool
Limited number of criteria and sub-criteria and a small number of alternatives	- Quantitative; - Qualitative; - Mixed	Definition of n alternatives valid in relation to objectives	- Yes; - No	- Participatory process not activated; - Participatory process activated with a limited and specialized number of stakeholder; - Participatory process activated with a significant number of stakeholder preferably organized in categories	ELECTRE
Limited number of criteria and sub-criteria and a large number of alternatives		A better overall alternative definition for the purpose; The ideal alternative definition closest to the lens			MAUT
Large number of criteria and sub-criteria and a small number of alternatives					AHP; ANP
Large number of criteria and sub-criteria and a large number of alternatives					MACBETH; PROMETHEE; TOPSIS

2.4. Endogenous Variables

Each endogenous variable is described in the following: (i) the type of decision-making problem; (ii) the solution approach; (iii) the input level; (iv) the implementation procedure; (v) the output typology or order of alternatives and (vi) the solution to the decision problem [30].

The types of decision-making problem according to Roy's viewpoint [16] and shared by Ishizaka et Nemery P. [9] and Guitoni and Martel [11], among others, can be grouped into three categories that express the qualification of the variable (Table 8).

Table 8. Types of decision-making problems.

Categories	Decision-Making Problem
Description problem	Identify the main distinctive features for a group of alternatives
Sorting problem	The definition of homogeneous groups of alternatives by characteristics
Ranking and Choice problem	The ranking of alternatives, from best to worst

Three clusters distinguish the approach to solving decision-making problems. They are identified from the different qualifications that represent the resolution of the evaluation problem (Table 9).

Table 9. Approaches to resolving problems.

Method of Approach	Qualification *
Full Aggregation Approach	"A score is evaluated for each criterion and these are then synthesized into a global score. This approach assumes compensable scores, i.e., a bad score for one criterion is compensated for by a good score on another".
Outranking Approach	"A bad score may not be compensated for by a better score. The order of the option may be partial because the notion of incomparability is allowed. Two options may have the same score, but their behavior may be different and therefore incomparable".
Goal, aspiration or reference level approach	"A goal for each criterion is defined, and then the closest options to the ideal goal or reference level are identified".

* The definitions of qualifications for the solving approach are taken from Ishizaka et Nemery P. [9].

In the case of a full aggregation approach, the scores allow each alternative to be comparable with another. They are expressed while taking into consideration the performance of the alternatives according to the criteria and sub-criteria selected for the analysis.

With regard to the outranking approach the incomparability is defined by observing alternative performance sets that are equally valid but qualified differently because they are based on different sets of criteria. The allocation of a full or partial score to the alternative involves a consideration of the performance set, based on the criteria and sub-criteria selected for the execution of the analysis.

In case of the "goal, aspiration or reference level approach", the options (alternatives) are evaluated using the aggregate collection (vector sum) of the performance in relation to the different criteria that allow one to define how far (vector) the alternatives fall from the final objective.

The input level describes the "modelling effort" [9] needed to achieve the desired results and is connected to the measurement (Indicators) of the data and the parameters to be drawn and considered in order to solve the decision-making problem (Table 10). It is necessary to emphasize that Strategic Planning Techniques [58] and Participation Techniques are employed in the evaluation and collection of data used in the MCDA. Indeed, several stakeholders are often considered directly or indirectly involved in the decision-making problem, including: (i) institutions (national, regional, local); (ii) contracting stations; (iii) entrepreneurs, economic operators; (iv) property owners; (v) workers and (vi) the population.

Table 10. Input levels.

Modelling Effort Parametres	Indicators
Data and parameters to be traced and inserted into the evaluation model	High, medium, low
Requested time to collect and process data	Long, medium, short
Skills needed to manage and process data	High, medium, low
Use of additional evaluation techniques for the collection of data used in the MCDA	Necessary, advised, unnecessary

A score is assigned to each parameter by using the indicators. The input level is a synthetic indicator of these scores, which expresses the level: High (H), Medium (M) or Low (L). The methodology of the calculation is described in [30] Appendix A (Table A1).

The different implementation procedures are defined using logical mathematical operations in order to process the data implemented in the evaluation matrix and to get a summary of results for the classification of the alternatives. Different methods of data processing and aggregation are necessary for the different implementation procedures. The procedures include: (i) preference thresholds, indifference thresholds and veto thresholds [59]; (ii) utility function [9,17]; (iii) pairwise comparisons on a ratio scale [27,60]; (iv) pairwise comparisons on a ratio scale with interdependencies [25]; (v) pairwise comparisons on an interval scale [26,61]; (vi) ideal option and anti-ideal option [9,28,62–64] (Table 11) [30].

Table 11. Implementation procedures.

Implementation Procedures	Data Processing and Aggregation
Preference thresholds, indifference thresholds, veto thresholds	Pairwise preference degree comparing the performance of n alternatives. To find the preference level, the evaluation must consider the preference and indifference thresholds. On the basis of these thresholds, positive, negative and unicriterion net and global flows are created taking into account the weights attributed to each criterion. If an action performs negatively according to a single criterion, it may also be included in a veto threshold that definitively excludes that option from the final ranking.
Utility function	The expression of the measure of desirability or preference of each alternative with respect to the others. Different criteria are considered in the function. For each criteria, the marginal utility is determined as representing the partial contribution that each criteria brings to the overall utility assessment. The Global utility is expressed by Global Utility Scores (generally expressed in values between 0 and 1) which are commonly calculated by the additive method or with a weighted sum, based on the weighted importance (weight) for each criterion, or by a simple addition.
Pairwise comparisons on a ratio scale	The construction of evaluation matrices. The comparison of the elements included in the evaluation matrices, structured according to a hierarchical system of criteria, sub-criteria and alternatives. It is performed by simultaneously comparing two elements at a time with respect to the hierarchically superior element on the basis of a rational numerical scale (Saaty Fundamental Scale).

Table 11. *Cont.*

Implementation Procedures	Data Processing and Aggregation
Pairwise comparisons on a ratio scale with interdependencies	The construction of evaluation matrices called Supermatrix. The Comparison of the elements included in the Supermatrix, which are organised into clusters of criteria, sub-criteria and alternatives, is performed by simultaneously comparing two elements at a time taking into account any interdependencies between them, for example: (i) inner dependencies in cluster criteria; (ii) inner dependencies in the alternative cluster; (iii) outer dependencies (correlation between two different clusters). Based on the influences (also called nodes) between elements or clusters, the Supermatrix is completed considering the influence of each node on the others and expressed on a rational scale (Saaty Fundamental Scale). In the case of no interdependence between the elements being compared, a value of zero is inserted into the Supermatrix.
Pairwise comparisons on an interval scale	The construction of evaluation matrices also called matrices of judgements. The comparison between the evaluation elements (alternatives and criteria) is implemented by a pairwise comparison based on a semantic qualitative scale (traditionally translated into quantitative values from 1 to 7). Values are generally included in the matrix of judgments where the relative attractiveness of the criteria and alternatives is also expressed by the consideration of the weight attributed to each criterion.
Ideal option and anti-ideal option	The expression for each alternative, of the shortest distance to the ideal (virtual) solution and the longest distance from the anti-ideal solution, taking into account the performance of alternatives referred to each criterion and to the weight of each criterion. The distance is expressed by calculating a distributive normalization and an ideal normalization of the recorded performances.

It is possible to obtain output modalities by putting in order alternatives with different qualities. The "granularity order" [9,15] varies according to the type of endogenous variables considered. The output typologies are obtained as a result of the evaluation implementation referring to the number (n) of alternatives evaluated (Table 12) [30]. This depends on different calculation methods, which represent the comparability or incomparability between the alternatives and of the distance (or the type of measurement or procedure by which the alternatives are ordered) of the alternatives from achieving the defined objective.

Table 12. Output typologies.

Output Typologies	Calculation Method
Partial and complete order obtained by expressing pairwise preference degrees and scores	A simultaneous consideration of the positive and negative global performance flows evaluated for each alternative or simply by considering the net flows that make it possible to understand whether the alternatives being deliberated obtain a higher rank, a minor rank or if two or more alternatives are incomparable or equally valid.
Partial and complete order obtained by expressing pairwise outranking degrees	Degrees of preference can lead to a partial rank (if two or more alternatives are incomparable) or a total rank (if the incomparability hypothesis is not allowed) of alternatives traditionally through the expression of degrees of concordance and discordance according to the criteria considered.
Full order obtained by considering the scores assigned to the alternatives in various ways (pairwise comparisons with or without interdependencies, utility functions, pairwise comparisons on an interval scale)	By complex and general scores (a hypotheses of incomparability between two alternatives is not admitted) and a general approval of the ordering of alternatives from the best to the worst.
Full order with a score closest to the desired objective	The calculation of the proximity coefficient for each alternative traditionally expressed in values between 0 and 1 where value 1 expresses the closest proximity to the aim.

The types of solution used to resolve the decision-making problem derive from the order (output) of the alternatives and depend on whether the incomparability between two alternatives is admitted or not. The solution is therefore based on different foundations (Table 13) [30].

Table 13. Solutions used for the decision-making problem.

Solutions	Incomparability	Solution foundation
n categories of alternatives of equal score but different behaviors	Admitted	The consideration of several valid alternatives at the same time
Alternative with the higher global score	Not admitted	The choice of alternative that gets the highest score
Alternative with the closest score to the ideal solution	Not admitted	Choosing the alternative that gets a score, which is closest to the ideal normalization of the recorded performances for the alternatives considered.

Table 14 summaries the features of the endogenous variables mentioned in this section.

Table 14. Features of the endogenous variables.

Type of Decision-Making Problems	Solution Approach	Implementation Procedure	Input Level	Output Typology	Decision Problem Solution	Tool
Sorting/ Description	Outranking approach	Preference thresholds, indifference thresholds, veto thresholds	Medium	Partial ordering obtained by expressing pairwise preferences degrees	*n* categories of alternatives of equal score but different behaviour	ELECTRE
Ranking/Choice	Full aggregation approach	Utility function	High	Full ordering obtained by considering the scores	Alternative with the higher global score	MAUT
		Pairwise comparison on rational scale and interdependencies	High	Full ordering obtained by considering the scores	Alternative with the higher global score	ANP
		Pairwise comparison on interval scale	High	Full ordering obtained by considering the scores	Alternative with the higher global score	MACBETH
		Pairwise comparison on rational scale	Low	Full ordering obtained by considering the scores	Alternative with the higher global score	AHP
	Goal, aspiration or reference level approach	Ideal option and anti-ideal option	Low	Full ordering with score closest to the aim assumed	Alternative with the closest score to the ideal solution	TOPSIS
	Outranking approach	Preference thresholds, indifference thresholds, veto thresholds	Medium	Partial ordering obtained by expressing pairwise preferences degrees	*n* categories of alternatives of equal score but different behaviour	ELECTRE
				Total ordering obtained by expressing pairwise preferences degrees	Alternative with the higher global score	
		Preference thresholds, indifference thresholds	Medium	Partial ordering obtained by expressing pairwise preferences degrees	*n* categories of alternatives of equal score but different behaviour	PROMETHEE
				Partial ordering obtained by expressing pairwise preferences degrees	Alternative with the higher global score	

2.5. Properties of MCDA Methods Transposed into a Binary Mathematical System

The analyses carried out in Sections 2.3 and 2.4 above make it possible to construct a matrix that summarizes the properties of the MCDA methods considered [30]. This matrix consists of 7 columns displaying the MCDA methods taken into consideration (Tn) and 38 rows representing the qualifications (Qn) to be deliberated as a set of indicators for each variable (Vn). At the point where each row and column meet, a score, Px(Tn;Vn;Qn), is assigned through a binary mathematical system used to illustrate whether each of the relevant properties of qualification is present (1) or absent (0) (Table 15) [30]. This transposition serves, in the following phase, for the implementation of the procedure used to select the MCDA method best suited to the decision-making problem being addressed. The transposition of the properties of MCDA methods into a binary mathematical system was performed by examining the most popular MCDA [30].

Table 15. Properties of Multi-Criteria Decision Analysis (MCDA) methods transposed in a binary mathematical system.

Type of Variables	Variables	Qualification of Variables	Properties of MCDA Tool in Binary System						
			ELECTRE	MAUT	ANP	MACBETH	AHP	TOPSIS	PROMETHEE
Exogenous	Number of evaluation elements	Limited number of criteria and sub-criteria and a small number of alternatives	1	0	0	0	0	0	0
		Limited number of criteria and sub-criteria and a large number of alternatives	0	1	0	0	0	0	0
		Large number of criteria and sub-criteria and a small number of alternatives	0	0	1	0	1	0	0
		Large number of criteria and sub-criteria and a large number of alternatives	0	0	0	1	0	1	1
	Typology of indicators	Quantitative	1	1	1	1	1	1	1
		Qualitative	1	0	1	1	1	1	1
		Mixed	1	0	1	1	1	1	1
	Stakeholders to be included in the decision process	Participatory process not activated	1	1	1	1	1	1	1
		Participatory process activated with a limited and specialized number of stakeholder	1	1	1	1	1	1	1
		Participatory process activated with a significant number of stakeholder preferably organized in categories	1	1	1	1	1	1	1
	Expected solution	A better overall alternative definition for the purpose	1	0	0	0	0	0	0
		The ideal alternative definition closest to the lens	0	0	0	0	0	1	0
		A better overall alternative definition for the purpose	0	1	1	1	1	0	1
		The ideal alternative definition closest to the lens	0	0	0	0	0	1	0
	Technical support of a Decision Aid Specialist	Yes (advisable)	1	1	1	1	0	0	0
		No (not necessary)	0	0	0	0	1	1	1

Table 15. *Cont.*

Type of Variables	Variables	Qualification of Variables	Properties of MCDA Tool in Binary System						
			ELECTRE	MAUT	ANP	MACBETH	AHP	TOPSIS	PROMETHEE
Endogenous	Type of decision-making problems	Sorting	1	0	0	0	0	0	0
		Description	1	0	0	0	0	0	0
		Ranking/Choice	1	1	1	1	1	1	1
	Solution approach	Outranking approach	1	0	0	0	0	0	1
		Full aggregation approach	0	1	1	1	1	0	0
		Goal, aspiration or reference level approach	0	0	0	0	0	1	0
	Implementation procedure	Preference thresholds, indifference thresholds, veto thresholds	1	0	0	0	0	0	0
		Preference thresholds, indifference thresholds	0	0	0	0	0	0	1
		Utility function	0	1	0	0	0	0	0
		Pairwise comparison on rational scale and interdependencies	0	0	1	0	0	0	0
		Pairwise comparison on interval scale	0	0	0	1	0	0	0
		Pairwise comparison on rational scale	0	0	0	0	1	0	0
		Ideal option and anti-ideal option	0	0	0	0	0	1	0
	Input level	High	0	1	1	1	1	0	0
		Medium	1	0	0	0	0	0	1
		Low	0	0	0	0	0	1	0
	Output typology	Partial ordering obtained by expressing pairwise preferences degrees	1	0	0	0	0	0	1
		Total ordering obtained by expressing pairwise preferences degrees	1	0	0	0	0	0	1
		Full ordering obtained by considering the scores	0	1	1	1	1	0	0
		Full ordering with score closest to the aim assumed	0	0	0	0	0	1	0
	Decision problem solution	*n* categories of alternatives of equal score but different behaviour	1	0	0	0	0	0	1
		Alternative with the higher global score	0	1	1	1	1	0	0
		Alternative with the closest score to the ideal solution	0	0	0	0	0	1	0

3. Selecting Methods of Multi-Criteria Decision Analysis: The Proposed Procedure

The selection of the most suitable MCDA method is carried out by comparing the framework of properties that characterize each MCDA method (Table 15) with the qualifications that the method should possess (the expected properties), depending on the decision-making problem to be addressed and taking into consideration both the exogenous and endogenous variables. As already seen in Section 1, the procedure is designed to satisfy the settlement transformation sector as follows:

1. *The weighting of variables (optional action)*: A set of variables (that represents the criteria) and their potential qualifications (Table 15) has been defined (see also Section 3). The variables can be considered of equal importance or weight (equal weight method) or of different importance and weight [65–67]. Should it be necessary to consider the varying importance of the variables, a weight can therefore be assigned to each of them [68]. Different weights will directly influence the results of MCDA procedure. Consequently, it is essential to define the rationality and veracity of the criteria weights. Several methods of achieving this are discussed in the reference literature. For example: (i) subjective weighting methods such as direct assignment, Simple Multi-Attribute Rating Technique (SMART), SWING, SIMOS, pairwise comparison, AHP; (ii) Objective weighting methods such as entropy method, TOPSIS and combination weighting methods [66,67,69–71]. The most appropriate weighting method can be chosen by taking into consideration: (i) the variance in the degrees of criteria; (ii) the independency of criteria; (iii) the subjective preferences of the decision-makers and stakeholders when communicating their weights [68]. The exact number of criteria (and sub-criteria) may also have some relevance [35,59]. Direct assignment, SMART and SWING are the most used methods for addressing decision-making problems related to the settlement transformation process. The advantages of these being: the fast implementation times and the possibility to collect the views of stakeholders through questionnaires. However, the various weakness must also be considered including the difficulties connected to quantifying the uncertainty of the human input [66] and the subsequent conflict between the thoughts and priorities of the stakeholders and the expression of ranking and values. Appendix B describes how stakeholders may express the index of importance for each variable and their aggregation modalities [30].
2. *Determining the framework of expected properties*: This involves the identification (presence or absence) of the qualifications needed by the different variables in order to address the decision-making problem in question. Those responsible for the process of settlement transformation must determine the needs and demands involved in the decision-making problem being examined. The choice must be based on the set of exogenous and endogenous variables and composed of both the required and expected properties, EP(Vn;Qn), of the method selected for the decision-making problem. The framework of the expected properties for each exogenous and endogenous variables (for the chosen method) is determined according to the formulas and Table A2 [30] attached in Appendix C.
3. *Calculation of the overall index of suitability*: This is based on a comparison of the properties of the various MCDA methods (Table 15) with their expected properties. A general index can be obtained for the suitability of each potential method for resolving the evaluation problem. Before an overall index of suitability can be calculated, the suitability, SR(Vn;Qn), must be determined for each qualification of the variables listed on the new table. The suitability is determined by comparing the data of the properties of the MCDA methods, for each qualification of the variable (Table 15) with the data included on the table to be filled identifying the expected properties for each exogenous and endogenous variables (see Appendix C Table A2) [30]. Refer to Appendix D.1, for the possible configurations deriving from the calculation of the overall index of suitability [30]. The suitability results, SR(Vn;Qn), for each variable are then combined for each MCDA method in order to produce an aggregate index of suitability IS(Tn). In order to weigh the variables, the suitability results must be multiplied by the index of importance for the factors

expressed by the stakeholders (see Appendix D.2 for the mathematical formula [30]). Should the suitability of 2 or more qualifications have been determined for a single variable, then it holds that if the binary system produces a number of results that are equal to 1, the overall result will be 1 when calculating the overall suitability. In the case of it not being necessary to weigh the variables, the aggregate index of overall suitability or IS(Tn) for each MCDA method is obtained as displayed [30] in Appendix D.3.

4. *The Identification of the method best suited to resolving the decision-making problem*: Obtaining a ranking of the MCDA methods with respect to the overall suitability indicators acquired. The ranking, POS(Sn), of the overall indexes of suitability for each MCDA method is reached by listing the indexes of aggregate suitability, IS(Tn) or ISW(Tn), in descending order. The most suitable method is the one with the highest index of overall suitability.

As already mentioned in previous sections, the procedure being proposed has been designed by considering the 6 endogenous variables that describe the different methods of MCDA [9]. In addition, we have the 4 exogenous variables derived from the Italian regulatory framework integral to settlement transformation processes. The selection procedure of the most appropriate MCDA method as proposed below may be employed in other territorial contexts, however, the endogenous variables remain unchanged in these possible applications as they are related to the implementation of MCDA "techniques". Instead, the exogenous variables can be reconsidered by using reduction, integration or substitution depending on the evaluation problem to be answered.

4. Application of the Proposed Procedure to a Case Study

4.1. A Procedural Application: The Evaluation of Design Proposals Responding to the Call for Tenders for a New Office Building at the Chamber of Deputies in Rome

The procedure proposed by this paper was applied to the selection of an MCDA method to be used in a hypothetical international call for tenders. The structure in question is a new office building at the Chamber of Deputies in Rome, for which the design ideas must be evaluated. The new building is to be constructed in an urban void adjacent to Palazzo Montecitorio in the historic center of Rome (Italy). The hypothetical request aims at identifying the best design idea for the solution of a situation unresolved since the first call for tenders for this potential building at the Chamber of Deputies in 1967 [1,72].

The purpose of the request is to choose from amongst multiple design proposals, the best one considering a set of criteria, sub-criteria, indicators and weights for the variables specifically designed by a team of experts (Table 16) [30,72] formed of technical officials from Rome's Public Administration (4) and professors (6) and researchers (8) involved in studying a new project for the Chamber of Deputies.

4.2. Weighting of the Variables

In this case study, a direct assignment has been proposed; without any mathematical normalization, so that the weighting operation can be performed easily and quickly. Direct assignment, SMART and SWING, appear to be the most appropriate methods when considering the features of the proposed procedure [35,59,68]. This is because the variables considered are different and independent from each other and limited in number, and the different stakeholders (both standard and interest groups) have the possibility to express their point of view. Direct assignment has been implemented, by attributing to every stakeholder for each variable an index of importance, W(Vn), considering: 0 no importance; 0.25 low importance, 0.5 medium importance, 0.75 high importance and 1 very high importance. This weighting operation has been performed by taking into account the opinions gathered (through interviews) from a representative sample of stakeholders (technical officials from Rome's Public Administration; professors and researchers involved in studying a new project for the Chamber of Deputies). The results of each category of stakeholders considered have been aggregated

(Table 17 column weight) according to the modalities shown in Appendix B considering a simple index of importance between stakeholders.

Table 16. Evaluation elements to be considered in the call for tenders for the office building at the Chamber of Deputies.

Goal	General Objectives	Criteria	Sub-Criteria	Typology of Indicators	Indicators
The urban void solution by the inclusion of new functions	Architectural and Urban quality	Urban fabric filling in relationship with the historical development process	Alignment of the new building to the urban fabrics before demolition (Rilievo IGM 1873)	Qualitative	- Total; - Partial; - Absent
			Presence of inner courts (covered or uncovered) following the tradition of the historical urban fabric	Qualitative	- Present; - Absent
		Organic relationship between buildings and urban spaces	Connection between design spaces, urban spaces and parliamentary functions close to the design area	Qualitative	- Very high; - High; - Medium; - Low; - Very low
			Mixed use providing by concentration of commercial functions on Matrix route in order to restore its functional and morphological continuity	Qualitative	- Total; - Partial; - Absent
			Easy access to non parliamentary functions on matrix route (Via di Campo Marzio)	Qualitative	- Total; - Partial; - Absent
	Technical and functional quality	Flexibility and integrability of inner and outer spaces from functional and distributive point of view	Minimizing of unmovable structures to reduce the impact on the dynamic and alternative use of spaces	Qualitative	- Very high; - High; - Medium; - Low; - Very low
			Minimizing of technical and structural elements to reduce the impact on the dynamic and alternative use of spaces	Qualitative	- Total; - Partial; - Absent
	Economic and financial aspects	Spending Control	Cost reduction	Quantitative	% on base amount established for call for tenders
			Cost sustainability connected with energy saving	Quantitative	€/year
			Maintenance costs por year	Quantitative	€/year
		Economic Convenience	Environmental costs	Quantitative	€
			Costs Benefits ratio	Quantitative	Net Present Value (€)

4.3. Determination of the Framework of Expected Properties

The expected properties of the MCDA method used to evaluate the design proposals have been defined when considering the objectives and the details of the request as well as summarized in Table 17 (columns expected properties to the decision-making problems), according to the modalities [30] shown in Appendix C.

Table 17. Expected properties for the MCDA method in the call for tenders for the office building at the Chamber of Deputies in Rome.

Type of Variables	Variables	Weight	Qualification of Variables	Expected Properties to Decision-Making Problem	
				Value	Motivation
Exogenous	Number of evaluation elements	0.5	Limited number of criteria and sub-criteria and a small number of alternatives	0	-
			Limited number of criteria and sub-criteria and a large number of alternatives	0	-
			Large number of criteria and sub-criteria and a small number of alternatives	0	-
			Large number of criteria and sub-criteria and a large number of alternatives	1	Related to Criteria, Sub-Criteria and Indicators of Evaluation; Considering a significant participation in the call
	Typology of indicators	0.75	Quantitative	0	-
			Qualitative	0	-
			Mixed	1	Related to Criteria, Sub-Criteria and Indicators of Evaluation
	Stakeholders to be included in the decision process	1	Participatory.Process not activated	0	
			Participatory.Process activated with a limited and specialized number of stakeholder	0	
			Participatory.Process activated with a significant number of stakeholder preferably organized in categories	1	Need to activate a participatory process with a significant number of categories of stakeholders
	Expected solution	1	Definition of n alternatives valid in relation to objectives	0	-
			A better overall alternative definition for the purpose	1	Need to select the best design proposal
			The ideal alternative definition closest to the lens	0	-
	Technical support of a Decision Aid Specialist	0.25	Yes (advisable)	1	Need to speed up decision making
			No (not necessary)	0	-
Endogenous	Type of decision-making problems	0.5	Sorting	0	-
			Description	0	-
			Ranking/Choice	1	Need to form a ranking among the design proposals
	Solution approach	1	Outranking approach	0	-
			Full aggregation approach	1	Necessity of project proposals in relation to all achievements
			Goal, aspiration or reference level approach	1	
	Implementation procedure	1	Preference thresholds, indifference thresholds, veto thresholds	0	-
			Preference thresholds, indifference thresholds	1	Need to check the performance of project proposals in relation to thresholds
			Utility function	0	-
			Pairwise comparison on rational scale and interdependencies	0	-
			Pairwise comparison on interval scale	0	-
			Pairwise comparison on rational scale	0	-
			Ideal option and anti-ideal option	1	Need to check the performance of project proposals in relation to thresholds

Table 17. *Cont.*

Type of Variables	Variables	Weight	Qualification of Variables	Expected Properties to Decision-Making Problem	
				Value	Motivation
Exogenous	Input level	0.75	High	1	- Amount of data and parameters: high (calculation for weighing the modelling effort level in relation to the input level parameters as indicated in Table A1) - Times for the definition: medium; -Skills and degree of knowledge of the decision-making problem: high; - Use of integrated techniques: not necessary
			Medium	0	-
			Low	0	-
	Output typology	1	Partial ordering obtained by expressing pairwise preferences degrees	0	-
			Total ordering obtained by expressing pairwise preferences degrees	0	-
			Full ordering obtained by considering the scores	1	Need to measure the performance of project proposals
			Full ordering with score closest to the aim assumed	1	
	Decision problem solution	1	*n* categories of alternatives of equal score but different behaviour	0	-
			Alternative with the higher global score	1	Need to identify the project proposal with the best performance in relation to the goals
			Alternative with the closest score to the ideal solution	1	

4.4. Calculation of the Overall Index of Suitability

Following the procedure, the comparison between the property framework of MCDA methods (Table 15) and the data included on the table to be filled identifying the expected properties for each exogenous and endogenous variable as indicated [30] in Table A2 in Appendix C, provides the results of consistency for each qualification of the variables (Table 18). We arrive at the synthetic global coherence indicator, the overall suitability index IS(Tn), relative to each of the most commonly used MCDA methods calculated according to the modalities [30] shown in Appendix D.

Table 18. Results of potential MCDA methods suggested for the selection of the best design proposal in the call for tenders for the office building at the Chamber of Deputies.

Type of Variables	Variables	Weight	Qualification of Variables	Consistency in Relation to the MCDA Tools in Relation to the Expected Qualification						
				ELECTRE	MAUT	ANP	MACBETH	AHP	TOPSIS	PROMETHEE
Exogenous	Number of evaluation elements	0.5	Limited number of criteria and sub-criteria and a small number of alternatives	0.00	0.00	0.00	0.00	0.00	0.00	0.00
			Limited number of criteria and sub-criteria and a large number of alternatives	0.00	0.00	0.00	0.00	0.00	0.00	0.00
			Large number of criteria and sub-criteria and a small number of alternatives	0.00	0.00	0.00	0.00	0.00	0.00	0.00
			Large number of criteria and sub-criteria and a large number of alternatives	0.00	0.00	0.00	0.50	0.00	0.50	0.50
	Typology of indicators	0.75	Quantitative	0.00	0.00	0.00	0.00	0.00	0.00	0.00
			Qualitative	0.00	0.00	0.00	0.00	0.00	0.00	0.00
			Mixed	0.75	0.00	0.75	0.75	0.75	0.75	0.75
	Stakeholders to be included in the decision process	1	ParticipatoryProcess not activated	0.00	0.00	0.00	0.00	0.00	0.00	0.00
			Participatory.Process activated with a limited and specialized number of stakeholder	0.00	0.00	0.00	0.00	0.00	0.00	0.00
			Participatory.Process activated with a significant number of stakeholder preferably organized in categories	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Expected solution	1	A better overall alternative definition for the purpose; The ideal alternative definition closest to the lens	0.00	0.00	0.00	0.00	0.00	0.00	0.00
			A better overall alternative definition for the purpose	0.00	1.00	1.00	1.00	1.00	0.00	1.00
			The ideal alternative definition closest to the lens	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Technical support of a Decision Aid Specialist	0.25	Yes (advisable)	0.25	0.25	0.25	0.25	0.00	0.00	0.00
			No (not necessary)	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 18. *Cont.*

Type of Variables	Variables	Weight	Qualification of Variables	Consistency in Relation to the MCDA Tools in Relation to the Expected Qualification						
				ELECTRE	MAUT	ANP	MACBETH	AHP	TOPSIS	PROMETHEE
Endogenous	Type of decision-making problem.s	0.5	Sorting	0.00	0.00	0.00	0.00	0.00	0.00	0.00
			Description	0.00	0.00	0.00	0.00	0.00	0.00	0.00
			Ranking/Choice	0.50	0.50	0.50	0.50	0.50	0.50	0.50
	Solution approach	1	Outranking approach	0.00	0.00	0.00	0.00	0.00	0.00	0.00
			Full aggregation approach	0.00	1.00	1.00	1.00	1.00	0.00	0.00
			Goal, aspiration or reference level approach	0.00	0.00	0.00	0.00	0.00	1.00	0.00
	Implementation procedure	1	Preference thresholds, indifference thresholds, veto thresholds	0.00	0.00	0.00	0.00	0.00	0.00	0.00
			Preference thresholds, indifference thresholds	0.00	0.00	0.00	0.00	0.00	0.00	1.00
			Utility function	0.00	0.00	0.00	0.00	0.00	0.00	0.00
			Pairwise comparison on rational scale and interdependencies	0.00	0.00	0.00	0.00	0.00	0.00	0.00
			Pairwise comparison on interval scale	0.00	0.00	0.00	0.00	0.00	0.00	0.00
			Pairwise comparison on rational scale	0.00	0.00	0.00	0.00	0.00	0.00	0.00
			Ideal option and anti-ideal option	0.00	0.00	0.00	0.00	0.00	1.00	0.00
	Input level	0.75	High	0.00	0.05	0.05	0.00	0.05	0.00	0.00
			Medium	0.00	0.00	0.00	0.00	0.00	0.00	0.00
			Low	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Output typology	1	Partial ordering obtained by expressing pairwise preferences degrees	0.00	0.00	0.00	0.00	0.00	0.00	0.00
			Total ordering obtained by expressing pairwise preferences degrees	0.00	0.00	0.00	0.00	0.00	0.00	0.00
			Full ordering obtained by considering the scores	0.00	1.00	1.00	1.00	1.00	0.00	0.00
			Full ordering with score closest to the aim assumed	0.00	0.00	0.00	0.00	0.00	1.00	0.00
	Decision problem solution	1	*n* categories of alternatives of equal score but different behaviour	0.00	0.00	0.00	0.00	0.00	0.00	0.00
			Alternative with the higher global score	0.00	1.00	1.00	1.00	1.00	0.00	0.00
			Alternative with the closest score to the ideal solution	0.00	0.00	0.00	0.00	0.00	1.00	0.00
Overall suitability index (IS)				0.23	0.53	0.60	0.64	0.57	0.61	0.43

4.5. Results: Identification of the Method Best Suited to Resolving the Decision-Making Problem

The decreasing order of the global coherence indicators obtained for each MCDA method considered identifies MACBETH as the best performing method according to the objectives of the request. Using this method could facilitate the evaluation problem of choosing the best design proposal, by giving a suitable answer to the established objectives (Table 19).

Table 19. The order of potential MCDA methods to select the best design proposal for the new services building at the Chamber of Deputies in Rome.

MCDA Tool	Overall Suitability Index (IS)	Ranking
MACBETH	0.64	1
TOPSIS	0.61	2
ANP	0.60	3
AHP	0.57	4
MAUT	0.53	5
PROMETHEE	0.43	6
ELECTRE	0.23	7

MACBETH sits at the top of the order with a consistency index of 0.64; TOPSIS (0.61) and ANP (0.60) also obtain a high consistency; AHP (0.57) and MAUT (0.53) reach a medium consistency and could potentially be used for solving the decision-making problem specific to the case study.

According to the objectives of the international call for tenders mentioned above, the consistency of PROMETHEE (0.43) is low and ELECTRE (0.23) is not recommended at all.

5. Discussion and Conclusions

Applying the proposed procedure to a case study allowed us to identify the TOPSIS method as that which was best adapted to the evaluation of design proposals in the call for tenders to construct a new office building at the Chamber of Deputies in Rome.

During the case study, it was observed that the proposed procedure works better when used in contexts where there is a proper knowledge of MCDA methods. Furthermore, a basic knowledge of how to implement MCDA methods is required by the process manager. The process manager must understand fully the relationship between the most suitable MCDA methods when compared with the suitability and strength of the results for a specific decision-making problem. The implementation of the proposed procedure may prove difficult at times because of a low level of MCDA knowledge, especially in the context of settlement transformation processes. In order to promote a wider use of the procedure proposed in this paper, some upgrades could be useful. These could focus particularly on contexts where there is a low knowledge of MCDA.

Further developments to the proposed procedure could involve: (i) How to identify the relevant stakeholders in relation to the decision-making problem to be solved. (ii) How to attribute indices of importance to them, which truly represent their role in the decision to be taken. (iii) How the process manager can arrive at a final decision (choice of MCDA method) in contexts characterized by multiple stakeholders. (iv) An in-depth analysis of the selection and use of criteria weighing methods. (v) The formulation of guidelines to facilitate creating the framework of expected properties, even by people not particularly qualified in the field of MCDA [30].

As mentioned above, the examination of the decision-making problem in question and the evaluation query (plus the related evaluation objective), represent the main critical aspects when implementing the MCDA. It should also be observed that, during MCDA implementation, other critically important stages could be incorporated. These may include: (i) a definition of the specific objectives, the criteria, the sub-criteria and the indicators; (ii) the ability to obtain the input data needed to structure the problem; (iii) the capacity to implement and control the analysis and to study it in greater depth, in addition to defining the timeframe within which to resolve the evaluation query [73,74].

Author Contributions: The paper must be attributed in equal parts to the authors.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A. Input Level Calculation

"To define the input level, a score is assigned to each of the 4 parameters considered in relation to the required modeling effort (Table A1) and by creating an average of the scores attributed to the parameters. If the total score is less than 0.33, the input level is low. If the total score is greater than 0.33 and not higher than 0.66, the input level is considered average. If the result is higher than 0.66, the input level is high" [30].

Table A1. Weighing the modelling effort level in relation to the input level parameters.

Score to Be Assigned	Parameters of the Input Level Definition and Calculation			
	Data and Parameter Quantity (1)	Definition Time (2)	Skills and Level of Knowledge of the Decision Problem (3)	Use of Other Integrated Techniques (4)
1	High	Long	High	Necessary
0.5	Medium	Medium	Medium	Advised
0	Low	Short	Low	Unnecessary

Appendix B. Weighting of the Variables by the Options Considered Preferable to the Stakeholders

If the person responsible for the evaluation process opts for a weighting of the variables by the stakeholders grouped into categories, the index of importance (of each variable) for each category must be determined aggregating through mathematical media to define a synthesis result used for the implementation procedure [30].

The different indices of importance for each variable can be aggregated by averaging them, as follows:

- Simple, if all stakeholders are considered of equal importance;
- Weighted, if the stakeholders are considered of varying importance [74].

When selecting the most suitable MCDA method, the process manager can select the solution that is preferred by the stakeholders whose added indices of importance are greater than a specified threshold (related to a simple/relative/qualified majority and unanimity). The process manager can set this threshold in relation to the composition of the stakeholders being considered (an increasing threshold as the stakeholders' points of view rise) [30].

Appendix C. Determination Modality of the Framework of Expected Properties

To define the set of expected properties for each exogenous and endogenous variables must be filled (Table A2) [30] by deciding whether, for a given variable, each qualification is actually required or not ((A1a) and (A1b)):

$$\text{if EP(Vn;Qn) = request} \rightarrow \text{EP(Vn;Qn) = yes (1)} \quad \text{(A1a)}$$

$$\text{if EP(Vn;Qn) = no request} \rightarrow \text{EP(Vn;Qn) = no (0)} \quad \text{(A1b)}$$

Table A2. Table to define the expected properties.

Type of Variables	Weight	Variables	Qualification of Variables	Expected Properties in Relation to Decision-Making Problem
Exogenous	$0 \leq W \leq 1$	Number of evaluation elements	Limited number of criteria and sub-criteria and a small number of alternatives	Request = 1; Not request = 0
			Limited number of criteria and sub-criteria and a large number of alternatives	Request = 1; Not request = 0
			Large number of criteria and sub-criteria and a small number of alternatives	Request = 1; Not request = 0
			Large number of criteria and sub-criteria and a large number of alternatives	Request = 1; Not request = 0
	$0 \leq W \leq 1$	Typology of indicators	Quantitative	Request = 1; Not request = 0
			Qualitative	Request = 1; Not request = 0
			Mixed	Request = 1; Not request = 0
	$0 \leq W \leq 1$	Stakeholders to be included in the decision process	Participatory process not activated	Request = 1; Not request = 0
			Participatory process activated with a limited and specialized number of stakeholder	Request = 1; Not request = 0
			Participatory process activated with a significant number of stakeholder preferably organized in categories	Request = 1; Not request = 0
	$0 \leq W \leq 1$	Expected solution	Definition of n alternatives valid in relation to objectives	Request = 1; Not request = 0
			A better overall alternative definition for the purpose	Request = 1; Not request = 0
			The ideal alternative definition closest to the lens	Request = 1; Not request = 0
	$0 \leq W \leq 1$	Technical support of a Decision Aid Specialist	Yes (advisable)	Request = 1; Not request = 0
			No (not necessary)	Request = 1; Not request = 0
Endogenous	$0 \leq W \leq 1$	Type of decision-making problems	Sorting	Request = 1; Not request = 0
			Description	Request = 1; Not request = 0
			Ranking/Choice	Request = 1; Not request = 0
	$0 \leq W \leq 1$	Solution approach	Outranking approach	Request = 1; Not request = 0
			Full aggregation approach	Request = 1; Not request = 0
			Goal, aspiration or reference level approach	Request = 1; Not request = 0
	$0 \leq W \leq 1$	Implementation procedure	Preference thresholds, indifference thresholds, veto thresholds	Request = 1; Not request = 0
			Preference thresholds, indifference thresholds	Request = 1; Not request = 0
			Utility function	Request = 1; Not request = 0
			Pairwise comparison on rational scale and interdependencies	Request = 1; Not request = 0
			Pairwise comparison on interval scale	Request = 1; Not request = 0
			Pairwise comparison on rational scale	Request = 1; Not request = 0
			Ideal option and anti-ideal option	Request = 1; Not request = 0

Table A2. *Cont.*

Type of Variables	Weight	Variables	Qualification of Variables	Expected Properties in Relation to Decision-Making Problem
Endogenous	$0 \leq W \leq 1$	Input level	High	Request = 1; Not request = 0
			Medium	Request = 1; Not request = 0
			Low	Request = 1; Not request = 0
	$0 \leq W \leq 1$	Output typology	Partial ordering obtained by expressing pairwise preferences degrees	Request = 1; Not request = 0
			Total ordering obtained by expressing pairwise preferences degrees	Request = 1; Not request = 0
			Full ordering obtained by considering the scores	Request = 1; Not request = 0
			Full ordering with score closest to the aim assumed	Request = 1; Not request = 0
	$0 \leq W \leq 1$	Decision problem solution	*n* categories of alternatives of equal score but different behaviour	Request = 1; Not request = 0
			Alternative with the higher global score	Request = 1; Not request = 0
			Alternative with the closest score to the ideal solution	Request = 1; Not request = 0

Appendix D. The Calculation of the Overall Index of Suitability

Appendix D.1. Possible Configurations

The comparison between properties of each method with expected properties can generate 4 possible configurations ((A2a)–(A2d)) [30]:

$$\text{if } P(Tn;Vn;Qn) = 1;\ EP(Vn;Qn) = 1 \rightarrow SR(Vn;Qn) = 1 \tag{A2a}$$

$$\text{if } P(Tn;Vn;Qn) = 1;\ EP(Vn;Qn) = 0 \rightarrow SR(Vn;Qn) = 0 \tag{A2b}$$

$$\text{if } P(Tn;Vn;Qn) = 0;\ EP(Vn;Qn) = 1 \rightarrow SR(Vn;Qn) = 0 \tag{A2c}$$

$$\text{if } P(Tn;Vn;Qn) = 0;\ EP(Vn;Qn) = 0 \rightarrow SR(Vn;Qn) = 0 \tag{A2d}$$

Appendix D.2. Equation to Obtain Weighted Suitability Results (Partial Coherence Results)

To obtain weighted suitability result must be considered the suitability results and the weight of the variables [30]:

$$SRW = SR(Vn;Qn) * W(Vn)$$

where

SRW(Vn;Qn): weighted suitability results (partial coherence results);
SR(Vn;Qn): suitability results (partial coherence results);
W(Vn): weighting judgement expressed in Vn variable (between 0 and 1).

Appendix D.3. Equation to Obtain Index of Overall Suitability (Overall Coherence Index)

To obtain weighted index of overall suitability must be aggregated the partial coherence results.

If the variables are not to be weighted, the aggregate index of overall weighted suitability ISW(Tn) for each MCDA index is obtained via the equation [30]:

$$\mathrm{IS(Tn)} = \frac{\sum_{k=0}^{n} \mathrm{SR(Vn;Qn)}}{\mathrm{NVn}} \tag{A3a}$$

where

IS(Tn): index of overall suitability (overall coherence index);
SR(Vn;Qn): suitability results (partial coherence results);
NVn: number of variables considered.

If the variables are to be weighted, the aggregate index of overall weighted suitability ISW(Tn) for each MCDA index is obtained via the equation [30]:

$$\mathrm{ISW(Tn)} = \frac{\sum_{k=0}^{n} \mathrm{SRW(Vn;Qn)}}{\mathrm{NVn}} \tag{A3b}$$

where

ISW(Tn): index of overall weighted suitability (overall coherence index);
SRW(Vn;Qn): weighted suitability results (partial coherence results);
NVn: number of variables considered.

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