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A decision support system for measuring and evaluating solutions for sustainable development

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ABSTRACT

While sustainable development has long been a subject of study, only in recent years have international organizations, nations, regions and communities intensified their action towards it and engaged in efforts to make its principles operational. The attempts to design policies and strategies and define measuring instruments for implementing sustainable development and reducing the uncertainty of the implementation process have been not completely successful and have been mostly confined to the environmental dimension of sustainability. Innovative strategies, policies and measuring instruments need to be develop, starting from the elaboration of indicators and indices to monitor progress towards the sustainability goals. Several instruments are available in the scientific and technical field; however, no consistent methodology to measure sustainability accurately has yet emerged.This study proposes a methodology to measure sustainability across its three declinations: environmental, economic and social. The proposed methodology focuses on a multi-criteria evaluation framework based on the Utility Value Analysis technique, using predetermined criteria and a set of indicators, and it is supported by a web application that simulates multi-criteria decision-making processes. The aim is to provide decision makers with a flexible tool for evaluating investment projects in very different contexts, such as, for instance investment in physical or social infrastructures or culture. Results based on the application of the proposed methodology to ongoing investment projects show that the methodology can meet the needs for flexibility and simplicity in assessing and measuring sustainability.

1. Introduction

Sustainability measurement is a topic of discussion among researchers, policy makers, private individuals and other stakeholders [1, 2]. The debate has grown further with the adoption of the 2030 Agenda for Sustainable Development (Allen et al., 2018; [3]). The 2030 Agenda is an action program for people, the planet and prosperity, whose goal is to achieve a better and sustainable future for all. The 2030 Agenda presents 17 Sustainable Development Goals (SDGs), in a large action program for a total of 169 targets. SDGs aim to mitigate climate change, ecological degradation, and biodiversity loss, while pursuing economic and social goals such as reducing hunger or poverty. In fact, an alteration of the environmental balance can have effects on the economic and social welfare of the population (De Felice et al., 2022). Social and economic change also causes environmental impacts [4].The 17 SDGs and their targets have been designed to be monitored through a set of global indicators that are integral to the 2030 Agenda. The relationship between objectives and targets is a complex one. According to Scherer et al. [5] the achievement of social goals has a environmental impact. The definition of key strategic objectives can help to set priorities to be implemented (Zhou, 2017). Therefore, policy makers should rely on a better description of biophysical, social, and economic systems [6] and integrate with private stakeholders. Public and private stakeholders need to think systematically about the interactions between different SDGs and related indicators [7]. Due to the complexity of interdependencies between SDGs and their development indicators, interventions can be appropriately designed when synergies between different objectives have been identified (Ospina-Forero et al., 2019).

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Indicators are essential for measuring the sustainability of the proposed projects with the aim of pursuing the SDGs. The indicators depend on the country and a project to be evaluated. However, indicators provide a reliable source of data; for this reason, the indicators should be used to evaluate the performance of a project. On the one hand, there is the United Nations Statistical Commission with the high-level expert group on SDG indicators and the various repositories agencies. They shall cooperate with different stakeholders for the statistical coverage of the indicators organized around the system that classifies the official indicators of the United Nations SDGs according to their level of methodological development and data coverage. On the other hand, official statistical institutions and the scientific world contribute to the development of analytical tools for the performance of sustainable projects in relation to SDGs. Measuring the sustainability of projects proposed by public or private entities becomes important. In this context, measuring sustainability is a complex issue from a technical or political point of view. From a technical point of view, the presence of multiple frameworks, possible interpretations and the selection of indicators preclude a consensus on a "right" or "objective" method to measure the sustainability of a project [8]. The indicators depend on the country and a project to be evaluated as the complexity of projects increases, the number of indicators to be evaluated increases (Baffo et al., 2018). Different methods adopted could also lead to different results. The choice of an assessment method implies the formulation of appropriate assumptions. Therefore, any choice of methodology, and the choice of assumptions, affect the final assessment [9]. From a political point of view, the existence of multiple indicators and the possibility of achieving conflicting results in aggregating them creates a difficult situation to manage. On the one hand, it is necessary to communicate a clear message. On the other hand, a focus on a single analysis can be confusing, as the audience is confronted with different results. The idea of political integration with the private sector may be subject to differing interpretations [10]. Thus, it is necessary to develop comprehensive and objective assessment methods ([11]b). Consciously connecting policymakers with the private sector supports the achievement of global goals. In this perspective, the application of the digital paradigm is inevitable. Digitalization can provide analytical skills and facilitate the process of evaluating sustainable projects [12]. Taking into account the considerations above, this study provides a tool for the sustainability assessment. In particular, a web prototype is developed designed by simulating a multi-criteria decision-making process using the Utility Value Analysis (UVA) technique. The web prototype aims to provide a decision support system for measuring and evaluating solutions for sustainable development based on environmental, social and economic criteria. The web prototype design involved the collaboration of political and scientific bodies. When it comes to sustainability, neither economic nor ecological reductionism is possible. Since economic sustainability has an ecological cost and sustainability has an economic cost, an integrative framework to address conflicts, such as multi-criteria assessment, is necessary for measuring sustainability. The study is structured as follows. Section 2 describes the main measuring instruments for sustainable development; Section 3 is dedicated to the measurement methodology chosen and used in this study; Section 4 is dedicated to development of a web prototype for the evaluation of sustainable solutions and projects; Section 5 describes the results from the implementation of the methodology. Finally, the main conclusions are set out in Section 6.

2. Background on measuring instruments for sustainable development

As reported in one of the first analytical contributions to the measurement of sustainability [13] in 1968, 30 experts – including scientists, educators, economists, humanists, industrialists and national officials – from ten different countries gathered at the Accademia dei Lincei, in Rome, upon invitation by Dr. Aurelio Peccei, to discuss the situation of humanity. From this encounter, the Club of Rome was born. The goal of the club was to address some of the main problems that afflicted humanity, through a global and holistic vision. Dennis Meadows joined the Club of Rome on the recommendation of MIT professor Jay Forrester, and wrote the first public document on the measurement of sustainability under the title "Limit to growth" (1977). According to his thesis, if the growth of the main variables that characterize the world (for example, the population or the availability of food) continued at the same level as the one then observed, it would come to dangerously hit some limits. If these limits were exceeded, they would lead to the collapse of the world's population and industrial capacity. However, the thesis also argued, the growth of these parameters could be modified, thereby allowing humanity to achieve a sustainable ecological and economic balance in the future. If humanity decided to take this second scenario, the sooner the change of course would occur, the better the chances of success would be. The following 15 years were spent by scholars, politicians and industrialists investigating how to overcome the limits to development that had been brought to light by the Club of Rome. A positive vision of development evolved whereby global economic and technological development was deemed as the key to success in reducing the consumption rate of natural resources, encouraging intelligent processes of recovery and re-use. This vision, today, lies at the core of the theories of Circular Economy, which have developed since the 2000s. The quantification of sustainability has always been the subject of intense research, due to the complex and multidimensional nature of field of investigation underpinning the topic. This involves the assessment of economic, social and environmental variables. Another reason for the scientific community to study the phenomenon is the dynamism of the concept of sustainable development. In fact, it depends on temporal evolution, international policies and related human actions [14]. In a recent study [15], the authors highlighted the importance of the circular economy in terms of environmental and economic sustainability. The dynamic, multidisciplinary and complex aspect of sustainability suggests that project management is the most congenial tool for managing initiatives aimed at achieving sustainable goals [16]. However, public and private financing mechanisms for development projects often lead project managers to follow short-term cost/profit or cost/benefit logic, paying more attention to aspects related to the respect of time deadlines and methods of spending. On the contrary, they should aim at measuring the results that can be obtained in the medium to long term. Sustainability has a dimension of measurability also in private business contexts as proposed in the concept of the Triple Bottom Line (TBL or 3BL), coined in 1994 by John Elkington, whereby companies should work simultaneously on three different budget lines: the traditional economic one, the impact on society, and the impact on the environment. Thus, the sustainability of a company would be measured by its ability to undertake a continuous improvement of economic, social and environmental performance [17]. In fact, these concepts have become part of the business world through such tools as sustainability reports, environmental certifications, Materiality Analysis [18]. However, the public sector, supported by international cooperation, offers the wider context for pursuing global sustainability goals. The world mission declared in the 2030 Agenda by the Member States of the United Nations is a long-term commitment to safeguard, manage, cure, develop countries towards a more sustainable and universally accessible future for future generations [19]. In this sense, public expenditure promoted at international, European and Italian level should aim to implement projects in line with these objectives. In such a complex framework of environmental, social and economic interrelations, in order to preserve resources and guarantee social services and the well-being of citizens, planning and policy actions contributing to sustainable growth are needed [20]. To this end, monitoring systems should be implemented that predict the impact in the implementation of publicly funded projects and programs and measure the actual results once they have been completed.

To measure sustainability in organizational and business contexts, various models have been made by the scientific community. Bottani et al. [21] have created a tool based on fuzzy logic for the assessment of corporate sustainability. The fuzzy inference tool architecture has been incorporated into ad hoc software developed in Microsoft Excel. Zhao et al. [22] develops a theoretical framework within the data envelopment analysis context to examine the efficiency of sustainable development systems, using the Data envelopment analysis (DEA). Measurement systems currently use different types of indicators (Bibri et al., 2021; [23]). Phases have been taken at the European level to define a set of performance indicators applicable to public spending. However, the adoption of approaches adequately designed to measure the contribution of public expenditure programs to sustainability is still a long way off. The use of indicators to monitor and control the selection, implementation and conclusion phase of publicly funded projects and to ensure their alignment with sustainability objectives is one of the most important challenges. Currently, many resource allocation models for investment projects through selection of alternatives do not yet consider sustainability aspects and criteria such as “maximum return, minimum risk” are still preferred [24]. Until 2015, sustainability analysis has been applied by scholars to the life cycle of projects in the industrial sector [25] or in the construction sector [26–28]. The models that can be used for the analysis of sustainability and identified through a review of the literature are of a quantitative nature, for their ability to measure and compare the various aspects of sustainable development. Examples of these models include simulation models [29], economic models [30], quantitative models approved by policies [31]. However, since 2015 new models for the allocation of financial resources oriented towards sustainability have enriched the scientific literature. Most new models are focused on applying multi-criteria decision-making methods. In particular, Marcelino-Sádaba et al. [32] show the interrelations between sustainability and project management and outline a new conceptual framework for managing sustainable projects. Their study is based on the assumption that the products of a project must be developed according to sustainability criteria, and that projects must incorporate sustainable management processes, sustainability-oriented organizations, and project managers trained in sustainability. Dobrovolskienė and Tamošiūnienė [33] propose an interesting study that includes sustainability in the decision-making process of selecting a portfolio of projects, including the criterion of sustainability through the implementation of multi-criteria decision-making methods (MCDM). Multi-criteria Decision Analysis (MCDA) is a multidisciplinary approach that analyzes problems from multiple perspectives, such as economic, social, ethical, esthetic, environmental, and cultural. The heterogeneity of the objectives clearly entails a number of problems to be taken into account. They include the:

- not comparability of the measures of the objectives through which to evaluate the design assumptions;
- incompatibility between objectives, sometimes in conflict with each other;
- degree of uncertainty about projects, due to lack of reliable data and information
- concomitance in the analysis of quantitative and qualitative aspects.

Multi-criteria analysis overcomes the need to bring all measures back to a single dimension of judgment and evaluation, for example monetary. In fact, this type of analysis accepts the diversity of measures and gives a positive impact to a project, combined with its ability to contribute positively to achieving the goal [34]. The consequences of implementing a project analyzed with multi-criteria techniques could be tangible or intangible. Often, the difficulty lies precisely in measuring the positive effects of the project in the intangible aspects. Given the heterogeneity of objectives, it is often difficult to find solutions that can maximize profit or value on all objectives for all stakeholders in the assessment. Therefore, a combination of parameters must be found that will bring maximum benefits for some objectives in general, without leading to a deterioration of other objectives. However, there are some limitations to multicriteria analysis. The most debated ones are the behavior of the decision maker, which is not always attributable to a paradigm of logic and rationality; the existence of non-independent problems, the increase in complexity due to the number of objectives and greater difficulty of coherent and logical evaluation. Moreover, during the decision-making process there is usually an enrichment of the information that can lead to an update of the objectives/criteria. Multicriteria analysis is now used in various application fields, such as finance, planning, telecommunications, ecology, etc. Generally, MCDA is used in domains where it is not possible to directly apply an optimization method, since there are many criteria for decision taking. Some of the most widely used MCDA methods are the Analytical Hierarchy Process (AHP), Multi-Attribute Global Inference of Quality (MAGIQ), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), Utility Value Analysis (UVA), and more.

In the field of organizational sciences and informatics, multicriteria analyses are often included within more complex Decision Support Systems (DSS). The DSSs cover a wide range of systems, tools, methods and technologies to support decision makers in decision making. Generally DSSs are implemented to solve unstructured and complex problems, characterized by multiple objectives even conflicting with each other, certain or estimated measures, data and information in the making and not easy to find. DSSs may include optimization and simulation models, such as cost-benefit or cost-profit analysis methods, as well as multicriteria analysis. The Decision Support System proposed in this study includes a tools of project management and functional to frame the project in the context where it will be carried out and at the historical moment in which it is evaluated its feasibility. The multicriteria analysis proposed is based on the Utility Value Analysis (UVA) technique and is aimed at supporting the decision-maker in making a sustainability assessment of a project based on predetermined criteria based on sustainability indicators.

3. Materials and methods

As part of the study, a project to be evaluated can be an investment alternative, a program of cultural enhancement, an economic commitment whose impacts will affect the parameters of sustainable development. The projects to be evaluated are complex and related to infrastructure, territorial cohesion, environmental protection, health, productive activities. The main role of the evaluation is to improve design and direct designers towards more efficient and effective solutions. This role generally has two connotations. One is related to data and information reading and one is related to decision making. Decision support tools use data to make the decision easier and more immediate. This applies even if the decision is based on elements of a qualitative, quantitative and multidisciplinary nature. The proposed decision support tool for the process of evaluating projects in terms of sustainability provides for the implementation of the UVA. This is a quantitative method that estimates the value of the benefits generated by an intervention based on the improvement it produces [35–37]. The UVA shall provide operators with information that they can use to assess the financial impact of an intervention ([38]; Wu, 2020). The analysis consists in identifying the areas of greatest functional impact of the project investments, highlighting the necessary and required functions that can meet the project needs. Moreover, in relation to function value indices, the analysis consists in suggesting alternative solutions, within the limits compatible with the required performance levels. The UVA method analyzes a series of complex alternatives, with the aim of sorting them according to the preferences of the decision maker in a multidimensional target system. Sorting is carried out by calculating utility values for alternatives. In the Utility Value Analysis, multiple target criteria are weighted according to their importance to the decision maker. In particular, the ability of the different alternatives to fulfill each objective is measured. The alternatives analysed are investment projects. In addition, a corresponding Partial Utility Value is provided.

3.1. Utility value analysis

Weighted partial utility values are summed to get a total value for each alternative (the utility value). For each alternative, the aggregation of partial utility values allows to compensate unfavorable results on a target measure with better results on other target measures. If certain criteria have minimum requirements, they must be met before a Utility Value Analysis (UVA) is performed. In fact this methodology does not allow a value of null judgment on the alternatives. The UVA consists of the following phases:

1 Phase#1 – Determination of criteria.
2 Phase#2 – Weighting of criteria.
3 Phase#3 – Calculation of partial utility value.
4 Phase#4 – Calculation of total utility value.
5 Phase#5 – Assessment of the total value.

Fig. 1 summarizes the phases of UVA in graphic form.

3.1.1. Determination of criteria

In the first phase of the utility value analysis, the determination of the target criteria is performed. The determination of the criteria requires careful structuring and analysis of the evaluation system according to the type of project. During this phase a measuring scale (which can be nominal, ordinal or cardinal) is required for each criterion. Consideration of project attributes should not be duplicated by applying more than one criterion per attribute. Moreover, the extent to which an investment project fulfills an objective criterion should be measured independently of the assessments made for other criteria. Monetary criteria are not normally included in a utility value analysis. Incoming and outgoing cash flows, or returns and expenses, are typically affected by many characteristics of investment projects that fall under some of the other two criteria. Therefore, the determination of the criteria requires careful structuring and analysis of the evaluation system according to the type of project. For the proposed decision support system, it is possible to enter a maximum of 12 criteria derived by the 2030 Agenda; specifically they are:

- a maximum of 6 for environmental sustainability aspects;
- a maximum of 3 for social sustainability aspects;
- a maximum of 3 for aspects of economic sustainability.

Examples of criteria that can be used for the assessment of investment projects in terms of sustainability can be: (i) climate change mitigation; (ii) climate change adaptation; (iii) sustainable use and protection of water and marine resources; (iv) health and well-being; (v) quality education; (vi) gender equality; (vii) economic growth. The criteria may be chosen from those proposed by Istat, the Italian National Institute of Statistics. Istat is a public research body present in Italy since 1926 and is the main producer of official statistics in support of citizens and public decision-makers. Istat is called upon by the United Nations Statistical Commission to play an active role of national coordination in the production of indicators for the measurement of sustainable development and the monitoring of its objectives. Periodically, Istat presents an update of the statistical measures useful for monitoring the Sustainable Development Goals of the 2030 Agenda. Every year Istat publishes the Report on the SDGs. Widespread statistical measurements are 367 (of which 338 different) for 138 UN-IAEG-SDGs indicators. istat

3.1.2. Weighting of criteria

In the second phase of the utility value analysis, a weighting is determined for each criterion in order to classify its importance for the decision maker. The choice of assigning more indicators to the single criterion derives from the frequent difficulty of finding data and measure useful to feed the indicators themselves, offering a range of measures can therefore be useful for the evaluation of the criterion. For each criterion is also defined the case of Benefit or Cost going to differentiate the cases in which the criterion is to be maximized or minimized. The weight attributable to each criterion can vary from 0 to 10, if the weight is equal to 0 it means that criterion is not applied in the decision-making process implemented for the evaluation of the project in question. If the weight is equal to 10 it means that the criterion assumes a maximum importance in the evaluation of the project.

3.1.3. Calculation of partial utility value

In the third phase, alternative projects are assessed against each criterion. Depending on the case, a nominal scale, ordinal or cardinal is assigned. The assessment is expressed in terms of the expected impact of the project on the criterion considered, taking into account the measures/indicators concerned by the criterion. Therefore, the results are transformed into partial utility values for each design alternative evaluated on the basis of the final criteria in the previous phase. In the case proposed, 5 levels of judgment are chosen [36]. Each assessment criterion has characteristics with a positive influence. However, different characteristics need to be considered as they have different effects on the achievement of the objectives. The following judgment and scores were applied in the analysis. The judgment and score are expressed in terms of the expected impact of the project with respect to the considered criterion, taking into account the measures/indicators envisaged for the criterion itself.

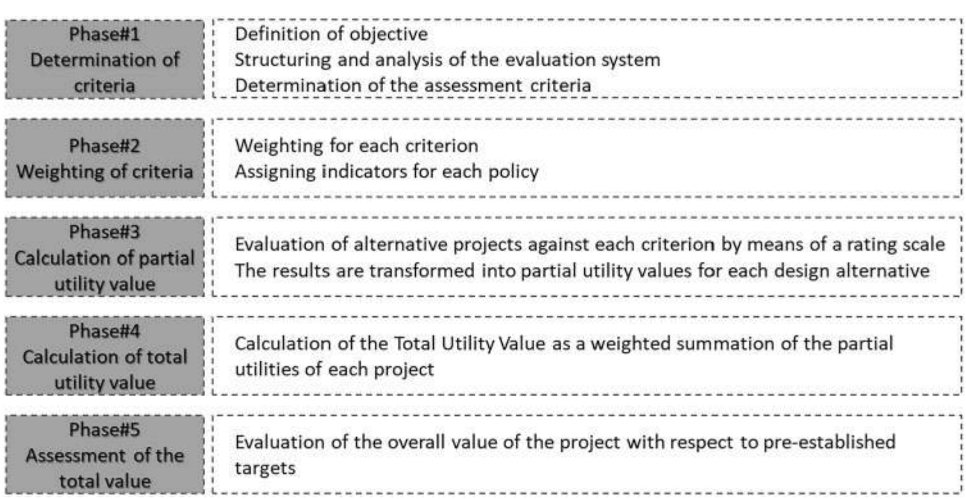

Fig. 1. Implementation phases of the utility value analysis.

The levels of judgment are summarized in Table 1.

3.1.4. Calculation of total utility value

In the **fourth** and last phase, a Total Utility Value (TUV) is calculated as a weighted sum of the partial utilities of each project compared to the final criteria weights in the previous phase. Finally, an assessment of the overall value of the project is carried out using the following definitions:

- The value of a project can be evaluated according to a scale of sustainability values (analysis of the absolute value established with respect to pre-established targets).
- The value of a project can be compared with an alternative investment project and the project can be considered preferred if its utility value is higher than that of any alternative project (relative value analysis).

Alternative projects must be evaluated against the same criteria and the same weights to the criteria.

The implementation of the method was applied to a web platform prototype. UVA was implemented by creating a web application capable of simulating multicriterial decision making. The aim is to offer a flexible tool for evaluating projects in very different contexts (for example, investment initiatives in infrastructure, culture or social sciences).

4. Design of a web prototype for the evaluation of sustainable solutions and projects

The development of the web prototype is based on the UVA method. The impacts are initially measured in different units of measurement. Subsequently, the impacts are transformed into dimensionless (normalized) quantities, in order to be compared. This transformation takes place through various value functions, one for each evaluation criterion. Therefore, the initial impacts are transformed into values representing the partial utility associated with the criterion, expressed as a score relative to the degree of pursuit of the specific objective. Once the partial utility value has been calculated for each criterion, the criteria are aggregated and each criterion is weighted. The weight assigned reflects the relative importance of that criterion in the system of global preferences. In this way, the partial utilities weighted by the various criteria are obtained. The partial utilities are then summed up to obtain the total utility of a given design alternative, to highlight its overall validity. The weight attributable to each criterion can vary from 0 to 10, if the weight is equal to 0 it means that criterion is not applied in the decision-making process implemented for the evaluation of the project in question. If the weight is equal to 10 it means that the criterion assumes a maximum importance in the evaluation of the project in question.

4.1. Computation algorithm for simulating evaluations

The computation algorithm consider the three dimensions of sustainable development, which are environmental, social and economic sustainability. Considering the dimensions of the concept of sustainable development, a weight is assigned to each dimension. This weight is defined as P_j^{env} with $j \in \{1,2,3\}$, where the value 1 indicates the environment dimension, the value 2 indicates the social dimension and the value 3 indicates the economic dimension. The weight P_j^{env} assumes integer values between 0 and 10, in order to define the impact of the dimension in the calculation of the TUV index. In particular, if $P_j^{env} = 0$, the dimension is not included in the assessment. From the weight, the relative weight of each dimension is determined, such that the sum of the weights of the dimensions is equal to 1. The relative weight of each dimension is expressed through Eq. (1).

Table 1
Levels of judgment for criteria evaluation.

Level	Judgment	Score
1	Weak (W)	2
2	Reasonable (R)	4
3	Good - Neutral (G)	6
4	Very good (V)	8
5	Excellent (E)	10

$$P_{j_{rel}}^{env} = \frac{P_j^{env}}{\sum_{j=1}^{n} P_j^{env}} \tag{1}$$

Eq. (1). Calculation of the relative weight associated with each dimension of sustainability

For each dimension, a fixed number of criteria is established. Therefore, the weights associated with the criteria for each dimension are determined. Specifically, they are expressed through Eq. (2).

$$P_{ij}^{cr} \text{ with } i \in \{1, \ldots, 6\} \text{ for } j = 1 \text{ environmental dimension} \tag{2a}$$

$$P_{oj}^{cr} \text{with } o \in \{1, \ldots, 3\} \text{ for } j = 2 \text{ social dimension} \tag{2b}$$

$$P_{zj}^{cr} \text{with } z \in \{1, \ldots, 3\} \text{ for } j = 3 \text{ economic dimension} \tag{2c}$$

Equation 2. Calculation of the weights associated with the criteria for each dimension of sustainability

Like the weight P_j^{env}, the weights associated with the criteria P_{ij}^{cr}, P_{oj}^{cr}, P_{zj}^{cr} may also have an integer value varying between 0 and 10. If one of these three relative weights assumes a zero value ($P_{ij}^{cr} = 0$ or $P_{oj}^{cr} = 0$ or $P_{zj}^{cr} = 0$), then the null value criterion is not taken into account for evaluation. At this point, the relative weight of each weight associated with the criteria is determined, through the following Eq. (3).

$$P_{\cdot j_{rel}}^{cr} = \frac{P_{ij}^{cr}}{\sum_{i=1}^{n} P_{ij}^{cr}} \quad \begin{array}{l} \text{for } j = 1 \text{environmentaldimension} \\ \text{for } j = 2 \text{socialdimension} \\ \text{for } j = 3 \text{economicdimension} \end{array} \tag{3}$$

Eq. (3). Calculation of relative weight of each weight associated with the criteria for each dimension of sustainability

From the relative weight of each scope and the relative weight of each criterion for each scope, it is possible to calculate the influence of each criterion in the evaluation process. It is defined by the product of the weight of each criterion (Eq. (3)) relative to the weight of the reference dimension (Eq. (1)), as shown below by the following equations (Eq. (4)).

$$P_{\cdot j}^{TUV} = P_{ij_{rel}}^{cr} \cdot P_{j_{rel}}^{env} \tag{4}$$

Eq. (4). Calculation of the influence of each criterion for the dimensions of sustainability

For each project p and for each evaluation parameter, an impact V is assigned, based on a scale including values of 2, 4, 6, 8, 10 (Table 1), with $V_{max} = 10$ and $V_{min} = 2$. This scale (Table 1) discreetly measures the impact of the parameter under consideration. Depending on whether the parameter is attributable to a cost (to be minimized) or a benefit (to be maximized) is normalized in the following way. Relating to benefits, the impact is calculated through Eq. (5).

$$V_{\cdot jp}^{eff} = \frac{V_{ijp}}{V_{max}} \tag{5}$$

Eq. (5). Calculation of actual impact of each indicator with respect to its dimension relative to the project – benefit

For costs, the impact is calculated through Eq. (6).

$$V_{\cdot jp}^{eff} = \frac{V_{min}}{(V_{min} + V_{max}) - V_{ij}} \tag{6}$$

Eq. (6). Calculation of actual impact of each indicator with respect to its dimension relative to the project – cost

$V_{\cdot jp}^{eff}$ is defined as actual impact of each indicator (i, o, z) with respect to its dimension j relative to the project p; V_{jp} is defined as impact of each indicator (i, o, z) with respect to its dimension j relative to the project. Finally, V_j represent impact of each indicator (i, o, z) with respect to its dimension j. These equations are formulated with the aim of maximizing benefits and minimizing costs. The TUV value of each dimension is obtained as the sum of the products between the actual evaluation of each parameter and the relative weight associated with it. The relative TUV value of each dimension is expressed by Eq. (7).

$$TUV_j = \sum_{i=1}^{n} \left(V_{ij}^{eff} \cdot P_{ij_{rel}}^{TUV} \right) \quad \begin{array}{l} \text{for } j = 1 \text{environmentaldimension} \\ \text{for } j = 2 \text{socialdimension} \\ \text{for } j = 3 \text{economicdimension} \end{array} \tag{7}$$

Eq. (7). Calculation of relative Total Utility Value value of each dimension

The TUV index of the project is determined as the sum of the utility values attributable to the 3 dimensions (Eq. (8)).

$$TUV = \sum_{j=1}^{n} TUV_j \tag{8}$$

Eq. (8). Calculation of Total Utility Value index of the project

4.2. Evaluation of project sustainability

The project is evaluated according to the value assumed by the TUV index on the pre-assigned scale according to the range of values. The TUV index is calculated by the algorithm presented in Section 4.1. For the problem to be sustainable, there is a sustainability threshold, which is 0.2. If the TUV index obtained by the algorithm is less than 0.2, the project is not sustainable and therefore not acceptable. The project becomes acceptable once the threshold is exceeded. In particular, as the TUV index increases, the sustainability of the project also increases. If the TUV index is within a range of values ranging from 0.2 to 0.6, then the project is less or average sustainable. If the TUV index is within a range between 0.6 to 0.9, the project is sustainable. Finally, if the TUV index equals or exceeds the unit value, then the project is more than sustainable. The desirable sustainability values for a project have a TUV index greater than 0.6. A detail of the sustainability values that depend on the TUV index is shown in Fig. 2.

Project evaluation	Index value
Very sustainable	$TUV \geq 1$
Sustainable	$0.6 < TUV \leq 0.9$
Average sustainable	$0.5 < TUV \leq 0.6$
Less sustainable	$0.2 < TUV \leq 0.5$
Unsustainable	$TUV \leq 0.2$

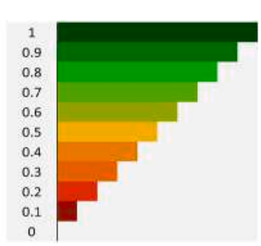

Fig. 2. Sustainability ranges according to the TUV index.

5. Results and discussion

5.1. Experimental scenario: the web application prototype

The web application prototype developed is deployed on a private server and designed according to a client-server logic. The web application needs three basic figures, which are as follows.

- **Administrator**, user with permissions to create designer and evaluator profiles and create new evaluation games on projects uploaded by the same administrator. The Administrator can associate to each evaluation game one or two projects to evaluate, a designer and one or two evaluators.
- **Designer**, user with the permissions granted by the administrator, then for the only games enabled by the Administration has the task of entering the "weights" for the criteria selected for the evaluation of the or the projects associated with the game;
- **Evaluator**, user with the permissions granted by the Administration, then for the only games enabled by the Administration has the task of inserting the assessments with respect to the criteria selected for the evaluation of the project or projects associated with the game.

The application prototype foresees the possibility to carry out simulations (games) of evaluation of one or two projects in terms of sustainability, each time defining:

- the project or projects to be evaluated (maximum 2 per game);
- the assessment criteria (maximum 6 for the environmental dimension, maximum 3 for the social dimension and maximum 3 for the economic dimension). Each criterion can be associated with one or more sustainability indicators;
- subjects with the role of designer (1 for each game);
- subjects with the role of evaluators (maximum 2 for each game).

When the Administrator chooses the Designer and the Evaluator, Administrator must choose people with technical skills in sustainability, since the Designer and the Evaluator are responsible for defining the indicators, criteria and weights of the criteria. This aspect is very important especially for the selection of the Designer. In Fig. 3, a graphical diagram of the implementation phases is shown. In the third phase, the Administrator creates the evaluation game by accessing one or more projects to be evaluated (inserting in the appropriate form the title of the project), one Designer and one or two Evaluators.

As shown in Fig. 3, the development of the simulation involves specific steps once logged in by the Administrator to the login screen to the system (Fig. 4).

The first phase involves the identification of one or more projects to be evaluated and the project profile is created by Administrator. In this phase, it is possible to collect data, material, information about the stakeholders and the risks, uploading the information as attachments to the project documents. These materials and information can be viewed by the Designer and the Evaluator associated with each evaluation game of the project at hand. The second phase involves the creation of the Designer and Evaluator profiles by the Administrator. The creation of the profiles requires the insertion of the personal data of the user to be configured: name, surname, username, email, password. It is also possible at this phase to specify the type of role (i.e., Evaluator or Designer). Then, activation email is sent consisting user ID and password. In Fig. 5 the creation of the Designer and the Evaluator profile is shown.

A fourth phase can then be implemented. The Designer associated with the game and appointed by the Administrator can access the personal area. Then the Designer inserts the project evaluation criteria, weights and the sustainability indicators deemed useful for the measurability of the criteria (taken from the Istat report). Moreover, each criterion is associated with a weight and a qualification of benefit or cost. The weight can vary in a scale from 0 to 10, depending on the importance that the Designer intends to give to the criterion with respect to the pursuit of sustainability objectives of the project. The qualification is used to determine whether the expected usefulness should be maximum in the case of benefit or minimum in the case of cost. Fig. 6 shows the evaluation screen: A1-A6 criteria are associated with the environmental dimension; the S1-S3 criteria are social, while the C1-C3 criteria are economic dimension criteria. For each criterion, there is a module related to their description, where the criteria chosen by the Designer are inserted.

The Evaluator accesses the personal area and evaluates the project initiative. Evaluator has to express a judgment according to the criteria defined by the Designer. For the evaluation, the Evaluator uses the same rating scale (from 0 to 10) with respect to each sustainability criterion. Also in this case, the Evaluator is required to enter an opinion about the

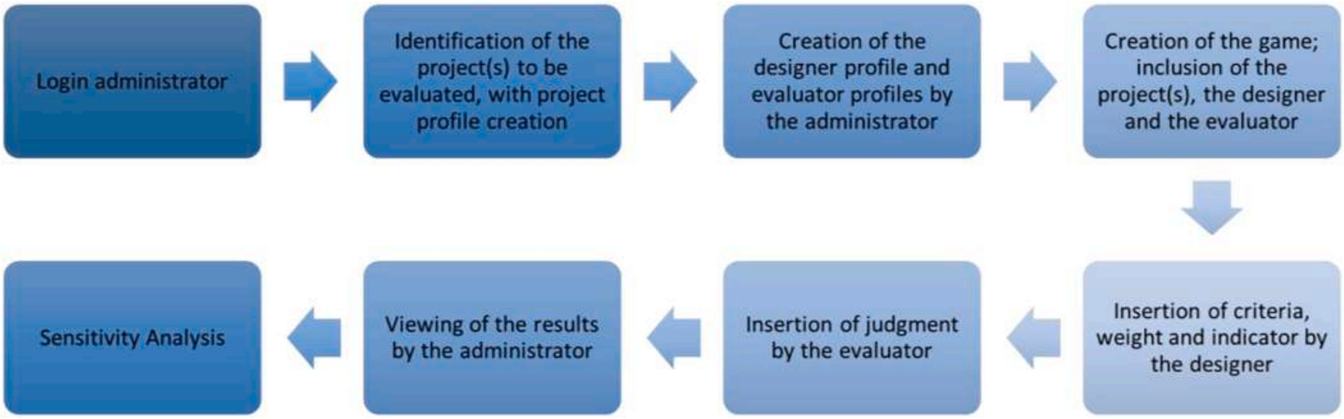

Fig. 3. Operation phases of the web application.

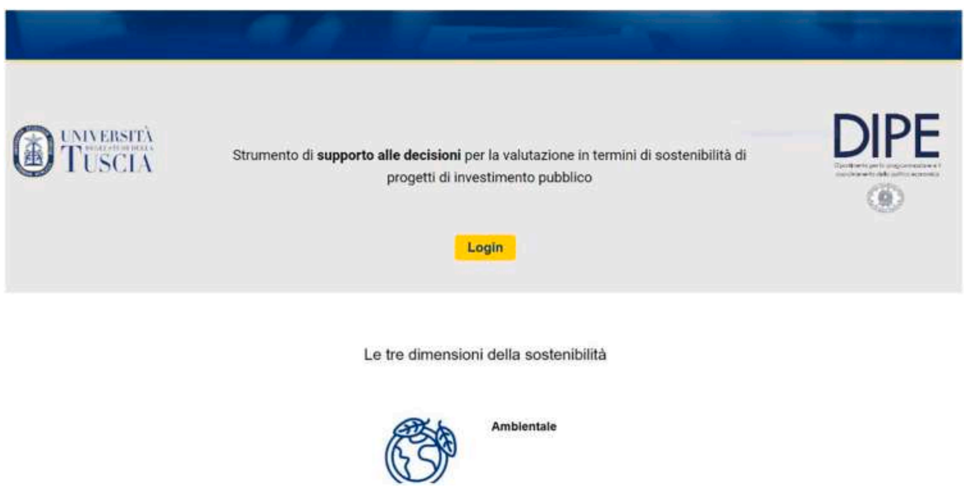

Fig. 4. Web application prototype home page.

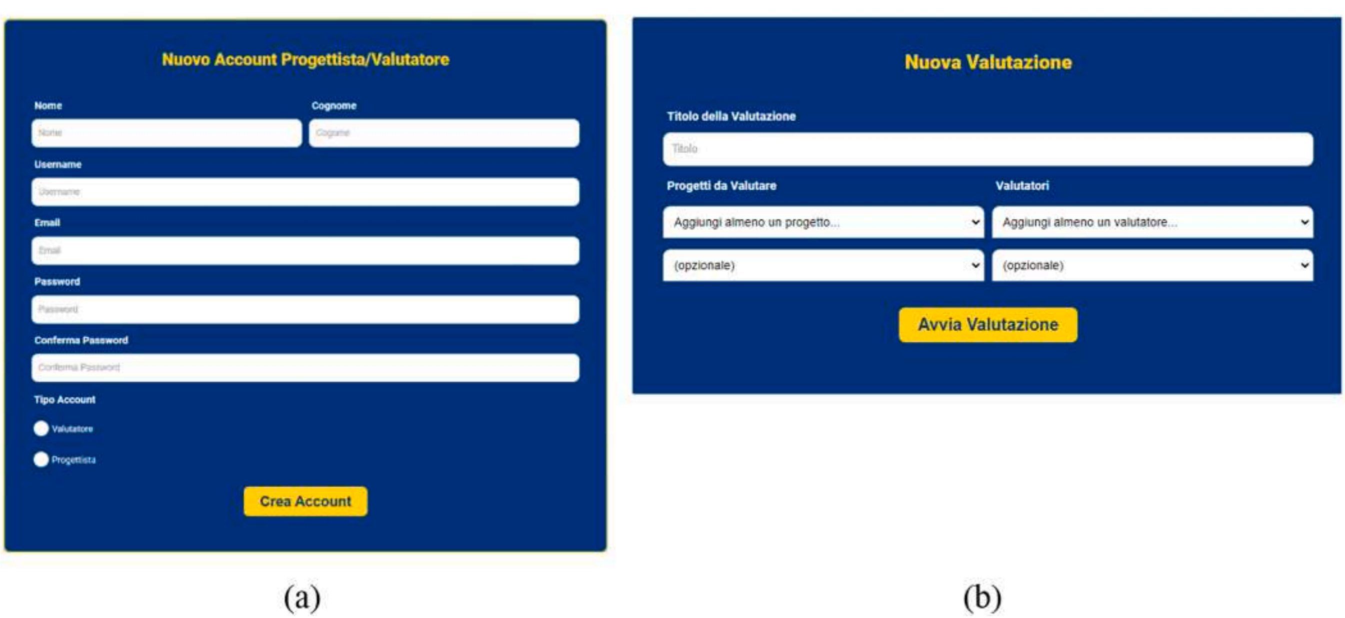

Fig. 5. (a) Creation of the designer/evaluator profile; (b) Start game evaluation.

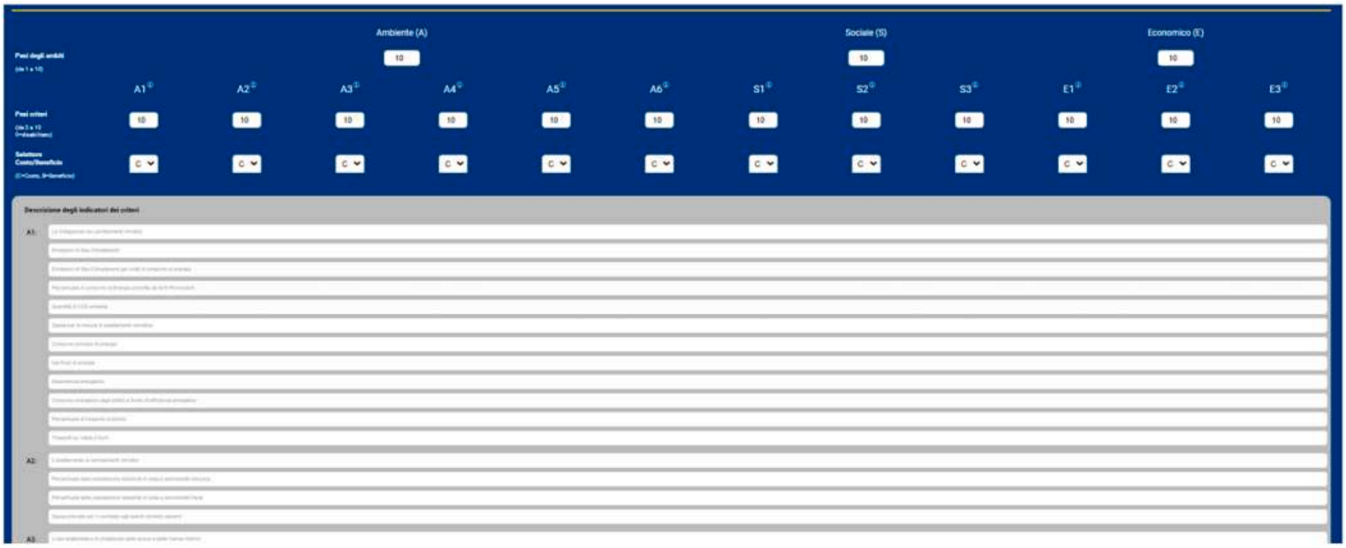

Fig. 6. Insertion of designer weights.

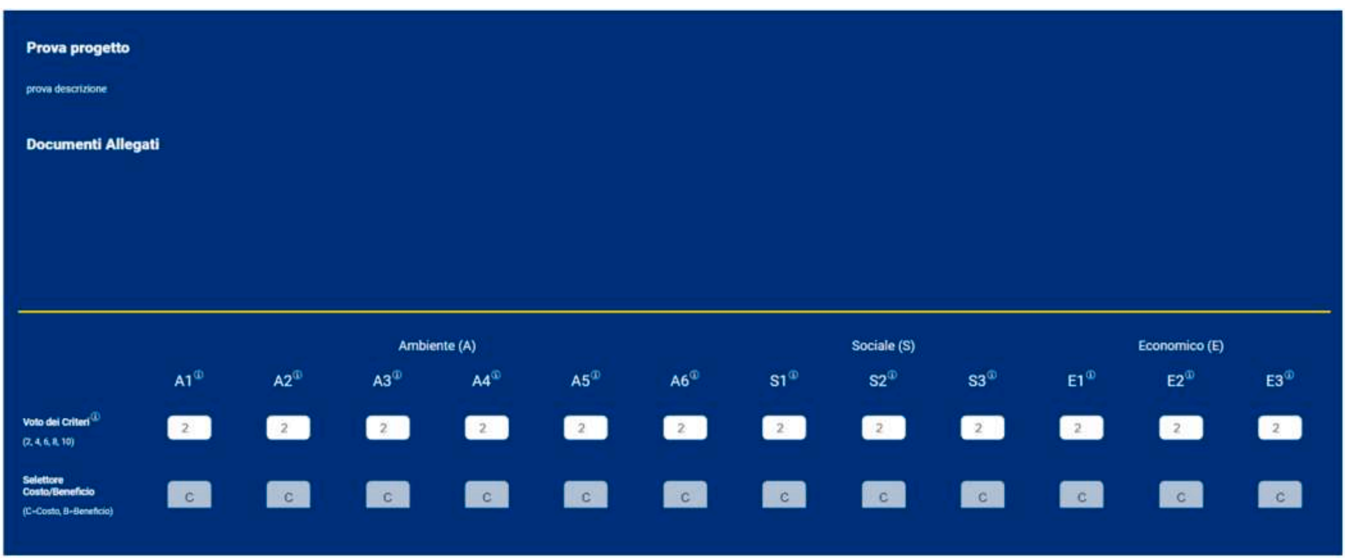

Fig. 7. Insertion of evaluator reviews.

criteria A1-A6 related to the environmental dimension, S1-S3, associated to the social dimension, and C1-C3 concerning the economic criteria, as shown in Fig. 7.

Once the Designer and the Evaluator have made their judgments, in the next phase the Administrator receives notification that the Designer and the Evaluator have completed their task. Then, the Administrator can access their personal area and view the outcome of the evaluations. In particular, the outcome of the evaluations is obtained through the implementation of the previously presented algorithm (Section 5.1). Then, the Administrator can view the numerical result obtained by the algorithms and can also display the Total Utility Value on a graphical level. The Total Utility Value is obtained and attributed to the project, and the Administator will be in a position to instantly detect the level of sustainability of the project against the predefined criteria.

An application example is shown below.

If two decision makers are asked to make judgments, each of them fills in the appropriate form, inserting the weights to each criterion, as shown in the following Table 2.

Through the computational algorithm, we obtain the partial utilities and the overall utility, reported in Table 3 from which the overall evalutation is calculated.

The total value (TUV) obtained is equal to 0.336 and is in the range between 0.2 and 0.5. Therefore the judgment to the project is "Less sustainable". An example showing the total value of the obtained utility

Table 2
Weighting assignments of two decision makers to criteria for each dimension.

	Environmental dimension criteria						Social dimension criteria			Economic dimension criteria		
	ENV1	ENV2	ENV3	ENV4	ENV5	ENV6	SOC1	SOC2	SOC3	ECO1	ECO2	ECO3
Decis. Maker 1	2	4	8	8	6	2	2	4	2	4	4	2
Decis. Maker 1	4	2	6	6	4	4	4	4	6	2	4	6

Table 3
Partial and total Utility value, related to the weight assignments of two decision makers and overall evaluation.

Partial Utility Value				Total Utility Value
	Environmental dimension	Social dimension	Economic dimension	
Decis. Maker 1	0.11	0.09	0.11	0.310
Decis. Maker 2	0.09	0.14	0.13	0.362
Overall evaluation	**0.10**	**0.11**	**0.12**	**0.336**

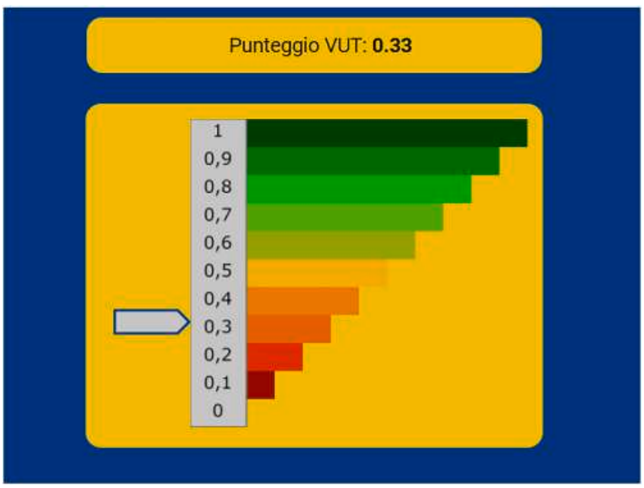

Fig. 8. Final utility value view.

is shown in Fig. 8.

5.2. Sensitivity analysis and overall remarks

The evaluation concludes with phase 7, which consistes of sensitivity analysis. This provides valuable support for decision making, especially through the assessment of the robustness of the decision taken. In fact, a decision is all the more robust when it does not change with the variation of some of the data upon which the decision was taken. Moreover, thanks to this type of analysis, it is possible to understand which data can be neglected, either because they are not material to the determination of the solution or because even small fluctuation of their value determine a variation of the decision taken. In the specific case of the proposed decision-making supporting tool, sensitivity analysis can be implemented at two levels. The first level concerns the weighting of criteria and the second level is the assessment of solutions against criteria. The more a decision remains unchanged as the parameters of the decision-making process change, the more robust the decision turns out to be. In the proposed model, it is not so important to perceive the absolute value of utility as the variables vary; on the contrary, it is important to understand if the evaluated project remains within the sphere of absolute or relative sustainability. Thanks to the sensitivity analysis, it is also possible to reduce the impact of subjectivity in the evaluation and in the attribution of weights to the criteria In fact, subjectivity can be reduced by repeating the evaluation on several decision-makers. If the resulting value remains within the sphere of sustainability, the solution appears robust with respect to the subjectivity dynamics of the judgment and the design of the system. Therefore, as a last step, the Administrator user performs sensitivity analysis by starting a new game on the same project to see how sensitive this is to changes in judgment and/or weight of criteria. The aim is to assess the robustness of the decision resulting from the assessment process. If the project remains in the green dimension of sustainability despite the change of the Designer, the Evaluator and the parameters entered by them, then the sustainability statement of the project proves to be strong and robust.

On the subject of sustainability, there is a lot of complexity and confusion. First, most applications are inherent in the industrial sector. An example of a more recent model is proposed by Bottani et al. [21]. The web application developed allows a possible reduction of this complexity and deficiency, necessary for management and project interventions in the public sector. The choice of indicators to be used in multi-criteria systems is of fundamental importance, as often some indicators are improving for the analyzed project, while others are pejorative, due to possible interference between the three dimensions. This is the classic conflict situation dealt with in multi-criterium decision theory. It should be noted that the construction of any assessment model depends on very strong assumptions about the purpose of the assessment (for example, a given sector in which the project is included), the scale of analysis, the set of dimensions (economic, social, environmental etc.), objectives and indicators used for the evaluation process. The potential of the proposed application model lies in the fact that, among the multi-criteria methods, UVA considers quality, use and value as fundamental attributes of evaluation. According to a certain purpose of evaluation, which depends on the type of public offering to be evaluated, uses this scientific method to analyze and evaluate the three fundamental dimensions of the quality, utility and value of the object of assessment returns a high level of quality. Above all, it allows you to adapt this model to all types of public and private projects.

6. Conclusions

In this study, a model has been developed for the evaluation of sustainable development projects consistent with the objectives set out in Agenda 2030. The multicriteria analysis integrated with the UVA method has been implemented through a prototype web application. This implementation has been conceived to allow for a rapid learning and use of the tool by institutional subjects called to express a judgment in terms of sustainability with respect to the different investment projects. The study of the literature in the field of sustainable development has highlighted the need to develop tools to support the sustainability assessment decisions of alternative public investment projects. This has therefore been the main objective of the study, which has eventually led to the creation of a prototype web application of simple use and immediate transferability for the evaluation of complex projects relating to all dimensions of sustainability. At the scientific level, a further study can be done by simulating a decision-making process parallel to the sustainability assessment of the projects presented in this study, implementing other multi-criteria techniques (e.g., AHP or TOPSIS) the impact on the decision of the applied method can be verified. This research progress also serves to validate the tool provided on a wider range of cases than the one for which the tool was tested. A period of use and testing of the tool on a wide range of projects would be useful and desirable. This would make possible to verify its functioning and also to create a database of evaluations, criteria and indicators used for the evaluation process. It would also be interesting to develop research to understand whether the use of additivity and compensation of the synthetic utility indicator in terms of sustainability may be envisaged for the selection of a portfolio of projects (for example, in the implementation of an investment project) At present, the proposed instrument appears to meet the needs for flexibility and simplicity. However, the greatest limitation in the use of the instrument is inherent in the mindset of the designer and the Evaluator. Although it is easy to insert a judgment in the instrument (for example equal to the value 4), it is not always easy to get to the cognition of this value.. The assigned value can be determined by the personal training of the Designer or Evaluator. As argued by

Silvius (2016), taking responsibility for sustainability requires adequate skills. In order to use the proposed instrument, training for the development of appropriate skills is necessary. Competencies must also be acquired to propose projects that have the characteristics suitable for a sustainability analysis. Specific training and skills are needed to understand what data can be used for indicators. In other words, training and skills are essencial to understand what interdependencies and impacts may derive from a proposed public investment project. Correct implementation of policies in terms of sustainability should include widespread training on sustainability priniciples. Such training should be offered to applicants of investment project initiatives (for example, they should be prepared to use formats reporting measures that can be used as indicators), and to evaluators who are responsible for assessment and should refine their assessment techniques over time. An experimental period could allow for field training of operators, to avoid their judgement being influenced by personal training. In addition, an experimental period may be useful to create a historicity of data and information to be used with new methods, best practices and approaches transferable in other contexts.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

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