Evaluation method for climate change mitigation instruments

Popi A. Konidari*

National and Kapodistrian University of Athens
Department of Informatics and Telecommunications
pkonidar@kepa.uoa.gr

Abstract. AMS is a specially developed evaluation method for climate policy instruments. The same method properly modified is also used for the evaluation of climate policy interactions. The method is a combination of three standard multi-criteria methods, AHP, MAUT and SMART. The criteria-tree and the interactions-tree of the method are structured according to the classification of the design characteristics of the climate policy instruments. The first tree reflects the framework under which climate policy makers proceed with the design and implementation of a climate policy instrument. The method has been applied for evaluating the performance of EU-ETS in eight EU member States and the overall interaction of two pairs of climate policy instruments, EU-ETS and IPPC, EU-ETS and RES under the Hellenic framework.

Keywords: Climate mitigation policy, evaluation, criteria, policy interactions, emission trading schemes, policy instruments.

1. Introduction

Several countries have implemented a spectrum of climate policy instruments (such as green taxes, negotiated agreements, emission trading schemes, green certificates etc) without being able to fully understand their effectiveness. Until now only qualitative evaluations were performed so as to provide an insight of the effectiveness of these instruments [2]. The aim of this thesis is the development and implementation of an appropriate tool that will assist climate Policy Makers (PMs) in performing quantitative evaluations using criteria that reflect their preferences and those of involved stakeholders. The quantitative evaluation of their overall interactions is also a significant component in understanding their performance since interactions can increase or decrease the effectiveness of climate policy instruments [1, 2].

This tool is a new evaluation method, named AMS from the initials of the three standard Multi-Criteria Analysis (MCA) methods that it incorporates. AMS is a

* Dissertation Advisor: Dimitrios Mavrakis, Associate Professor

combination of the Analytical Hierarchy Process (AHP), the Multi – Attribute Theory (MAUT) and the Simple Multi – Attribute Ranking Technique (SMART). AMS method was adjusted properly for assessing also aggregately climate policy interactions. In both types of the method AMS, AHP is used for determining weight coefficients for criteria, sub-criteria and the different forms of interactions, while MAUT and SMART for grading the performance of the climate policy instruments, the type and extent of interactions under criteria/sub-criteria. The AMS method allows the recognition of the weaknesses and the strengths of the evaluated policy instruments and identifies the most effective one of them [1, 2, 4].

2 The AMS method

The method consists of four (4) basic steps. First - creation of the criteria-tree. Second - determination of weight coefficients for criteria/sub-criteria. Third - grading of the instrument's performance under a criterion/sub-criterion. Finally, fourth - collection of the previously produced grades and formation of the aggregate grade of each evaluated instrument. Consistency and robustness tests are performed within the relevant steps.

Step 1: Creation of criteria- tree

The first level concerns the primary objective of all climate policy mitigation instruments [2, 3]. The goal of these instruments is to be effective in mitigating climate change through GHG emissions reductions. The second level includes three criteria, environmental performance, political acceptability and feasibility of implementation. Their definitions, along with those of the corresponding sub-criteria that support them and form the third level, are quoted as follows [2].

Environmental performance (denoted as x_1) is defined as the overall environmental contribution of the instrument towards the goal. Assessment of an instrument under this criterion is based on two sub-criteria. *Direct contribution to reduction of GHG emissions* (x_{11}) determines the synthesis and the magnitude of GHG emissions reductions directly referred and attributed to the assessed instrument. *Indirect environmental effects* (x_{12}) of the instrument are ancillary outcomes attributed to it.

Political acceptability (denoted as x_2) is defined as the attitude of all involved entities towards the instrument. Assessment of an instrument under this criterion is facilitated using the following six sub-criteria that concern target groups and rules-influencing mechanisms. *Cost effectiveness* (x_{21}) is defined as the property of the instrument to achieve the goal under the perspective of a financial burden acceptable and affordable by the involved entities. *Dynamic cost efficiency* (x_{22}) is defined as the property of the instrument to create, offer or allow compliance options that support research projects, incremental and radical pioneer technologies and techniques, and institutional or organizational innovations leading to GHG emission reductions. *Competitiveness* (x_{23}) is defined as the capacity of the entity to compete via price, products or services attributes with other entities and maintain or even increase the magnitude of specific indicators describing its financial performance. *Equity* (x_{24}) is defined as the fairness of the instrument in distributing emission rights, compliance costs and benefits among entities (countries/sectors) for accomplishing GHG emission reductions. *Flexibility* (x_{25}) is defined as the property of the instrument to offer a range of compliance options and measures that entities are allowed to use in achieving reductions under a time frame adjusted according to their priorities. *Stringency for non-compliance and non-participation* (x_{26}) is defined as the rigidity of the instrument's provisions towards emitters that failed to comply or did not participate.

Feasibility of implementation (or enforcement) (denoted as x_3) is defined as the aggregate applicability of the instrument linked with national infrastructural (institutions and human resources) and legal framework. It is based on the following three sub-criteria. *Implementation network capacity* (x_{31}) is defined as the ability of all national competent parties to design, support and ensure the implementation of the instrument. *Administrative feasibility* (x_{32}) is defined as the aggregate work exerted by the regulatory implementation network during the enforcement of the instrument. *Financial feasibility* (x_{33}) is defined as the property of the instrument to be implemented with low overall costs by the pertinent regulatory authorities.

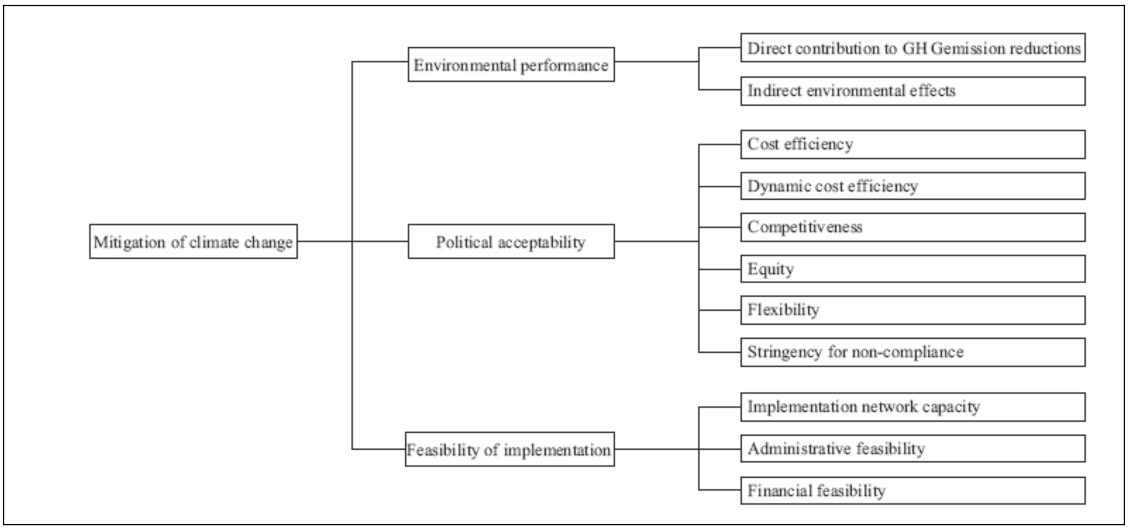


Figure 1: Criteria – tree according to the AHP hierarchy.

Step 2: Determination of weight coefficients for the criteria

Each criterion/sub-criterion has a different significance for climate policy. Its weight coefficient is determined by the potential user of the method using the AHP procedure. Pairwise comparisons are performed between the criteria/sub-criteria marking out their relative importance (prefer ability) for the effectiveness of the instrument. The extent to which one criterion/sub-criterion outperforms the other is presented at a (n x n) matrix. Weight coefficients are defined based on the expressed preferences of three stakeholder groups (PMs, researchers and target groups) actively involved in climate policy issues.

Testing consistency of weight coefficients: Consistency of weight coefficients is tested using two different approaches. The first approach is based on the consistency index of the AHP method by Saaty. The second approach was developed by Peláez J.I. and Lamata M.T. in 2002 [1,2].

Step 3: Grading of instrument's performance

The effectiveness of the jth instrument, denoted as U_j, is a function of its performances $U_{ji}(x_i)$ under the i criteria, denoted as x_i. $U_{ji}(x_i)$ are in turn a function of its performances under the respective sub-criteria.

The performance of the jth instrument on a specific sub-criterion is graded through MAUT utility functions – one for each sub-criterion - if there are credible and available data. The jth instrument is assigned a grade $u(v_{jik})$ (utility) under each k sub-criterion of the i criterion, because of its actually measured performance v_{jk}.

A linear function $u(v_{jik}) = a\ v_{jik} + b$, is used to calculate $u(v_{jik})$ in the scale of [0,100]. Coefficients a and b are defined for each k sub-criterion separately, solving a system with the following requirements. Grade $u(v_{jik})$ is equal to 100.0 (best) when the instrument has the highest v_{ijk} measured performance and equal to 0.0 (worse) for the lowest v_{ijk} measured performance according to the observed available data [2].

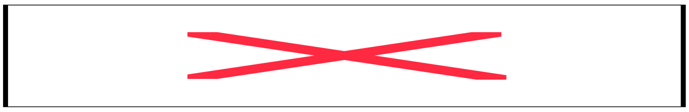
In the case that there are no credible and available data, the performance of the instruments on a specific sub-criterion is graded using SMART instead of MAUT. The elicitation procedure is simplified since the DM is asked to grade the performance of the instrument under a particular sub-criterion using scale [0,10]. Direct assessments are converted to normalized grades expressing the relative importance (prefer ability) that a DM shows in performances of evaluated instruments as in the case of weight coefficients of criteria. Taking m_k to stand for the grade assigned by the DM to the instrument for its performance at the k sub-criterion,) is its un-normalized grade according to SMART. The normalized grades are calculated based on equation

$$k=1 \quad (2.51) \qquad \text{(I)}$$

where n is the number of evaluated instruments under the k sub-criterion. Number 2.51 is used instead of number 2 of the SMART method, because 2.51 is the solution of equation) . Using number 2.51, grade 10 corresponds to grade 100 of the MAUT scale [2].

Step 4: Calculation of grades

Grades (commonly measured performances) of the jth instrument on the k sub-criterion are multiplied with the respective weight coefficients. All products are added and form the grade of the criterion x_i that is supported by the sub-criteria. Grade of jth instrument on the ith criterion is multiplied with the respective weight coefficient of the criterion. All new products are added and form the final grade, U_j, which expresses the effectiveness of the jth instrument:



(II)

Testing robustness and uncertainty: Sensitivity analysis (SA) is performed to check the robustness of the results. As the value of one weight coefficient increases, the weight coefficients of the remaining criteria decrease proportionally and results are recalculated. One weight coefficient is changed at a time. Changes in second level of sub-criteria are not performed [2].

3 Modified AMS

The modified AMS method for the evaluation of climate policy interactions consists of six (6) basic steps. First step, the potential user determines the interaction forms. Second he/she assigns weight coefficients to forms using AHP. Third, determines the criteria-tree. Fourth step, determines weight coefficients for criteria/sub-criteria using again AHP. Fifth, grades the interaction size using MAUT or SMART. Finally, collects the previously produced grades and forms the aggregate value of the interaction. Consistency and robustness test are performed within the relevant steps.

Step 1: Interaction forms

The potential user determines the interaction forms that according to his/her judgments occur during the parallel implementation of climate policy instruments. The following four main interaction forms are observed [3].

Interactions due to objectives: Two policy instruments interact due to objectives during one of the following three cases. First, they share the same primary objectives; this interaction form is named primary to primary (p-p). Second, one primary objective is the same with a secondary objective, interaction form named primary to secondary (p-s). Third, they share the same secondary objectives, interaction secondary to secondary (s-s).

Interactions due to target groups: Interactions due to target groups occur when instruments are imposed at the same target groups or when operations of other sectors, linked with the specific target groups of the two examined instruments, are affected. The first form of interaction is named direct target group interaction, while the second indirect (i-i). Using TP1 and TP2 to denote the set of target groups in policy instrument 1 and 2 respectively, three possible combinations for direct interaction occur described by the following relationships. First, if $TP1 \subseteq TP2$ then $(TP1 \cap TP2) = TP1$ or if $TP2 \subseteq TP1$ then $(TP1 \cap TP2) = TP2$ (One Set PArticipation, os-pa). Second, if $TP1 \cap TP2 = TP3$ and $TP3 \subseteq TP1$ or $TP3 \subseteq TP2$

(partial participation, p-pa). Third, TP1 = TP2 (full participation, f-pa). If TP1 ∩ TP2 = { ∅ }, then there is no direct interaction, but there may be indirect interaction.

Interactions due to implementation network: This interaction form occurs in the following cases. First, when the same competent authority has full responsibility for implementing both instruments; the form is named full responsibility interaction (f-r). Second -named partial responsibility interaction (p-r)- when two or more authorities are assigned partial responsibilities for implementing both instruments. Third, different authorities are responsible for the equivalent number of different policy instruments; form named different responsibility interaction (d-r).

Interactions in rules-influencing mechanisms: Trading and regulative interaction (denoted t and r respectively) are encountered within this leve,. Two market-based instruments interact under t when rules for the same trading commodity (emission permit, green certificate etc) or market regulations of commodities of one instrument are affected due to the respective ones of the other. R is defined as interaction due to similar or same rules and influencing mechanisms of the two instruments regarding regulatory issues.

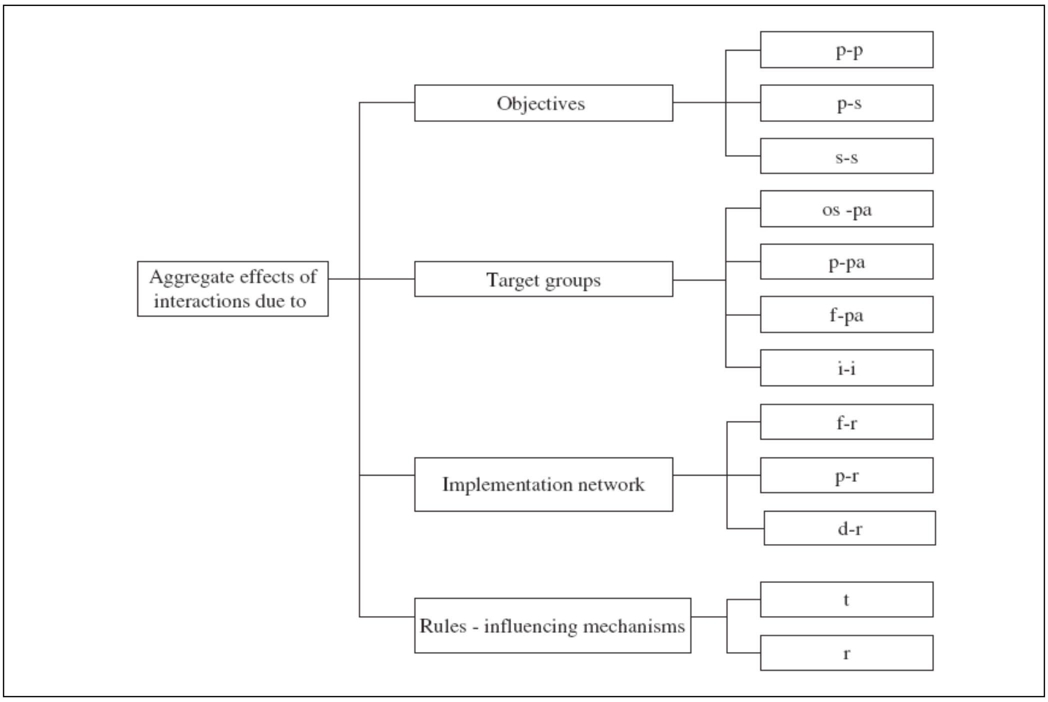


Figure 2: Interaction forms tree.

Step 2: Determination of weight coefficients for interaction forms

The potential user of this method assigns to each one of the defined interaction forms a weight coefficient determined with AHP as in step 2 of AMS. Weight coefficients were assigned based on the work that other researchers have performed on climate policy interactions [1].

Testing consistency of weight coefficients: Consistency of weight coefficients is tested by the user through the two aforementioned different approaches.

Step 3: Determination of criteria-tree

Each interaction form of step 2 is assessed by any potential user for its type (positive, negative or neutral) and size under specific criteria. Policy interaction between two instruments is defined as the observed or foreseen deviation from the actual or expected performance of either one or both instruments during implementation. Three types of interaction are proposed for this method. Positive interaction occurs when the performance of one or both examined instruments against a criterion or variable increases because of their co-existence. For the opposite reasons interaction is negative. Neutral interaction occurs when none of these cases is observed (stable performance, unchanged policy mix).

The criteria needed for characterizing the type and assessing the size of interaction forms are selected according to the experience and needs of DMs. The potential user of this method may assess interactions due to objectives under *environmental performance*.

Interactions due to target groups are assessed under *political acceptability*, which is supported by cost efficiency, dynamic cost efficiency, equity, flexibility. Cost efficiency is the property of both instruments to achieve a defined level of environmental performance at an aggregate lowest cost. Dynamic cost efficiency is defined as the property of both instruments to create, offer or allow compliance options for research projects, incremental and radical pioneer technologies and techniques, and institutional or organizational innovations leading to GHG emission reductions. Equity is defined as the fairness of both instruments in distributing emission rights, compliance costs and benefits among sectors for accomplishing GHG emission reductions. Flexibility is defined as the amplitude of compliance options and means that sectors are allowed to use in achieving reductions under both instruments and at a time frame adjusted according to their priorities.

Interactions due to implementation network are assessed under *feasibility of implementation* which is supported by two sub-criteria, administrative and financial feasibility. Administrative feasibility is defined as the aggregate work exerted by the regulatory implementation network during the enforcement of the instruments.

Interactions due to rules/influencing mechanisms are assessed under *transparency*. It is defined as the property of both instruments to create a transparent and understandable framework of rules/influencing mechanisms.

Step 4 – Determination of weight coefficients for sub-criteria

Sub - criteria do not have the same importance for interactions. Using again AHP as described in Step 2, weight coefficients are assigned to them by the potential user. Consistency is also tested by him/her.

Step 5 –Grading the type and size of interactions

The potential user of the proposed method assesses each interaction form as positive, negative or neutral against the respective criterion/sub-criterion. He/She assigns grades using MAUT. Formation of MAUT functions is based on credible, relevant and available data. In the absence of such data SMART is used instead.

The interaction form is assessed for its type and size under each criterion/sub-criterion and receives a quantitative value v_{ij} (utility). A linear function, y = ax+b, equivalently $u(v_{ij}) = a\, v_{ij} + b$, is used to calculate the corresponding value $u(v_{ij})$ in the scale of [0,+100] following MAUT procedure for positive interactions. Coefficients a and b are defined for each criterion/sub-criterion separately, solving a system with the following requirements. Function y is equal to 100 when interaction is extremely positive. Function y is equal to 0 reflecting the situation without the interaction. Respectively, a and b are defined again when using scale [-100,0] for negative interactions.

SMART is used in the case that a and b can not be determined due to lack of appropriate data. The potential user or the DM grades interactions by interaction type and size under a particular criterion/sub-criterion using scale [-10,+10]. Grade -10 corresponds to -100. Grade 10 is assigned according to the DM 's judgement for the situation in which performance of both instruments has increased reaching the maximum possible outcome. Grade -10 is assigned to the opposite situation.

Step 6: Calculation of grades

Grades are assigned to all observed interaction forms. In the case that criteria are supported by sub-criteria, their grade is calculated as the sum of products between weight coefficients and sub-criteria grades of MAUT or SMART procedure. Grades of criteria are then multiplied with the weight coefficients of the interaction forms. All new products are added providing the final value (equation (II)).

Testing robustness and uncertainty: Potential users perform sensitivity analysis (SA) for checking the robustness of the results.

4 Applications

The EU ETS effectiveness (its aggregate performance in mitigating climate change) is assessed in eight countries, Denmark, Germany, Greece, Italy, Netherlands, Portugal, Sweden and United Kingdom (UK). These countries were selected because they represent all Kyoto compliance trends in EU-25 [2].

The application of the AMS method showed that Netherlands have the highest value due to the high grades that the instrument received in all three criteria. Political acceptability is highest in Netherlands, because of cost efficiency and flexibility (strengths of the instrument in this country). On the other hand, EU-ETS is not effective for Portugal since environmental performance is zero and the other two criteria received low grades (weaknesses).

Robustness of these results was tested using sensitivity analysis. This analysis showed that the second weight coefficient is more sensitive since for its smallest relative changes the ranking of the fourth and fifth country is reversed.

The modified method is tested for two pairs of interactive instruments, IPPC and EU-ETS, EU-ETS and policies for the promotion of RES, within the Hellenic climate policy framework. EU-ETS and IPPC interact more positively compared to the second pair. This is justified also from the fact that IPPC was the forerunner of EU-ETS for Hellenic climate policy. Hellenic sectors became aware of EU procedures and standards for emission reductions. EU-ETS and RES are based on different concepts. Both contribute to the Kyoto Hellenic obligation through different approaches.

The robustness of these results is tested using sensitivity analysis. In all examined cases there was no reversal of the initial results [1].

Table 1: Final grades. DK-Denmark, GE-Germany, GR-Greece, IT-Italy, NT-Netherlands, SE –Sweden, UK-United Kingdom, PT-Portugal.

Countries	**DK**	**GE**	**GR**	**IT**	**NT**	**PT**	**SE**	**UK**
X_{11} (0.833)	33.54	30.29	28.13	83.30	54.10	0.00	80.06	11.0
X_{12} (0.167)	6.72	6.07	5.64	16.7	10.84	0.00	16.05	2.17
X1 (0.168)	**40.26**	**36.36**	**33.77**	**100.0**	**64.94**	**0.00**	**96.10**	**13.00**
Sub-Total for criterion X1 (A)	**6.76**	**6.11**	**5.67**	**16.8**	**10.91**	**0.00**	**16.14**	**2.18**
X21 (0.276)	0.53	27.4	18.4	2.70	100.00	1.20	0.7	0.0
X22(0.108)	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
X23 (0.084)	21.10	3.35	3.35	3.35	13.32	21.10	13.32	21.10
X24(0.359)	15.18	12.02	9.55	12.02	12.02	12.02	15.18	12.02
X25(0.118)	17.92	17.92	2.84	2.84	17.92	11.31	11.31	17.92
X26 (0.055)	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
X2 (0.738)	**11.52**	**16.30**	**11.18**	**7.70**	**37.19**	**9.80**	**10.13**	**10.24**
Sub-total for criterion 2 (B)	**8.50**	**12.03**	**8.25**	**5.68**	**27.44**	**7.23**	**7.48**	**7.56**
X31 (0.309)	18.57	23.46	3.71	1.47	18.57	1.47	9.30	23.46
X32(0.581)	18.81	14.89	1.18	0.75	18.81	1.83	14.89	18.81
X33 (0.110)	24.54	2.45	19.42	2.45	19.42	19.42	6.15	6.15
X3 (0.094)	**19.37**	**16.17**	**3.97**	**1.61**	**18.80**	**9.46**	**12.21**	**18.86**
Sub-total for criterion X3 (C)	**1.82**	**1.52**	**0.37**	**0.15**	**1.77**	**0.89**	**1.15**	**1.77**
Total (A+B+C)	**17.09**	**19.66**	**14.30**	**22.60**	**40.12**	**8.12**	**24.77**	**11.51**

Table 2: Aggregate grades for both pairs of interactive instruments and for all interaction forms.

5 Conclusions

The developed evaluation tool is simple, reliable, flexible, utilitarian and convenient with the needs of climate policy evaluations.

The tool is simple because it requires the minimum inputs and efforts from the perspective of DMs. The DMs can accept the proposed set of criteria and their respective weight coefficients since these are selected and calculated based on their own preferences. The DMs' judgments are needed for grading the performance of each instrument under each sub-criterion. If DMs have credible and available data for some of the sub-criteria then their experience and knowledge is restricted to grade the instrument under the remaining sub-criteria. DMs do not need to know the underlying concepts and procedure for the calculation of the weight coefficients or the assignment of the grades. They apply the equations, use the scale and calculate the value indexes for the instruments. The Clim-AMS software tool was developed so as to facilitate the users [4].

The tool is reliable because the proposed set of criteria is based on the official expressed preferences of three stakeholder groups involved in climate policy issues. The reliability of the weight coefficients was tested with the Saaty and Peláez J.I. and Lamata M.T. consistency indexes. Consistency indexes for all matrixes were less than the upper limits of both approaches. Robustness test was also performed showing that the second criterion is more sensitive in reversing the ranking of the fourth and fifth position of these results. Assumptions of the standard methods were also taken into consideration.

The tool is flexible and simple since DMs may assess the performance of an instrument under a certain criterion/sub-criterion using MAUT utilities or the SMART procedure. The selection of one of them over the other depends on the DM's accessibility to the necessary numerical data, so as to grade the instruments' performance against the particular sub-criteria. One more element of flexibility and simplicity of the method is the possibility to use the criteria and their supporting sub-criteria for any type of climate policy instruments.

The application of the method shows that the user is facilitated in identifying weaknesses and strengths of the evaluated instruments. Therefore, results from any application of the method constitute the basis of recommendations for forming, redesigning and modifying specific design characteristics of a particular instrument.

References

1. Konidari P., Mavrakis D.: Multi-criteria evaluation of climate policy interactions, Journal of Multi-Criteria Decision Analysis, Volume 14, Issue 1-3, 35 – 53, January – June 2006, (2007)
2. Konidari P., Mavrakis D.: A multi-criteria evaluation method for climate change mitigation policy instrumens, Energy Policy 35, 6235-6257 (2007).
3. Mavrakis D., Konidari P.: Classification of emission trading scheme design characteristics, European Environment, 13, 48-66, (2003).
4. Konidari P., Thomaidis F.: Clim-AMS, the software tool for climate policy evaluations, MCDA64, Euro Working Group of & Multi-criteria Decision Aiding, September 28-29 2006, Larisa, Greece.