LIFE19 CCA/ES/001209

LIFECITYADAP3

MULTICRITERIA ASSESSMENT METHOD TO PRIORITIZE ADAPTATION MEASURES INCLUDED IN LAS ADAPTATION PLAN

LIFE CITYAdaP3 LIFE 19 CCA/ES/001209

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Multicriteria assessment method to prioritize adaptation measures included in LAs adaptation plan (Task C2.2)

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1. Summary

Adapting to climate change in our cities is one of the priority axes in local climate ambition. The Covenant of Mayors represents a valid instrument to address the problem. The municipalities that voluntarily adhere to this initiative put into practice local action, thinking globally. Their participation in this initiative involves an analysis of the current situation and the elaboration of an action plan that includes measures to mitigate, adapt and combat energy poverty (PACES).

Unlike mitigation actions, in which their profitability favours investment, adaptation actions, in addition to being more expensive, have longer-term returns (up to 50 years), hindering their immediate profitability. This means that the use of municipal resources in adaptation actions has to be carefully prioritised. And this prioritisation must be carried out in a multi-criteria way, taking into account various aspects that, being independent of each other, can facilitate decision-making on where and how to act at all times.

In addition, the LIFE CITYAdaP3 project has demonstrated the validity of public-private partnership agreements to finance local adaptation actions to climate change. This also requires the selection of actions that can be financed by local companies, through their CSR.

The work developed proposes the use of the TOPSIS (Technique for Order Preference by Similarity to an Ideal Solution), multi-criteria decision-making methodology, based on the Hierarchical Analytical Process (AHP) to identify solutions from a finite set of alternatives. The basic principle is that the chosen alternative should be as close as possible to the ideal solution. In this way, decision-making and prioritisation of local adaptation actions will be based on a number of criteria.

The definition of the criteria requires a decision-making process in two phases: a first eminently technical and a second in which the protagonists are the companies that select the action they prefer to finance, based on another set of previously established criteria.

The result is a powerful decision-making tool that facilitates the prioritisation of actions to be addressed by local (and regional) administrations, as well as the identification of actions that could be financed by local companies through their CSR.

2. Introduction

The Covenant of Mayors is the largest global initiative to fight climate change locally. Started by European municipalities, it already has a global reach and, at present, more than 11,000 municipalities have voluntarily acceded to this way of tackling the local fight against climate change. The Pact proposes to act at three levels, always in a local way: mitigation of climate change (actions of energy efficiency and use of renewable energies), adaptation to climate change and, recently, the fight against energy poverty, which acquires special relevance in the current situation of energy emergency.

Climate change mitigation actions are well known, as they have been working on them for more than two decades. In addition, its development always implies a reduction in energy costs and a certain economic profitability, remarkable in some cases. However, the adaptation of our territories to climate change is much more complex, based on the fact that the return on investment is seen in the medium-long term. This makes local governments focus on mitigation-related investments rather than adaptation-related investments, which are also more expensive.

Within the framework of the LIFE CITYAdaP3 project (LIFE19 CCA/ES/001209), a new financing scheme for local adaptation actions to climate change has been developed, based on public-private collaboration. In fact, the project has begun a new path in which, through the involvement of local companies and their active corporate social responsibility (CSR), companies take sides in the design of local adaptation to climate change, involving themselves in decision-making and in the financing of actions.

The municipalities adhered to the Covenant of Mayors develop an Action Plan for Climate and Sustainable Energy (PACES), which defines and schedules the actions to be carried out in the municipality. The Pact suggests the use of multi-criteria methodologies when prioritising these actions and defining the timetable for action. For this, the municipalities create a working group with the agents involved (*stakeholders*), who also participate in this prioritisation of the actions.

The criteria that are usually taken into account when selecting the actions are usually effectiveness, equity, flexibility, urgency, cost, availability of financing, etc. However, when local companies become part of this group of agents involved, other criteria arise that may be necessary to promote the commitment of local companies to the financing of the actions that are most interesting to them. These new criteria can be the demonstrative character, relevance, social acceptance, visibility or even your own interest in co-financing them.

To address this challenge, this paper proposes the application of multi-criteria decision-making methodologies. These techniques allow prioritising between different options to solve a certain problem, based on the assessment of a certain number of criteria that affect decision making. In particular, the*Analytic Hierarchy Process (AHP*) and the*Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) technique have been applied simultaneously*. The proposed method allows prioritising climate change adaptation actions based on the criteria identified.

The LIFE CITYAdaP3 project involves the municipalities of Alcantarilla, Lorquí and Molina de Segura, in Spain and Reggio Emilia in Italy. In addition, the project is led by the Federation of Municipalities of the Region of Murcia and the CSR Chair of the University of Murcia and the company EuroVértice Consultores, expert in the fight against climate change and author of this work. The technicians of the municipalities have contributed to define both the method and the criteria to be taken into account in the prioritisation process., as will be explained below.

3. Selection of the assessment criteria

Representatives of all the partners of the LIFE CITYAdaP3 project participated in this process. The first step should be to identify the criteria that will serve to assess the different actions proposed. Experience warns us that the evaluation of actions under certain criteria is not available to all participants in the decision-making process. For example, the availability of funding, cost, urgency or impact generated may be criteria well known to municipal representatives, but to a lesser extent by the actors involved, mainly co-financing companies.

Therefore, a selection in two phases is proposed:

Phase 1: assessment by **municipal representatives**, both technical and political, as well as *stakeholders* who are part of the PACES working group. As a result of this deliberation process, the following criteria have been selected:

ENVIRONMENTAL AND TECHNICAL CRITERIA

- **Urgency:** how necessary is the measure for adaptation to climate change of the municipality?
- **Effectiveness:** will the action be able to solve the climate problem/risk addressed?
- **Impact:** how much population will benefit from the action?

SOCIAL AND POLITICAL CRITERIA

- **Complementarity:** is it a multi-objective action? Does it have a positive impact on other climate risks?
- **Acceptability:** will most of the inhabitants/agents interested in this action accept this action?

ECONOMIC CRITERIA

- **Financing/Cost:** does the municipality have financial capacity or potential access to funds to implement the action? Will it also be able to assume its long-term maintenance?
- **Cost-benefit ratio:** are the benefits generated by the action sufficient to bear the necessary cost to carry it out?

Phase 2: assessment by **companies interested** in co-financing climate change adaptation actions through their CSR. In this case, the following criteria have been selected:

ENVIRONMENTAL AND TECHNICAL CRITERIA

- **Innovation/Demonstrative character:** will this action lead to progress on the state of the art at regional/national/European level?
- **Relevance:** is the action really important to solve a problem/climate risk of the municipality?

SOCIAL AND POLITICAL CRITERIA

- **Social Acceptability:** will most of the inhabitants/agents interested in this action accept this action?
- **Visibility:** could the action have a positive impact from the point of view of the media, CSR or the reputation of the company?
- **Possibility of co-design:** can companies, interested agents or residents collaborate in the co-design of the action?

ECONOMIC CRITERIA

- **Interest in co-financing:** would the company be willing to collaborate in its financing?

4. Methodology

Once the endpoints have been identified, the combined AHP-TOPSIS methodology has been applied. This combination has been used to identify suitable solutions in other areas: Hanine et al. (2016)[1], Balioti et al. (2018) [2] and Jahanshahlooa et al. (2006)[3].

4.1. Hierarchical Analytical Process (AHP)

The AHP technique is a process consisting of the following steps (Saaty and Vargas 2001[4]; Saaty 2008[5]):

Step 1: Definition of a comparison matrix in which the proposed set of criteria compares with itself. To do this, the fundamental scale of preferences defined by Saaty has been used:

- C_i and C_j are equally important (II): 1
- C_i is moderately more important than C_j (m+I): 3
- C_i is more important than C_j (+I): 5
- C_i is much more important than C_j (M+I): 7
- C_i is extremely more important than C_j (E+I): 9

Otherwise, when the 'i' criteria are less important than the 'j', the reverse values are used: 1/II, 1/(m+I), 1/(+I), 1/(M+I) and 1/(E+I).

The binary comparison tables between criteria, with the average of the values obtained by the 15 experts participating in the assessment surveys, are represented in Tables 1 and 2

Table 1. Binary comparison between criteria (Phase 1)

	C1	C2	C3	C4	C5	C6	C7
C1	1,000	0,273	0,216	0,656	0,471	0,298	0,432
C2	3,667	1,000	1,616	3,086	1,295	0,831	0,890
C3	4,632	0,619	1,000	1,404	0,497	0,312	0,509
C4	1,524	0,324	0,712	1,000	0,220	0,181	0,176
C5	2,123	0,772	2,013	4,547	1,000	0,298	0,329
C6	3,356	1,204	3,210	5,533	3,356	1,000	1,066
C7	2,316	1,124	1,965	5,667	3,044	0,938	1,000

C1 Urgency
C2 Effectiveness
C3 Impact
C4 Complementarity

Source: own elaboration

C5 Acceptability
C6 Financing/Cost
C7 Cost-benefit ratio

Table 2. Binary comparison between criteria (Phase 2)

	C1	C2	C3	C4	C5	C6
C1	1,000	0,498	0,508	0,325	1,087	0,261
C2	2,007	1,000	0,858	0,833	1,346	0,323
C3	1,969	1,165	1,000	0,795	2,331	0,348
C4	3,080	1,201	1,258	1,000	1,639	0,336
C5	0,920	0,743	0,429	0,610	1,000	0,269
C6	3,836	3,099	2,875	2,978	3,711	1,000

C1 Innovation/Demonstrative character
C2 Relevance
C3 Social Acceptability
C4 Visibility
C5 Possibility of co-design
C6 Co-financing interest

Source: own elaboration

Step 2: Determination of the weight vector (P_i), which represents the relative importance of the factors. To do this, the own vectors corresponding to the comparison values are calculated, according to the following expression:

$$P_i = \frac{\sqrt[n]{\prod_{j=1}^{j=n} V_{ij}}}{\sum_i \prod_{j=1}^{j=n} V_{ij}}$$

where V_{ij} corresponds to the comparison values between criterion C_i and C_j, and n is the number of criteria assessed.

Step 3: Verification of the consistency of comparison judgments through the Consistency Index (CI) and the Consistency Ratio (RC).

$$IC = \frac{\lambda_{máx} - n}{n - 1}$$

where λ_{max} is the Eigen value corresponding to the comparison matrix V_{ij}:

$$\lambda_{máx} = \frac{\sum_i \left[\frac{\sum_j (V_{ij} \cdot P_j)}{P_i}\right]}{n}$$

The consistency ratio (RC) is defined as the ratio between the CI and the random consistency index (RC), a value that depends on the number of criteria, according to Table 3. This index represents the consistency of the results obtained with the expert surveys, so that AQI values below 0.1 indicate an acceptable consistency of the comparison values and therefore verifies the validity of the method. In our case, the RC values are:

- $RC_{\text{municipal representatives}} = 0.055$
- $KR_{\text{interested companies}} = 0.014$

Table 3. AQI Standardised Values

Number of criteria	ICA
6	1.24
7	1.32

Source: Saaty (2008)

As a result of the application of the AHP technique, the weight vectors corresponding to the batteries of criteria established for both phases are obtained. Their values are shown in Tables 4 and 5.

Table 4. Weight vector corresponding to Phase 1 criteria

	C1	C2	C3	C4	C5	C6	C7
P_i	5.0 %	18.0 %	10.2 %	5.1 %	12.7 %	26.5 %	22.5 %

Source: own elaboration

C1 Urgency
C2 Effectiveness
C3 Impact
C4 Complementarity
C5 Acceptability
C6 Financing/Cost
C7 Cost-benefit ratio

Table 5. Weight vector corresponding to Phase 2 criteria

	C1	C2	C3	C4	C5	C6
P_i	7.6 %	13.2 %	15.3 %	16.7 %	8.6 %	38.5 %

Source: own elaboration

C1 Innovation/Demonstrative character
C2 Relevance
C3 Social Acceptability
C4 Visibility
C5 Possibility of co-design
C6 Co-financing interest

4.2. Technique to sort preference for similarity to the ideal solution (TOPSIS)

The TOPSIS method was developed by Hwang and Yoon (1981) [6] for multi-criteria decision-making problem solving. It is based on the fact that the chosen action must be as close as possible to the positive ideal solution($A+$) and as far as possible from the negative ideal solution (A^-). In short, according to this method, the ideal positive solution maximises the effectiveness of the action and minimises its cost, while the ideal negative solution maximises the cost and minimises its effectiveness.

Once the decision matrix that arises from the assessment, by the participants, of each of the actions according to each of the criteria established, according to Tsaur (2011) [7] and Ding (2012)[8], the steps of the TOPSIS methodology are:

Step 1: Normalise the decision matrix using the following equation:

$$mdn = \frac{v_j(A_i)}{\sqrt{\sum_{i=1}^{m}\left[v_j(A_i)\right]^2}} \quad i = 1,2,\dots,m; y\ j = 1,2,\dots,n$$

where $v_j(A_i)$ is the average value of the A_i stock valuations under criterion C_j, n is the number of criteria and m is the number of adaptation actions proposed for prioritisation or selection.

Step 2: Calculate the standard and weighted decision matrix according to the weight vector obtained with the AHP method (P_i). This matrix is obtained by multiplying the standard decision matrix by the weight associated with each criterion:

$$mdnp = mdn_{ij} \cdot P_j$$

Step 3: Identify the positive ideal solution (A^+) and the negative ideal solution (A^-). The A^+ is defined as the vector formed by the actions that offer the lowest value, for each criterion, of all those obtained in the standardised and weighted decision matrix. On the contrary, the A^- is defined as the vector formed by the actions that present the maximum value in that matrix. In this way, both solutions conform as a vector with specific values for each criterion.

Step 4: Measure the Euclidean distance of each alternative with respect to the positive and negative ideal solutions, according to the expressions:

$$D_i^+ = \sqrt{\sum_{j=1}^{m}\left(mdnp_{ij} - A_j^+\right)^2}$$

$$D_i^- = \sqrt{\sum_{j=1}^{m}\left(mdnp_{ij} - A_j^-\right)^2}$$

Step 5: Determination of the relative proximity of the i-th alternative to the ideal solution using the following equation:

$$RA_i = \frac{D_i^-}{D_i^+ + D_i^-}$$

So that the values calculated for RA_i shall be between 0 and 1. The action selected from among the actions proposed on the basis of the assessment of the n criteria will result in greater relative proximity. Similarly, if you want to select or prioritise a certain number of them, these will correspond to the one that best RA_i obtain.

5. Results

In the process of monitoring the PACES of the municipality of Lorquí, a technical assessment of the proposed actions (phase 1) is carried out, under the criteria proposed for this phase. The proposed values can be seen in Figure 1. The application of the model gives as a result the values shown in Figure 2. These values represent the percentage of proximity to the ideal solution, which is 100 %.

This allows to identify the actions that represent a higher priority for the municipality, according to the opinion of the respondents (in this case, municipal technicians and agents involved).

These actions are the ones that move to phase 2. In this phase, companies interested in participating, through their CSR, in the adaptation of their municipality to climate change. In this

phase, the proposed criteria try to select the actions with which companies are most identified and that offer them greater profitability in terms of visibility and citizen acceptability, among others.

For the identification of companies, communication actions, dissemination of the initiative, information workshops, etc. In addition, interested companies have received an individualised visit from the mayor, councillors or municipal technicians to comment, first hand and in a detailed manner, on the characteristics of the commitment they acquire by participating in this initiative.

	Acciones PACES	Urgencia	Efectividad	Impacto	Complementariedad	Aceptabilidad	Financiación/Coste	Relación coste/beneficio
		Máx: 10 Min: 1	Máx: 10 Min: 1	Máx: 10 Min: 1	Máx: 10 Min: 1	Máx: 10 Min: 1	Máx: 10 Min: 1	Máx: 10 Min: 1
A1	Fomento de edificaciones con elementos de adaptación al cambio climático	10	8	10	10	9	8	9
A2	Plan de estabilización de cabezos y mantenimiento de casas cueva	7	9	8	10	10	7	8
A3	Creación de corredores y zonas verdes ensombradas en áreas urbanas y periurb	8	10	9	8	7	8	10
A4	Programa de rutas seguras a centros escolares	9	8	4	8	9	9	9
A5	Servicio de ayuda frente a la pobreza energética	7	8	2	9	8	8	6
A6	Concienciación y sensibilización para la reducción de la demanda energética en	10	7	10	5	7	10	8
A7	Fomento de hábitos para la reducción del consumo de agua en el hogar	9	7	10	5	7	10	8
A8	Creación de un tanque de tormentas ecológico en el municipio	9	9	10	7	8	6	7
A9	Seguimiento y mejora de la eficiencia de la red de distribución de agua	6	7	10	5	6	7	6
A10	Fomento de sistemas tradicionales de almacenamiento de agua para recogida de	5	5	8	6	7	8	8
A11	Programa para la reducir la generación de residuos urbanos e incrementar su tas	7	6	10	7	6	9	7
A12	Control y vigilancia de los depósitos de residuos	7	9	10	5	6	8	7
A13	PGOU con criterios de adaptación al cambio climático	7	8	10	9	8	10	9
A14	Fomento de los huertos escolares	6	7	3	7	8	10	8
A15	Cursos de agricultura y jardinería ecológica	3	7	4	6	6	8	5
A16	Plan de arbolado de sombra del municipio	9	8	9	7	7	8	10
A17	Mejora en el diseño y gestión de parques y jardines	9	7	8	6	7	9	10
A18	Recuperación del bosque de ribera del municipio de Lorquí	8	7	7	8	9	7	8
A19	Mejora de los sistemas de control de vectores infecciosos	6	7	10	5	8	6	7
A20	Creación de rutas saludables y seguras	5	8	10	6	8	8	9
A21	Campañas de sensibilización para la protección contra la radiación solar y tempe	7	6	10	5	8	9	9
A22	Mantenimiento y mejora de los servicios de teleasistencia	9	8	10	9	10	8	10
A23	Desarrollo de una cartografía de los riesgos existentes	6	7	5	8	7	7	6
A24	Campañas de concienciación y sensibilización a la ciudadanía	10	6	10	10	10	10	9
A25	Participación en proyectos de demostración que permitan incrementar la capacid	9	8	10	10	9	10	8

Figure 1. Assessment of the actions proposed in the CAPES (phase 1)

Source: own elaboration

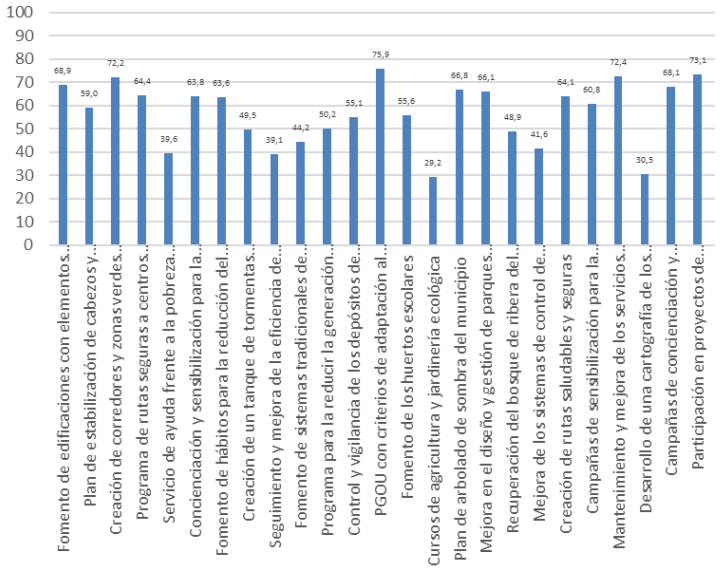

Figure 2. Outcome of the prioritisation of actions — phase 1. (Source: own elaboration)

The valuation of shares by companies, based on the six criteria proposed, is as shown in Figure 3. The methodology applied, offers as a result the values presented in Figure 4.

	Acciones propuestas	Innovación/Carácter demostrativo Máx: 10 Min: 1	Relevancia Máx: 10 Min: 1	Aceptabilidad social Máx: 10 Min: 1	Visibilidad Máx: 10 Min: 1	Posibilidad de co-diseño Máx: 10 Min: 1	Interés de co-financiación Máx: 10 Min: 1
A1	PGOU con criterios de adaptación al cambio climático	7	7	7	5	5	3
A2	Participación en proyectos de demostración que permitan incrementar la capacidad d	8	6	7	7	8	5
A3	Creación de corredores y zonas verdes ensombradas en áreas urbanas y periurbanas	8	8	10	9	9	9
A4	Mantenimiento y mejora de los servicios de teleasistencia	7	9	10	6	5	5
A5	Fomento de edificaciones con elementos de adaptación al cambio climático	8	7	8	7	7	6
A6	Campañas de concienciación y sensibilización a la ciudadanía	7	8	8	9	7	6
A7	Plan de arbolado de sombra del municipio	8	9	9	9	10	9
A8	Mejora en el diseño y gestión de parques y jardines	9	8	8	8	9	8
A9	Programa de rutas seguras a centros escolares	8	8	9	8	9	7
A10	Creación de rutas saludables y seguras	8	8	10	8	9	8

Figure 3. Assessment of priority actions by companies (phase 2)

Source: own elaboration

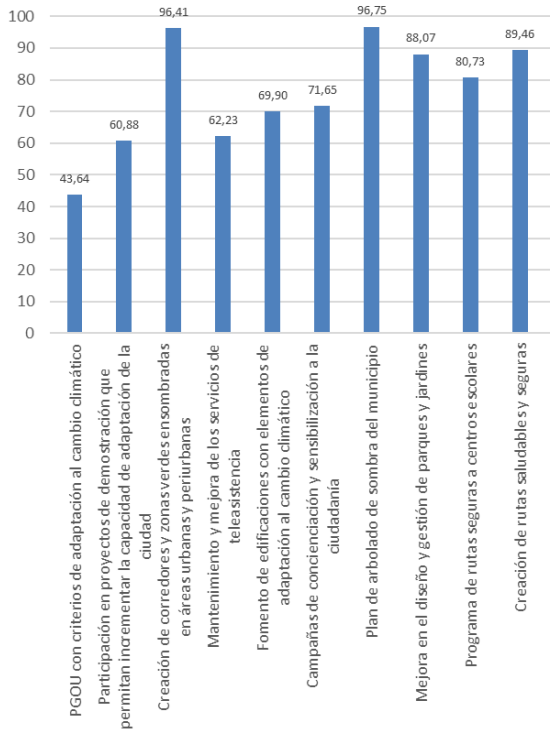

Figure 4. Result of the prioritisation of shares by companies — phase 2. (Source: own elaboration)

In short, the result of this analysis is a series of actions in which local companies would see well participate as co-financers of these:

1. Shade tree plan of the municipality.
2. Creation of corridors and shaded green areas in urban and peri-urban areas.
3. Creation of healthy and safe routes.

6. Discussion

The proposed model has proven to be consistent and reliable. The participation of a significant number of agents (municipal technicians and representatives of the different municipalities) gives strength to the proposed method. Hence the consistency ratios resulting from the binary comparison of criteria offer a more than adequate value.

Certainly, the selected actions meet most of the requirements proposed by companies to contribute financially to their development: they offer visibility to companies, the possibility to participate in their design, a high social acceptance at the moment, etc. In short, they are actions that offer greater ease to arouse the interest of local companies and thus contribute to their financing.

7. Conclusions

The proposed multi-criteria decision-making methodology, developed as a combination of AHP and TOPSIS, is a valid tool for prioritising actions in the local fight against climate change. In this way, two well differentiated objectives are achieved: in phase 1, local authorities can prioritise their investments, generating maximum impact with available economic resources; in phase 2, it is possible to identify a range of actions that could interest local companies to help financially in their implementation, through their corporate social responsibility.

As a result, the LIFE CITYAdaP3 project has developed two prioritisation tools (one per phase), which will be disseminated through the Covenant of Mayors to all those municipalities engaged in the fight against climate change, in order to help them in this commendable and necessary task.

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