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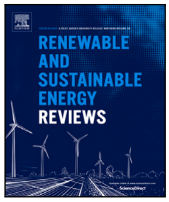

Assessing gender and climate objectives interactions in urban decarbonisation policies

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ABSTRACT

Gender studies have highlighted how policies and actions that are not drafted and planned with a gender perspective tend to produce a gender bias. Climate policies are not an exception. Measures to mitigate and adapt cities to climate change might lead to undesired outcomes regarding gender equality or, in contrast, may help to improve equality. Ideally, cities should prioritise actions that aim to reduce their carbon footprint but also help promote gender equality. The aim is to facilitate the inclusion of gender perspective in the 100 Climate-Neutral and Smart Cities by 2030 European Mission. We propose a Multicriteria Decision-Making Method to assess urban policies and relate them to climate and gender criteria. We describe urban decarbonisation policies with non-negative gender outcomes and compare their impact when using climate and gender criteria. The objective is to analyse how the prioritisation of actions varies from different perspectives: one taking into account the field of expertise of the different experts and the other taking into account the different typologies of criteria separately. A DEMATEL-ANP technique is used to determine how policies contribute to climate action and gender equality. Experts in different areas and city planning respond to the DEMATEL-ANP model by comparing and relating criteria and actions. The results show which policies have a significant potential to reduce cities' carbon footprint and increase gender equality. Prioritisation of policies changes when only gender criteria or climate criteria are considered. Regarding the former, it can be concluded that gender criteria will contribute to closing the gender gap while having a widening impact on decarbonisation. Nevertheless, including gender criteria is not enough to avoid bias, and multidisciplinary teams must participate in the decision-making process.

1. Introduction

Global warming is becoming evident as a problem that must be addressed. Evidence suggests that addressing global warming is crucial and needs to be approached both on a larger scale (global or national) and at the local level [1]. Cities are undergoing a significant effort towards decarbonisation. Cities concentrate over 75% of the population in Europe [2], two-thirds of global energy consumption worldwide [3], and about 75% of CO_2 energy-related emissions [4]. Therefore, actions to mitigate their footprint are essential to achieve the objectives of the Paris Agreement. At the same time, cities present features such as heat islands and lower soil absorption capacities [5], which are highly dependent on background climate and urban fabric properties. Food and material dependency have regional sustainability implications that must be considered in urban planning, and policy-making [6]. These problems will require increasing actions to adapt cities, enhance their resilience to climate change and avoid increasing unequal impacts on them. Additionally, urban women often face significant disadvantages compared to men, such as limited access to decent work, constrained asset ownership, restricted mobility, safety concerns, and underrepresentation in urban governance [7]. Addressing these gender disparities is crucial for equitable urban development.

The European Mission "100 Climate-neutral and Smart Cities by 2030" encourages these efforts at the EU level [8]. The Mission involves local authorities, citizens, businesses, investors, and regional and national authorities to deliver 100 climate-neutral and smart cities by 2030 and ensure that these cities act as experimentation and innovation hubs so that all European cities follow suit by 2050. The Mission

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Nomenclature

A	Direct-relation matrix
a_{ij}	Values of the direct-relationships matrix
D	Sum of the columns of the Total-relation matrix
I	Identity matrix
k	Normalisation factor
R	Sum of the rows of the total-relation matrix
T	Total-relation matrix
t_{ij}	Values of the total-relationships matrix
X	Normalised direct-relation matrix
w_{ij}	Values of the weighted matrix

Abbreviations

ANP	Analytic Network Process
C-C	Climate Criteria
C-G	Gender Criteria
$DANP$	DEMATEL - ANP
E	Energy actions
F	Food actions
G	Governance actions
$MCDM$	Multi Criteria Decision Making
M	Mobility actions
U	Urban planning actions

is the European Commission's most important program for achieving decarbonisation at the urban level. Accordingly, governments and institutions promote various policies and programmes to achieve this goal. However, the mainstream approach and technocratic tradition may favour detachment from social aspects over sustainability, resulting in the persistence of social inequalities, energy injustices, and citizens' passive participation [9]. Cities should prioritise actions that aim to reduce their carbon footprint while contributing to a more inclusive, democratic and just scenario through urban decarbonisation [10].

Gender disparity is one of the key challenges when tackling injustices in urban areas [7]. Gender studies have highlighted how policies and actions not drafted and planned with a gender perspective tend to produce a gender bias [11]. Climate policies are not exempt from this bias [12], and several studies highlight how some actions towards decarbonisation create gender inequalities [13–15]. The European Green New Deal and the European Gender Equality Strategy are clear messages that both environmental protection and gender equality are priorities for the European Commission. Nevertheless, these strategies lack coordination, and in most cases, the objectives are not addressed together. Policies must address the complexities of gender roles and identities and the root causes of inequality in the climate change context if they aim to be effective and redistributive [16,17].

Although there is literature on the impact of climate policies on gender, it is focused on providing a knowledge base on how climate policies impact gender and vice versa [18,19]. Others have studied how a specific type of sustainable urban measures affect the gender gap, e.g. Vajjarapu et al. [20] studied how sustainable urban transport measures affect differently depending on income and gender, while Gonda [21] explored a feminist political ecology framework to show how policymakers struggle to implement the complex climate and gender relationships in their policy formulation. Indeed, returning to the European framework, the Mission "100 Climate-Neutral and Smart Cities by 2030" mentions inclusiveness and the gender perspective. However, it lacks guidelines and specific targets that include a gender perspective in transforming cities to climate-neutral. As far as current research indicates, the literature has not yet made a concerted effort to rank and quantify the impacts of urban policies on both gender and climate aspects. Particularly, how do urban decarbonisation actions contribute to close the existing gender gap in cities?

This research proposes prioritising urban actions regarding climate and gender criteria to close this gap. The contribution of this research is threefold. First, it aims to map the urban decarbonisation actions that generate non-negative consequences to the gender perspective and to characterise the main climate and gender criteria affected by urban policies. Second, the research aims to quantify the influences between them and their expected positive impact on both gender and climate criteria. Third, due to the silos approach in developing urban policies [22], the research aims to understand the existing biases in evaluating these actions regarding the professional experts' background and their impact on gender or climate criteria. In sum, the aim is to improve the limited comprehension of the issue among decision-makers and practitioners.

Given the extensive range of gender and climate criteria, this study suggests the utilisation of a Multicriteria Decision-Making Method (MCDM) as an approach to address this challenge. Evaluating urban policies establishes connections with a comprehensive set of climate and gender criteria, aiming to achieve this goal. This analysis specifically targets medium-sized cities situated in southern Europe. Even though urban climate policies are transversal and affect most areas, significant efforts are being made both where emissions are more intense and regarding governance aspects. Consequently, the examination centres on five key policy dimensions: energy, food, governance, mobility, and urban planning. Within each of these dimensions, the initiatives of four policies that yield positive or neutral results from a gender standpoint are outlined. Subsequently, the alignment of their outcomes with four distinct climate and gender criteria is assessed. To achieve this goal, an evaluation of urban policies is conducted, establishing connections with a comprehensive set of climate and gender criteria. This analysis specifically targets medium-sized cities situated in southern Europe. While urban climate policies exhibit a cross-cutting influence impacting numerous domains, concentrated endeavours are noticeable in regions of heightened emissions as well as concerning governance aspects. Consequently, the focus of the examination centres on five critical policy dimensions: energy, food, governance, mobility, and urban planning. Within each of these dimensions, the outline presents the initiatives of four policies demonstrating favourable or neutral outcomes from a gender standpoint. Following this, an evaluation is conducted to gauge the alignment of their results with four distinct climate and gender criteria. To facilitate this assessment, the study employs a multicriteria approach known as the DEMATEL-ANP (DANP) technique, utilised to ascertain the contributions of policies towards climate action and gender equality. Expert input from various domains is solicited to engage with the DANP model, enabling comparisons and relationships between criteria and actions.

The findings, according to the consulted experts, show which policies have the greatest potential to reduce cities' carbon footprints while also increasing gender equality. The results also show that if policymakers aim to promote equitable decarbonisation of cities, social factors should be broadly considered. Prioritisation of policies changes when only gender criteria or climate criteria are considered. Furthermore, policies are prioritised differently depending on the expertise field.

This study aims to provide both theoretical and methodological contributions to the field of urban, climate and gender policies. From a theoretical point of view, the results (prioritisation of criteria and actions) serve as a learning tool for the research field since they complement previous studies and can provide new perspectives for city council managers on urban public policies over time. From the methodological point of view, the contribution is twofold. Firstly, the combination of methodologies, DEMATEL and ANP, is novel in the context of climate and gender policies. Secondly, the description of the process followed allows it to be replicated in other contexts or with different groups of experts.

The rest of the paper is organised as follows: Section 2 discusses the current literature around gender and climate change policies and the adequacy of the multicriteria decision methods used, Section 3 presents the study design and the methodology employed. Section 4 describes the model characterised by a network of clusters of criteria and actions. Section 5 shows the results from the analysis and their implications. Finally, Section 6 concludes by summarising the paper's main findings.

2. Bridging complexities between gender and climate in urban decarbonisation policies

This section presents an overview of the current state of the art on the interaction between climate policies and gender implications at an urban scale. This issue's complexity and multidisciplinary nature lead us to assess it with MCDM techniques. The second part of the section describes and outlines similar approaches to these interactions.

2.1. Gender perspective approach in urban decarbonisation policies

Urban climate policies are cross-cutting issues and strategic for decarbonisation because they account for most Greenhouse gas emissions. According to the European Environmental Agency [23], the main emission sectors worldwide are energy, industry, transport, residential/commercial, agriculture and waste. Furthermore, the Intergovernmental Panel on Climate Change "Climate Change 2022: Impacts, Adaptation and Vulnerability" report [24] cites energy, urban and other settlements, transport, buildings, industry, agriculture and other land use as sectors where mitigation should be addressed. According to the Intergovernmental Panel on Climate Change "Climate Change 2014: Impacts, Adaptation, and Vulnerability" report [25], the key adapting sectors at the urban scale are energy, transport, food, housing, and urban planning. This report also outlines the role of government, planning, and management in putting the urban environment in place.

The transition to more resilient cities should include justice, not just the avoidance of unjust outcomes, but also the consideration of resilience engineering as a means of promoting urban justice [26]. It is necessary to go beyond plans and objectives and focus on actions [27]. Although climate change and its related policies are likely to have profound consequences for gender relations [28], policies focus on the economic and technical aspects, with justice issues, such as gender inequalities, playing a marginal role [29]. Cities have been planned and designed to reflect traditional gender roles and the gender labour division. Consequently, cities work better for men than for women [30]. If urban decarbonisation policies do not acknowledge and reflect these inequalities in their designs, they will perpetuate them. Some of these inequalities relate to time access due to differences in care tasks [31]; access to spaces of power, decision and participation [32]; economic and income disparities [33]; and urban mobility, access and usage of the public space [34].

For instance, when the gender representation of sectors is examined, it is noticeable that the sectors with the most significant carbon impact also have a low representation of women [35]. Energy, transport, housing and agriculture are also analysed as crucial sectors in other reports on climate change policies and gender, where women's inclusion in decision-making and other aspects of governance is also highlighted as decisive [36–38]. These previous studies emphasise the importance of including a gender perspective in climate change action [36]. However, the role that the gender perspective plays in climate action is limited [29,35]. These studies do not quantify the effects of urban policies simultaneously in gender and climate spheres or assess the bias produced due to the expertise field of the decision-makers.

The gender implications of urban policies designed to mitigate and adapt cities to climate change arise at different scales and viewpoints. Climate urban policy actions differ regarding their sectorial approach. Urban administration departments and policy actions tend not to be connected and conceive themselves as separated silos [22], but gender and climate implications have common approaches and interdependent objectives.

2.2. Multi-criteria decision methods

This multidisciplinary combination of quantitative and qualitative objectives makes MDCD techniques appropriate for assessing their interactions. In particular, this study uses a combination of DEMATEL and ANP (DANP), two widely used MDCM techniques. Several studies employ these techniques to assess climate, gender, and urban issues in a complex context that combines qualitative and quantitative information. In climate terms, these methods are applied to the study of barriers to renewable energy sources at a national scale [39], the selection of technologies for rural electrification [40], and the barriers to transport decarbonisation at an urban scale [41]. Its application in gender studies is focused on understanding aspects related to customer behaviour [42,43] but also in more strategic studies associated with policy strategies such as [44].

Regarding the analysis at an urban level, recent studies have tackled the selection of urban-related issues with MCDM approaches. Addae et al. apply DEMATEL to analyse the barriers to Smart Energy City in Accra [45], and [46] explores the compelling factors that drive urban development projects for Tehran in Iran. Two studies dice into the prioritisation of development strategies for tourist development and the pedestrianisation of the streets of Cartagena de Indias in Colombia [47,48]. Finally, [49] assesses the management of urban transport systems for Donostia-San Sebastian in Spain and audits the city's local government in its policy decision-making processes. Therefore, these studies show the usefulness of MCDM methods, particularly DEMATEL and ANP, to climate, gender, and urban issues. While some of these studies combine two of these approaches, none of them holistically combines the three of them nor uses the combination of DEMATEL and ANP for the approach.

DEMATEL is an MCDM technique used to analyse the relationships between different criteria or objectives. In this research, the criteria would be both gender and climate criteria, where DEMATEL evaluates the interdependence among them. A group of experts would be asked to evaluate the relationships between the different criteria using a structured questionnaire. The experts would rate the strength and direction of the relationships between the criteria, with higher numbers indicating a stronger relationship. Based on the responses from the experts, the DEMATEL method would be used to identify the most important criteria and to determine how they are interrelated. This information could then be used to evaluate the different policies or initiatives, considering the impact on gender equality and climate change criteria. This analysis could help inform decision-making by providing a better understanding of the potential trade-offs and synergies between different objectives, which is one of the main objectives of this paper.

The Analytic Network Process (ANP) is also an MCDM technique used to evaluate and compare options or alternatives based on multiple criteria. It is based on the idea that the criteria and options being considered are interrelated, and the relative importance of each criterion can change depending on the context. Thus, ANP is well-suited to complex decision-making situations where many criteria need to be considered and where the relative importance of each criterion can vary.

The combination of the two techniques allows both advantages to be exploited. The ANP allows a comprehensive analysis of the influences of all the elements that make up a network. The number of questions required by the ANP is very high, as it works with paired comparisons for all the triads of the network. Thus, DEMATEL will be used instead, which requires a much lower number of questions for the experts as it works with direct influences rather than through comparisons, consequently saving time. In addition, DEMATEL allows a cause–effect analysis of the different network elements involved, which would not be possible if only the ANP was applied [50–52]. Studies have used the combination of these two techniques on many previous occasions with success. In the field of climate change, the methodology has been used recently by [53] analysing the influence of some key factors when

looking for urban carbon neutrality in a city of China, [54] analysing the factors to prioritise and select renewable energy resources. However, to the best of the authors' knowledge, this methodology has never been used before, either in gender equality research or in the combined analysis of climate and gender aspects.

3. Study design and method

The methodology used to approach this research is organised in two stages. The first stage, *Preparation of the prioritisation model*, is a stage that could be replicated in any study whose objective is to analyse the impact of policy actions in which there are several influencing criteria. This step is carried out by the facilitators of the prioritisation process, in this case, the authors involved in this research and does not require the collaboration of the expert group. The second stage, *Resolution of the prioritisation model*, requires the participation of experts and must, therefore, be adapted according to the context of the case study. It involves answering lengthy questionnaires that need a little preparation and description beforehand. Access to information from the experts has to be adapted to the characteristics of the experts.

The second stage uses an integrated MCDM approach based on a combination of DEMATEL and ANP (DANP) to determine the impact of urban policy actions simultaneously on urban decarbonisation and gender gap closure. This is accomplished through an evaluation of different gender criteria for the two goals of urban decarbonisation and gender gap closure. The selected policy actions belong to five clusters (energy, food, governance, mobility, and urban planning). All the selected actions have at least a theoretical non-negative outcome regarding climate and gender objectives.

Multi-criteria analysis is used to evaluate the actions and the criteria, enabling ranking of the actions concerning the two objectives. Fig. 1 presents the different steps of the methodology that guided this study. Each major step is described in detail in the following subsections.

3.1. Definition of the model

The ranking model is based on a network of criteria and actions that influence each other. The criteria and actions are derived from a literature and context review that experts validate. Both climate and gender criteria are selected to represent the diversity of elements in consideration to achieve both goals. The policy actions include mature measures commonly implemented by city planners and promoted by urban stakeholders. Socio-technical sectors and specific governance policies cluster actions. To ensure the model's traceability, maintaining adherence to a maximum of four criteria and actions within each cluster is upheld. This approach captures the diversity of policy actions and criteria without making the model intractable for expert consultation nor losing detailed comparison between representative elements of the model.

3.2. Consultation with experts

A panel of experts is selected to assess the criteria. Experts from different socio-technical systems considered policy actions in the model. Therefore, experts have professional backgrounds in energy, food, governance, mobility, and urban planning. In this type of MCDM technique, due to the semi-quantitative and expert nature of the information, the quality of experts is crucial compared to the number of them [55]. Experts should thoroughly understand their field's implications in the case study and a holistic view of urban transformation. Due to the interdependence between urban actions and climate and gender criteria, the experts have expertise in their fields and evaluated criteria but also understand the rest of the actions. Experts' backgrounds are diverse and formed by academics, urban public policy-makers, and private sector professionals.

Table 1
List of experts.

Id.	Expertise	Sector
Ex1	Energy	Academia
Ex2	Energy	Academia
Ex3	Energy	Academia
Ex4	Energy	Academia
Ex5	Energy	Public sector
Ex6	Food	NGO
Ex7	Food	NGO
Ex8	Governance	Academia
Ex9	Governance	Academia
Ex10	Governance	Academia
Ex11	Governance	Academia
Ex12	Governance	Academia
Ex13	Mobility	Academia
Ex14	Mobility	Private sector
Ex15	Urbanism	Private sector
Ex16	Urbanism	Private sector
Ex17	Urbanism	Public sector

A total of seventeen experts were consulted to answer the DANP questionnaire. The experts were selected based on their area of knowledge, i.e. their background expertise. For this purpose, experts from these five areas were selected: energy, food, governance, mobility and urbanism. The experts selected are people working in academia, Valencia City Council or private companies with a professional link to urban policies. An attempt has also been made to ensure gender parity in each group. While the specific number of experts required for a decision-making process can vary depending on its complexity and scope, working with 17 experts can indeed be sufficient when they are carefully selected to represent the problem's interests and are committed to collaborative efforts. The advantages of a smaller, focused team include enhanced expertise, efficiency, collaboration, and adaptability, all of which contribute to the likelihood of a successful study. It is also important to ensure that there is a commitment from the experts to the proposed task, as it requires time and some effort. The experts should be closely attentive to how they respond. In Table 1, the list of experts is shown, along with their areas of expertise and affiliation.

When arranging the groups of experts, it must be ensured that these groups present a sufficient degree of compatibility based on the Garuti and Kendal indexes. Experts inside a group are compatible with at least another expert, considering either a Garuti index above 0.85 [56] or a Kendall p value above 0.6 [57].

3.3. Weighting of the criteria and actions

Once the model is drawn and validated by the experts, the DANP method is applied in five steps.

Step 1: Generation of the direct-relation matrix A. First, measuring the relationship between criteria requires that the comparison scale is designed in a 0–4 scale:

- 0 (no influence)
- 1 (low influence)
- 2 (medium influence)
- 3 (high influence)
- 4 (very high influence)

Experts make pairwise comparisons of the influences between criteria and between criteria and actions. Then, the initial data is obtained as the direct-relation matrix. The A matrix is a nxn matrix in which a_{ij} denotes the degree to which the criterion i affects the criterion j.

Step 2: Normalising the direct-relation matrix. On the base of the direct-relation matrix A, the normalised direct-relation matrix X can be obtained through equations:

$$X = k \times A \tag{1}$$

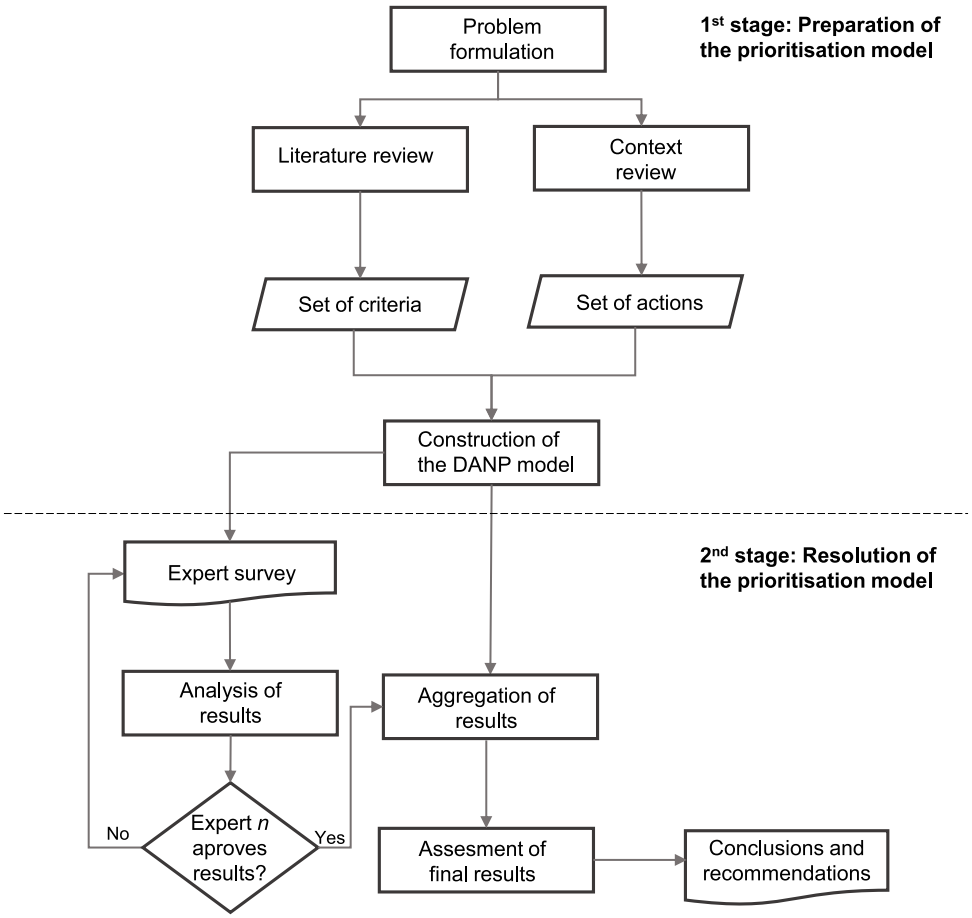

Fig. 1. Summary of the followed methodology.

$$k = \frac{1}{\max_{1 \le i \le N} \sum_{j=1}^{n} a_{ij}} \tag{2}$$

where, a_{ij}: values of the direct relationships matrix.

Step 3: Attaining the total-relation matrix: T can be obtained by using Eq. (3), in which the I is denoted as the identity matrix

$$T = X(I - X)^{-1} \tag{3}$$

Once all the values of the matrix T have been obtained, the value of the individual influences that each of the criteria in the rows exerts on the other criteria of the network in the columns, i.e. the influences of the criteria on each other, is obtained. In this way, by setting influence thresholds, the most prominent relationships of the criteria network can be discovered.

Step 4: The parameters D and R for each criterion are obtained from the values of the matrix T using the Eqs. (4) and (5). The two values for each criterion allow us to obtain the causal diagram of the criteria.

$$D = \sum_{j=1}^{n} t_{ij}, i = 1, 2, \ldots, n \tag{4}$$

$$R = \sum_{i=1}^{n} t_{ij}, j = 1, 2, \ldots, n \tag{5}$$

The cause–effect diagram enables the analysis of the degree of prominence, indicated by the sum of D and R (horizontal axis), and the degree of cause or effect, indicated by the subtraction of D and R (vertical axis).

Step 5: Normalising each column of the T matrix (unweighted) by its sum, the weighted supermatrix is obtained.

$$w_{ij} = \frac{t_{ij}}{\sum_{i=1}^{n} t_{ij}} \tag{6}$$

where, w_{ij}: values of the weighted supermatrix and t_{ij}: values of the total-relation matrix.

Step 6: Calculating the limit matrix. In this step, the weighted matrix is multiplied by itself until all of its columns become equal, i.e. the values converge, and the process ends. This way, each element's individual influences on the network's other elements are obtained from this limit supermatrix. The criteria and action values are extracted from the vector of the limit supermatrix and normalised by the sum to obtain their final weights. In this way, the ranking can be obtained, which will allow for an understanding of the decision profile of the experts. After obtaining the individual evaluation results of DANP each expert validates her/his own results. If the results are unsatisfactory, she/he revises the evaluation round of the pairwise comparisons to ensure that the results agree with her/his knowledge and overall assessment. This second round relates mainly to experts not being familiar with the methodology and it is a way to check that their initial thoughts are translated into the results.

3.4. Analysis of the results

The study results are presented with different granularity levels: expert, group, and aggregated. The results focus on both criteria and policy actions. Besides, two extra models are presented where either only climate criteria or only gender criteria are considered. When clustering the DANP results, the group limit supermatrix represents

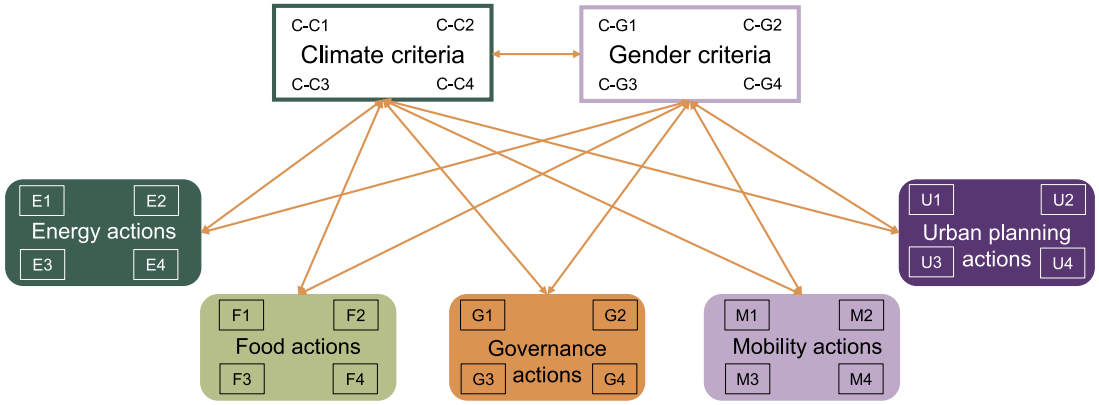

Fig. 2. Overview of the studied model.

Table 2
Set of climate and gender criteria.

Id.	Climate criteria	Refs.
CC1	Reduction of emissions associated with economic and social activity.	[59,60]
CC2	Rationalisation and reduction of energy consumption and raw material consumption.	[61,62]
CC3	Increasing energy generation from renewable sources.	[63,64]
CC4	Improving urban resilience to the impacts of climate change.	[63,65]
	Gender criteria	
CG1	Visibility, co-responsibility and improvement of conditions for the development of care tasks.	[66,67]
CG2	Women's access to and improvement of conditions for fair work, participation and decision-making environments.	[68,69]
CG3	Women's safety and reduction of violence against women and other vulnerable minorities.	[70–72]
CG4	Autonomy and economic independence and independence of women's movements for the development of a personal project.	[73,74]

the aggregation of the group experts' matrices. The aggregation is performed with a geographic mean, as suggested in [58]. That is, the Food group results represent the geographical mean of all the individual results of the Food experts, while the mean results represent the combination of all experts' judgements. Since DANP is based on expert opinions, it is essential to recognise the potential for subjectivity inherent in expert judgements when interpreting the results. This potential source of error can be mitigated by involving sufficient experts with varied experience [55].

4. Model description

Fig. 2 presents the ranking model characterised by a network of clusters of criteria and actions. The model is framed in the context of medium-sized European cities. Both the criteria and actions are derived from a literature review. The actions include measures to be implemented by city planners and all stakeholders involved at the city level or influencing it. A set of criteria is selected to represent achieving both goals, climate change mitigation and adaptation and closing the gender gap. Four criteria represent each goal.

Table 2 presents both climate and gender criteria. Climate criteria refer to reductions in emissions (C-C1), rationalisation of energy and raw material consumption (C-C2), increasing energy generation from renewable energy sources at the urban level (C-C3) and adapting cities to the impacts of climate change (C-C4). Regarding gender criteria, these refer to the visibility of care tasks (C-G1), the access of women to work and decision-making positions (C-G2), women's safety (C-G3), and the free and safe movement of women (C-G4).

Following the criteria selection, Table 3 presents all the policy actions analysed, classified into five clusters: food, governance, mobility, energy, and urban planning. These actions are selected based on common policy intervention at urban scales. The policy actions vary from direct public intervention, such as Improving the public transport network (M1) or Increasing the diversity of uses in dense urban areas (U1) to economic incentives to achieve objectives, such as Promoting self-consumption (E1) or Ensuring energy efficiency in the residential stock (E2) or softer decision-making actions such as Promoting healthy public procurement with environmental and social criteria (F4) and Governance actions.

Finally, the panel of experts for this study consisted of seventeen experts grouped into five clusters. Experts composing the panel have the following profile: five energy experts, two food experts, five governance experts, two mobility experts and three experts in urban planning.

5. Results and discussion

This section presents the results of the study in four main parts. Initially, the role of each criterion in the model is delineated, along with an exploration of their mutual interactions. Subsequently, an analysis is conducted to ascertain the relative weight of various policy actions. Then, the results are divided considering the biases, first by the expert group and finally by comparing the complete, climate, and gender models.

5.1. Weight and interaction of the criteria

The DANP method prioritises the selected criteria and actions from the most to the least important for the decarbonisation of a city while closing the gender gap simultaneously, according to the participant experts.

The prioritisation of criteria for the aggregated group of experts is shown in Fig. 3. Three climate criteria and one gender criteria stand out slightly: rationalisation and reduction of energy consumption and raw material consumption (C-C2), improving urban resilience to the impacts of climate change (C-C4), reduction of emissions associated with economic and social activity (C-C1), autonomy and economic independence of women's movements (C-G4), and fair work and participation and decision-making (C-G2). This result shows how experts

Table 3
Set of policy actions.

Id.	Energy	Refs.
E1	Promoting self-consumption: individual, collective and energy communities.	[75–77]
E2	Ensuring energy efficiency in the residential stock.	[78,79]
E3	Direct aid for fuel poverty.	[80,81]
E4	Energy education	[82,83]
	Food	
F1	Promoting production and access to organic products	[53,84]
F2	Reduce animal protein consumption	[85,86]
F3	Promote sustainable consumption and markets	[87,88]
F4	Promote healthy public procurement with environmental and social criteria	[84,89]
	Governance	
G1	Ensuring the presence and participation of women in jobs and decision-making	[13,90]
G2	Promote neighbourhood cooperative projects and community organisation.	[91,92]
G3	Designing and implementing citizen engagement processes.	[93,94]
G4	Analyse and evaluate measures and actions from a gender perspective.	[38,95]
	Mobility	
M1	Improve the public transport network including inter-modality and metropolitan connection	[96,97]
M2	Implementation of a dense network of pedestrian and cycle routes	[98,99]
M3	Promote car-sharing platforms.	[100,101]
M4	Promote EVs: Replacement and infrastructure	[102,103]
	Urban planning	
U1	Increasing the diversity of uses in dense urban areas.	[104,105]
U2	Re-naturalise urban open spaces and connect green infrastructure.	[106,107]
U3	Ensuring access to decent housing.	[108,109]
U4	Adapt housing to new standards of quality, diversity and accessibility.	[110,111]

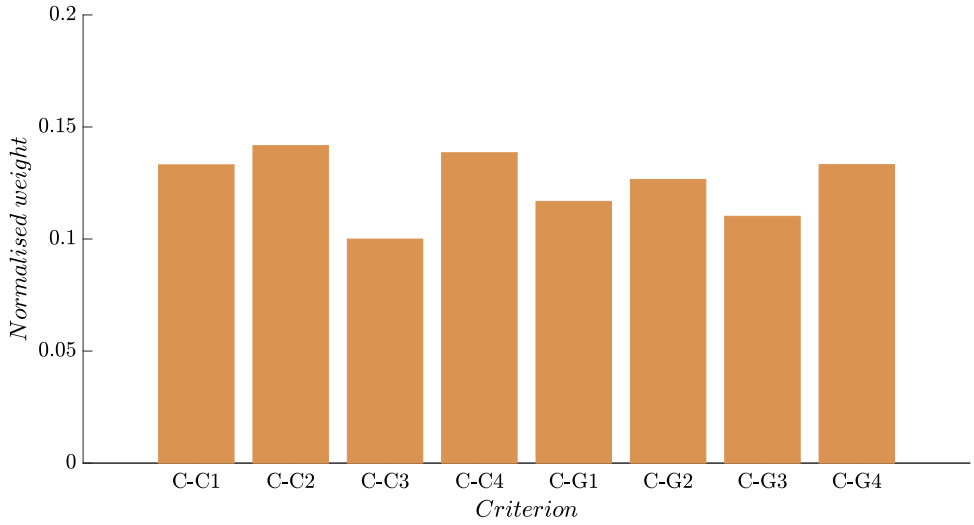

Fig. 3. Aggregated weight of criteria.

prioritise climate criteria over gender criteria, focusing on criteria that mainly affect urban metabolism and its dependence on inputs and adaptation needs. Regarding gender criteria, the ones with more significant importance are the ones related to decision-making and the economic sphere of gender inequalities. According to the experts, the other gender criteria regarding co-responsibility and safety (C-G1 and C-G4) follow the outstanding group. Finally, a lower prioritisation is given to increasing energy generation from renewable resources (C-C3), which relates to the constrained nature of renewable energy generation in urban areas.

Regarding criteria influences, Table 4 presents the aggregated value of the influence of each criterion against each other. This is the total relationship matrix mentioned in Step 3 of the weighting procedure (Eq. (3)). The highest influences have been highlighted. Two thresholds have been calculated to indicate two different levels of influence [53]:

- Threshold 1. Moderate influence: mean (0.069)
- Threshold 2. High influence: mean plus standard deviation (0.090)

The results show that within the gender cluster, criteria are highly influenced by each other, and climate criteria are also highly influenced by each other. Still, climate criteria do not highly influence gender criteria or gender criteria climate criteria. Regarding the influence between the two clusters and when considering moderate influences, the gender criteria influence the climate criteria, while the climate criteria have very little influence on gender criteria. A Cause-Effect diagram is presented in Fig. 4 (see Step 4 in) in which the X-axis shows the degree of importance of each factor. In contrast, the Y-axis shows each factor's degree of cause (positive values) or effect (negative values). As can be seen in this diagram, criteria are classified into four quadrants [53]. It can be observed that the four gender criteria and one of the climate criteria are causal factors. They get positive D+R and have a certain effect on all other indicators. The only criterion in the II quadrant is C-G4 Autonomy and economic independence and independence of

Table 4
Total relationship matrix among criteria. Grey values are below the relationship average, black values are values above the average, and bold values are values above the average plus one standard deviation.

	C-C1	C-C2	C-C3	C-C4	C-G1	C-G2	C-G3	C-G4
C-C1	0.0628	**0.0997**	0.0726	**0.0950**	0.0497	0.0504	0.0476	0.0590
C-C2	**0.1145**	0.0641	0.0758	**0.0983**	0.0596	0.0610	0.0527	0.0753
C-C3	**0.0987**	0.0827	0.0318	0.0805	0.0391	0.0439	0.0380	0.0567
C-C4	**0.0956**	**0.0972**	0.0717	0.0592	0.0649	0.0653	0.0650	0.0778
C-G1	0.0704	0.0732	0.0415	0.0698	0.0421	0.0864	0.0790	**0.0972**
C-G2	0.0799	0.0795	0.0543	0.0789	**0.0915**	0.0467	**0.0928**	**0.1027**
C-G3	0.0549	0.0562	0.0395	0.0629	0.0793	0.0812	0.0409	**0.0969**
C-G4	0.0761	0.0757	0.0529	0.0771	**0.0935**	**0.1016**	**0.0926**	0.0551

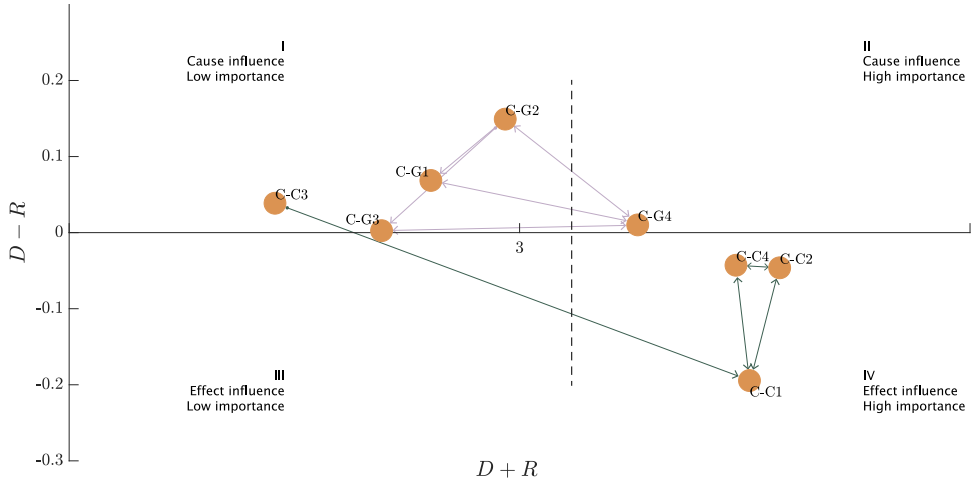

Fig. 4. Causal diagram.

women's movements for developing a personal project, which can be regarded as a critical factor and should be considered when designing actions.

From the interaction of the criteria, it is concluded that despite the greater importance of the climate criteria for decarbonising cities, these criteria do not influence the gender criteria. Therefore, not considering gender criteria may result in a transition without a fair gender perspective. This finding backs up what the literature says about the risk of technocratic visions of energy politics [29].

In contrast, the gender criteria do influence the climate criteria. Incorporating a gender perspective into policies for major sustainability transition processes can engage and reinforce these processes, as authors such as Braunger et al. [90] pointed out.

5.2. Weight and dispersion of the actions

Fig. 5 shows the final average priority of each action for the whole group of experts. According to them, the actions that better contribute to the two goals are improving the public transport network (M1), ensuring the presence and participation of women in jobs, decision-making and project management (G1), analysing and evaluating measures and actions from a gender perspective (G4), promoting neighbourhood cooperative projects and community organisation (G2), and implementing of a dense network of pedestrian and cycle routes (M2). In contrast, promoting electric vehicles (M4) is the lowest-scoring action.

Governance actions are of great importance and belong in the most important cluster. This result is interesting because governance complements many other actions due to its more organisational and less capital-intensive role. Thus, governance actions could complement more capital-intensive actions in the built environment, such as mobility, urban, and energy. The first two mobility actions are of great importance due to the high impact of mobility in cities and the considerable emission reduction potential of these promoting public transport and cycling or foot trips. Concerning mobility actions, U1 is one of the two most valued urban plan actions due to the significant correlation between reducing mobility needs and having a diversity of uses and densely populated areas. Meanwhile, U4 relates to the residential energy demand in cities, which correlates with E1 and the promotion of renewable generation in cities.

The first group of the presented capital-intensive actions respond to the need to reduce transport emissions, while the second one responds to and resolves the energy needs in buildings. These two elements represent the primary sources of city emissions due to a common absence of industrial facilities in urban areas. Besides, these actions relate to areas where urban policies have competencies to mitigate and adapt to climate change. The rest of the actions with larger scores relate to actions with no infrastructural changes, such as governance actions and E4 energy culture, which have a significant impact at a climate level but especially on a gender level.

Fig. 6 shows the dispersion of the evaluation of policy actions according to the whole group of experts. Of particular relevance are those actions without layers that show significant discrepancies among experts. It is important to note that while Governance actions are prominent, they do not present any large discrepancy among the seventeen experts.

5.3. Bias by expert type

The results are analysed according to the experts' field of knowledge, as shown in Figs. 7 and 8. Fig. 7 highlights how experts prioritise the criteria with some differences depending on their expertise field. However, rationalisation and reduction of energy consumption and raw material consumption (C-C2) are among the two main criteria for four of the five groups of experts. Nevertheless, energy experts attach the greatest importance to reducing emissions associated with

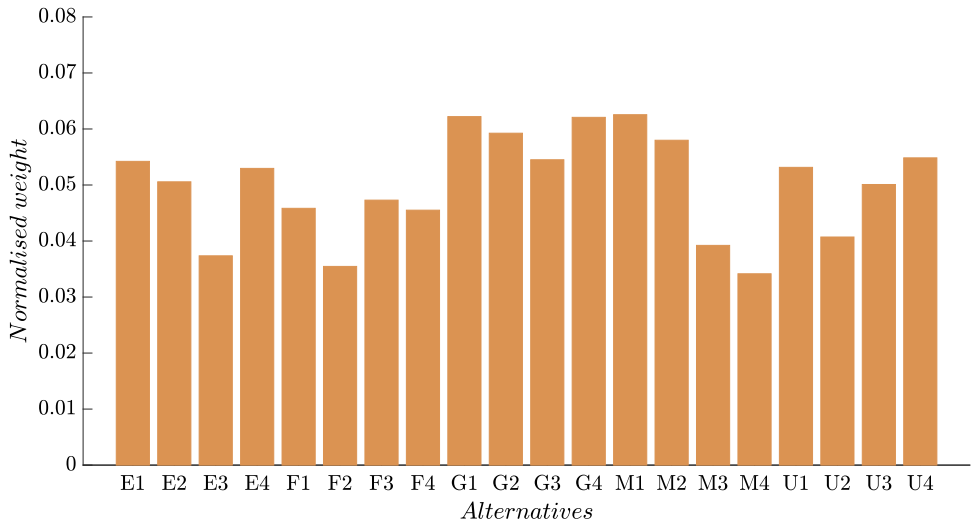

Fig. 5. Aggregated weight of actions.

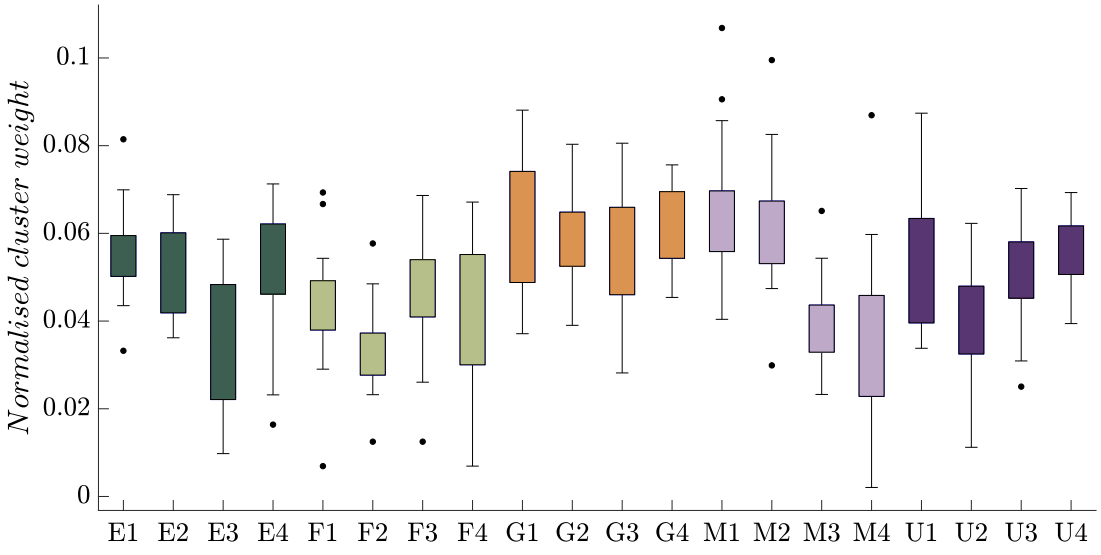

Fig. 6. Dispersion of the value for each action.

economic and social activity (C-C1). In contrast, urban and governance experts emphasise improving urban resilience to the impacts of climate change (C-C4), and mobility experts prioritise autonomy, economic independence, and independence of women's movements (C-G4). Food experts maintain a similar level of prioritisation across all criteria.

Fig. 8 shows how the priority of actions varies depending on the respondents' expertise field, although governance importance is extended among all groups. Urban planning and mobility experts tend to allocate higher importance to mobility and urban planning actions (M1, M2 and U1), while governance experts prioritise the governance actions. Energy experts give the highest value to most energy actions (E2, E1 and E4). Food experts are the only experts giving a high priority to a food action (F4). These results show expert decision-making is biased towards their field, reinforcing the need for multidisciplinary decision-making teams to have complementary perspectives.

5.4. Bias by criteria type

Finally, Fig. 9 presents the bias between criteria, considering the results when the model only considers climate or gender criteria, showing a variation between action priorities. In this sense, this study aims to deliver in this analysis how the prioritisation of actions would

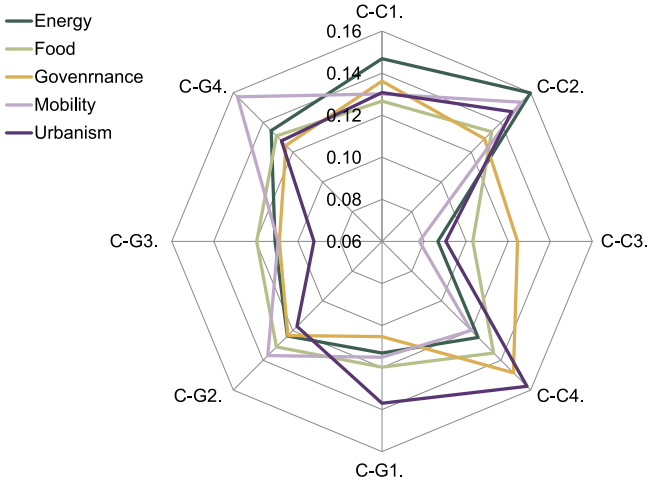

Fig. 7. Analysis of the criteria considering the bias by expert's group.

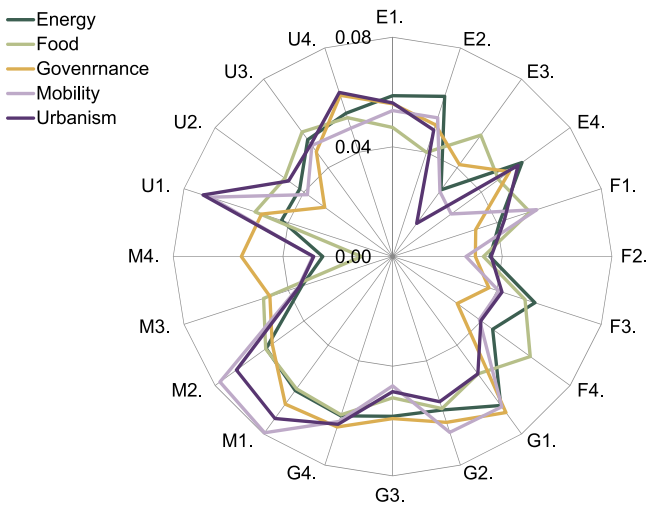

Fig. 8. Analysis of the actions considering the bias by expert's group.

be if only one group of criteria is considered. One criteria group is eliminated from the general DANP model to analyse this. Hence, the sequences studied only refer to the criteria in the model on the actions or alternatives for analysis.

For the climate model, when only climate criteria are analysed, the main actions are promoting self-consumption in individual, collective and energy communities (E1), ensuring energy efficiency in the residential stock (E2), energy education (E4) and improving the public transport network (M1). The importance of all energy cluster actions is increased compared to the general model, except for the case of action E3. Direct Aid for Fuel Poverty is a measure with more impact on social emergency than decarbonisation, as it involves economic aid to vulnerable socioeconomic groups. At the same time, for the gender model, consequently, this action rises. Furthermore, it is observable that governance actions experience a decrease in priority, whereas actions within the remaining clusters garner heightened significance.

For the gender model, when only gender criteria are analysed, the main action differences belong to analysing and evaluating measures and actions from a gender perspective (G4), ensuring the presence and participation of women in jobs and decision-making (G1), promoting neighbourhood cooperative projects and community organisation (G2) and ensuring access to decent housing (U3). In this model, governance actions become significantly more relevant than the general model and less relevant for the climate model, correlating to the importance of governance actions to reduce gender biases.

Some actions of urban planning and mobility clusters (M1, M2, U1, and U4) follow a consistent trend independently of the model, i.e., type of criteria. The reason to focus on these actions is that, in addition to consistency, regardless of the criteria followed, they have high importance in the overall result (Fig. 5). Nevertheless, most actions are affected by the type of criteria applied. That is, some actions increase, and others decrease in importance when analysing each model separately.

When comparing the climate model with the complete model, some actions significantly reduce their importance by including gender criteria. Among these actions are E1, E2 and E4, the most important actions according to the climate model. In the complete model, adding gender criteria, actions with more social elements gain importance. This can be seen in the difference between the climate model and the complete model in Fig. 9, where the complete model shows a greater emphasis on governance action, ensuring access to decent housing (U3) and adapting housing to new standards of quality, diversity and accessibility (U4) and direct aid for fuel poverty (E3). Therefore, it can be concluded that there is a gender bias in these actions, and thus, the energy transition needs specific gender criteria to be inclusive.

In sum, the main actions to be implemented change whether gender criteria are included. If gender criteria are not included (climate model), there is a bias towards actions with a more technical component. When gender criteria are included (full model), such actions of a purely technical nature lose importance to actions with more social elements.

Furthermore, it is essential to note that according to the criteria analysis (Section 5.1), the gender criteria influence the climate criteria. Considering gender criteria will also contribute to and reinforce climate objectives. However, the climate criteria do not influence the gender criteria, so they would not contribute to both objectives. Moreover, the actions that stand out considering gender criteria are governance actions, which can improve gender equality while reinforcing actions to be bolder in climate terms. Without gender criteria, actions with a technical component are favoured. If policymakers aim to promote just decarbonisation of cities, the inclusion of a gender perspective in general and particularly at governance levels should be broadly considered.

In the absence of a gender perspective in formulating urban decarbonisation policies, there is a risk of perpetuating existing gender inequalities. The criteria analysis indicates that incorporating gender criteria plays a pivotal role in narrowing the gender gap, although it may simultaneously impact the decarbonisation process, as suggested by the analysis. Conversely, when policymakers incorporate gender criteria into developing city climate policies, they can serve as catalysts for addressing urban inequalities. However, it is important to note that including gender criteria alone is insufficient to eliminate bias. To ensure unbiased and effective decision-making, it is imperative to involve multidisciplinary teams in the policy formulation process.

6. Conclusions

This study conducts a Multicriteria Decision-Making Method to assess urban policies and relate them to climate and gender criteria. Urban decarbonisation policies with non-negative gender outcomes are described, and their impacts are compared using climate and gender criteria. The DANP technique is used to determine how policies contribute to climate action and gender equality. Experts in the various fields involved in urban decarbonisation respond to the DANP model by comparing and relating criteria and actions.

First, the criteria for the two goals are established after a literature review. Then, actions with a non-negative outcome from a gender perspective are proposed in five critical areas for urban policies. Seventeen experts from the five action clusters responded to the DANP model by comparing and relating criteria and actions. Then, the results are analysed from three perspectives.

The first is considering the complete model that includes all the experts and the criteria of both groups. Governance actions are crucial, which is an interesting result given that governance complements many other actions due to its more organisational and less capital-intensive role. As a result, governance actions may be combined with outstanding mobility actions. Due to the significant impact of mobility within urban areas and the substantial potential for emission reduction associated with these two actions, the initial two mobility measures also attain a heightened level of importance.

The second one considers the field of expertise of the respondents. Experts prioritise the criteria differently depending on their field of expertise. However, rationalisation and reduction of energy consumption and raw material consumption are among the two main criteria for four of the five groups of experts. The priority of actions varies depending on the respondents' expertise field, although governance importance is extended among all groups. From these results, it is concluded that expert decisions are biased towards their field of knowledge. However, mobility experts highlight autonomy and economic independence and

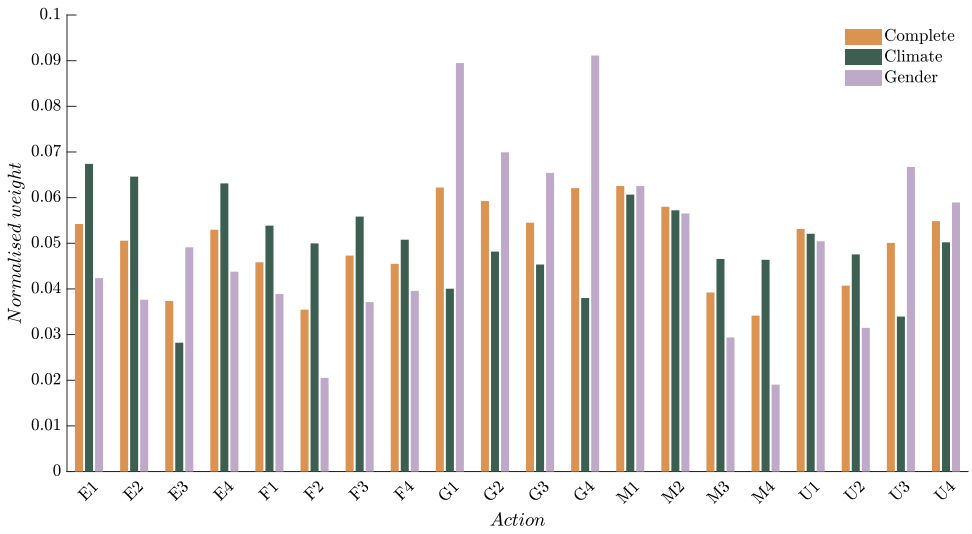

Fig. 9. Aggregated weight of actions considering only Climate or Gender criteria.

independence of women's movements for developing a personal project as the most relevant criterion. Regarding the results obtained, this criterion is the most influential and important criterion in the model and must be considered a key factor in designing policy actions.

The third one analyses the groups of criteria separately to observe how actions are prioritised according to each of the criteria groups: climate and gender. Gender criteria prioritise efforts with more significant social importance above technical elements. When gender criteria are included (full model), such actions of a purely technical nature lose importance to actions with more social elements. Furthermore, the gender criteria impact the climate criteria, according to the criteria analysis. Both results show that actions with significant social efforts will ensure a just transition as they would also catalyse and achieve the climate objectives needed.

To summarise, the results indicate that the inclusion of gender criteria affects the prioritisation of actions. Without gender criteria, actions with a technical component are favoured. However, with gender criteria, actions involving social elements become more important. Additionally, gender criteria impact climate objectives, but not vice versa. The relationship between gender and climate criteria in policy actions is complex and context-dependent. While gender considerations can inform and enhance climate policies, climate change itself can also have differential impacts on different genders and necessitate specific gender-sensitive responses. To address these interrelated issues effectively, comprehensive policies should consider the bidirectional relationship between gender and climate criteria, ensuring that both are integrated into decision-making processes and strategies for a more sustainable and equitable future. If no gender perspective is used in formulating urban decarbonisation policies, these can lead to the reproduction of the existing gender inequalities. In contrast, if policymakers formulate climate policies in cities with gender criteria, these can become a catalyser to overcome these urban inequalities.

The prioritisation of urban policy actions changes depending on the goal of the focus. The ranking is different for the same actions depending on whether the purpose is only climatic or also closing the gender gap. Policymakers should take a gender perspective into account to achieve a just decarbonisation of cities. If both targets are set together, a better balance is established in the type of actions contributing to achieving just decarbonisation and creating a positive reinforcement loop between gender and climate criteria. Integrating gender criteria into urban decarbonisation policies is not just about addressing gender disparities but also about creating more resilient, sustainable, and inclusive cities. This study sets a precedent for including gender criteria in urban policies to decarbonise cities. The study aims to facilitate the inclusion of gender perspective in the 100 Climate-Neutral and Smart Cities by 2030 Mission. The inclusion of gender criteria contributes to closing the gender gap while having a widening impact on decarbonisation, as the criteria analysis suggests. Nevertheless, including gender criteria is insufficient to avoid bias, and multidisciplinary teams must participate in decision-making. The process of analysis and synthesis can yield valuable insights and principles that guide the development of gender-sensitive climate policies in cities and interventions on a broader scale. While each context has its unique challenges and opportunities, local lessons can draw lessons that can inform and inspire more inclusive and effective climate policies in cities worldwide.

CRediT authorship contribution statement

I. Aparisi-Cerdá: Writing – original draft, Methodology, Visualisation, Data curation. **D. Ribó-Pérez:** Conceptualization, Methodology, Software, Data curation, Visualisation, Writing – original draft, Writing – review & editing. **J. Gomar-Pascual:** Conceptualization, Methodology, Writing – review & editing. **J. Pineda-Soler:** Conceptualization, Methodology, Writing – review & editing. **R. Poveda-Bautista:** Conceptualization, Writing – review & editing, Supervision. **M. García-Melón:** Methodology, Supervision, Writing – review & editing.

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

Data will be made available on request.

Declaration of Generative AI and AI-assisted technologies in the writing process

During the preparation of this work the authors used Grammarly in order to avoid grammatical and spelling errors. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

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