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Prioritizing climate change adaptation options : Application of multi-criteria decision-making (MCDM) with stakeholder participation in water resources management

Kim, Ji Yeon* · Park, Chae Yeon** · Huh, Ju Young*** · Hyun, Jung Hee**** and Lee, Dong Kun*****†

*PhD Student, Interdisciplinary Program in Landscape Architecture, Seoul National University, Seoul, Korea
**Researcher, Environmental Management Research Institute, National Institute of Advanced Industrial Science and Technology (AIST), Tsukuba, Japan
***Independent Researcher, Seoul, Korea
****Research Scholar, Systemic Risk and Resilience Research Group Advancing Systems Analysis, International Institute for Applied Systems Analysis (IIASA), Laxenburg, Austria
*****Professor, Dept. of Landscape Architecture and Rural System Engineering, Seoul National University, Seoul, Korea

ABSTRACT

The complexity and uncertainty of climate change and differing stakeholder interests present substantial challenges to prioritization in adaptation strategies. Given that priorities can vary widely based on stakeholder composition and the selected adaptation measures, decision-making methodologies must possess the flexibility to accommodate these differences. With its multidisciplinary nature and diverse stakeholder involvement, water resources management requires comprehensive and integrated methods for rational priority-setting. This study assembled expert groups, including municipalities and civic organizations, to form a governance system. Trustworthy adaptation policy priorities were subsequently derived from this governance system's evaluation results. Recognizing that priority outcomes may differ across groups, we applied the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), a Multi-Criteria Decision-Making (MCDM) method. The application of TOPSIS within governance offers a variety of flexible priority options, surpassing the limitations of a single top priority, and allows decision-makers to adapt their choices to both national and local contexts. While survey-derived priorities may differ based on stakeholder composition, this approach allows for developing plans that reflect the urgency of regionally tailored policies. Our findings offer a foundation for understanding each priority's significance.

Key words: Climate Change Adaptation, Participatory Approach, Adaptation Option, Decision-support, Policy Priority, Water Management, TOPSIS, MCDM

1. Introduction

Adaptation policies and practices can vary depending on the governance mode; however, many studies have treated them as a "black box," meaning that the specific mechanisms through which governance modes influence adaptation are not fully understood (Wellstead et al., 2013; Bednar et al., 2019). Previous studies illustrate the heterogeneity in adaptation planning related to the context-specific nature of adaptation and the differences in resources, values, needs, and perceptions among and within societies (Petzold et al., 2020; Wilson, 2022). The diversity in adaptation planning is emphasized, as it can vary due to the context-specific nature of adaptation as well as differences in resources, values, needs, and perceptions among and within societies (Werners et al., 2021).

Adaptation to climate change involves addressing problems

†Corresponding author : dklee7@snu.ac.kr (Room 9211, Bldg. 200, Gwanak-ro 1, Gwanak-Gu, Seoul, 08826, Korea. Tel. +82-2-880-4885)

ORCID Kim, Ji Yeon 0000-0003-4566-4794 Hyun, Jung Hee 0000-0001-6960-9277 Park, Chae Yeon 0000-0002-5641-892X Lee, Dong Kun 0000-0001-7678-2203 Huh, Ju Young 0000-0001-770-5887

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from a long-term perspective, which challenges traditional values and priorities in moderate to short-term planning (Carlsson-Kanyama et al., 2013). Significant efforts have been made to prioritize policies that need to be developed, implemented, and funded (Burton et al., 2002). Priority setting is especially crucial in areas where various sectors and impacts are integrated and face pressure from limited resources (Chen et al., 2016). Furthermore, setting appropriate priorities for each local context requires incorporating local knowledge to ensure effective implementation and policy performance (Petzold et al., 2020). However, achieving an acceptable outcome for all stakeholders can be challenging, particularly when interests are sharply opposed at local and national scales, as is often the case with priorities.

Although there is room for debate regarding a clear concept of governance, it is a multidimensional concept that involves not just a single actor responsible for policy decisions and implementation but also a variety of institutions, sectors, and government levels, including numerous public and private stakeholders (Driessen et al., 2012; Glass and Newig, 2019). In the context of climate adaptation, governance is necessary for enabling transformational change by exchanging information in learning processes across different knowledge domains (Termeer et al., 2017; Gonzales-Iwanciw et al., 2020). To achieve climate adaptation, a wide range of actors is involved, from the role of government to the voluntary efforts of non-governmental actors (Molenveld et al., 2020). Therefore, it is crucial that such governance provides information for theory and practice to mainstream adaptation (Dellmuth and Gustafsson, 2021).

To overcome these limitations, the multi-criteria decision-making method (MCDM, or multi-criteria decision analysis, MCDA) can offer a solution for effectively translating individual priorities into credible results (O'Brien and Brugha, 2010; Jun et al., 2011; Kim and Chung, 2013; Golfam et al., 2019; Zamani et al., 2020; Akbari et al., 2021). The weighted sum method (WSM) and analytic hierarchy process (AHP) are primarily used for this purpose due to their ease in synthesizing expert opinions into quantifiable data. However, limitations exist, such as specific points becoming unnecessarily emphasized depending on the respondent's preferences (Pong, 2006), or decreased accuracy when the number of evaluation criteria increases (Widianta et al., 2018). A more comprehensive methodology is needed to evaluate climate adaptation policies with various characteristics and distinct evaluation criteria.

A participatory approach can be employed to overcome the limitations of traditional MCDM methods in governance by reconciling different opinions among stakeholders and providing data. It takes into account the perspectives of various stakeholders under uncertainty to support decision-making (Baudry et al., 2018), facilitates discussions involving diverse actors and interests (Sisto et al., 2022), and can be applied across multiple fields (Gomontean et al., 2008; de Brito et al., 2018; Ahmad et al., 2021; Pérez et al., 2021). This paper utilizes a participatory approach to engage relevant stakeholders in the process. A participatory approach can be defined in various ways, ranging from engaging appropriate people (key stakeholders) to empowering them to have a say in fundamental decisions through active involvement (Few et al., 2007; Cvitanovic et al., 2019). In climate change adaptation, participatory methods, such as support tools, are applied to incorporate community-based local and traditional knowledge into the decision process (Reed et al., 2013; Champalle et al., 2015; Cvitanovic et al., 2019). In selecting, evaluating, and prioritizing adaptation options, the guidelines for adaptation to climate change in developed countries necessitate the engagement of various stakeholders (Ribeiro et al., 2009; ICLEI, 2010; Brown and Davidson, 2011; Giordano et al., 2013; ICLEI, 2019; National Climate Change Adaptation Research Facility (NCCARF)).

Water resource management has been emphasized in previous research due to its interconnected nature with various impacts and stakeholders (Castro Campos et al., 2020). The uniqueness of the water sector lies in its connection to and embedment within most of the goods and services we rely on as individuals, communities, countries, and regions (Neal, 2020). To meet domestic and local needs, it is essential to prioritize different management strategies (Rousta and Araghinejad, 2015). The reasons why priorities are highlighted in the water resources management sector are as follows: 1) the water sector is intertwined with various areas such as agriculture, disaster management, and urban infrastructure, and has socio-economic impacts (Iglesias and Garrote, 2015); 2) we can identify factors i nfluencing a system's long-term sustainability by incorporating information such as literature and expert and stakeholder opinions into the assessment model (Milman and Short, 2008). Water management is heavily dependent on infrastructure, making it crucial to maintain resilience against stresses such as climate impacts and aging. Determining when, where, and how to renew and prioritize water infrastructure, which itself functions as a resource, is highly complex due to the need to connect it with the infrastructure's function (van der Wal et al., 2021). Therefore, setting priorities that reflect various interests across different domains while considering conflicts and synergies in water planning (Miller and Belton, 2014) is a prerequisite for climate change adaptation.

In this study, an adaptation framework using TOPSIS and governance is introduced. This framework was applied at the national level for the water resources management sector; however, it also needs to be downscaled to fit regional-level needs. We aim to 1) verify the efficiency of the TOPSIS method for facilitating more participation in determining priorities among conflicting policies; 2) identify priorities that vary depending on stakeholder group characteristics; and 3) present downscaling approaches from regional climate change to national policies and further to local implementation of actual adaptation processes. By utilizing this framework, countries and communities alike would be allowed to adapt successfully to local contexts and resolve the ambiguity of establishing adaptation plan priorities through this integrated process.

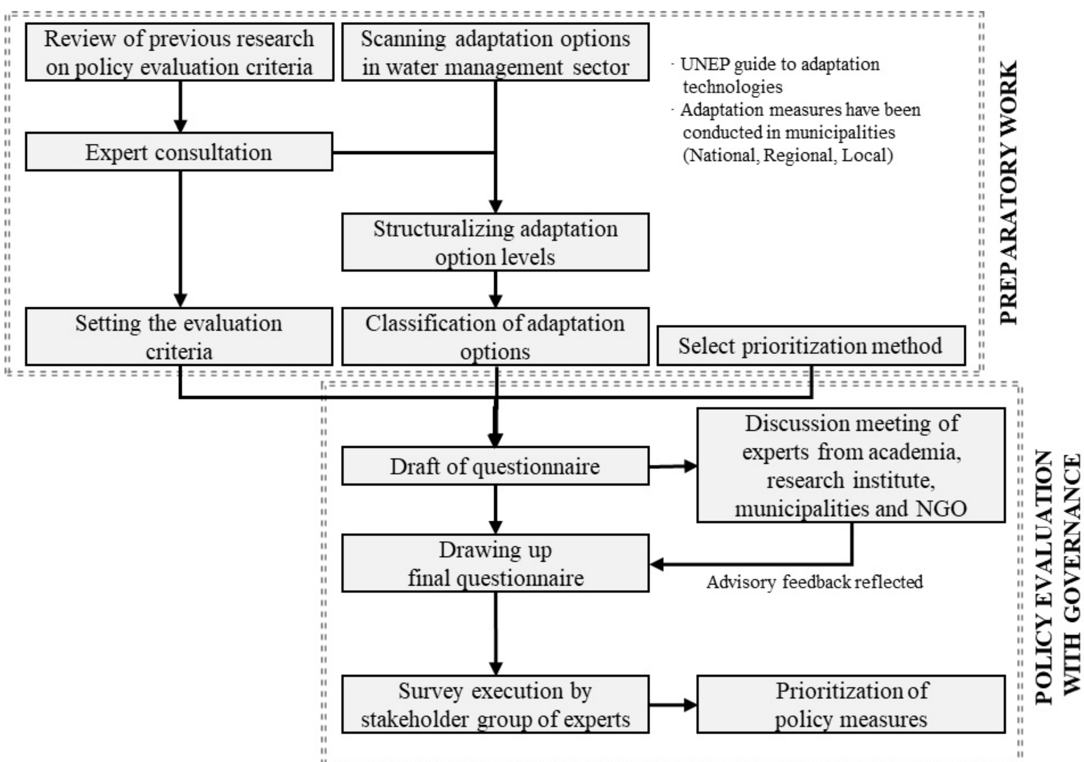

Fig. 1. Categorization of climate services according to level of scientific complexity and number of target users. The research flow is composed of preparatory work and policy evaluation with governance. An adaptation options list was composed in preparatory work, and the criteria for evaluating adaptation options and prioritization methods were determined. A discussion meeting was held via *The National Assembly Forum on Climate Change* for policy evaluation

2. Material and methods

For this study, the adaptation-option-prioritizing method was designed to be participatory in order to derive values that can be more generally applied by incorporating opinions from differing stakeholders, such as academic experts, public officials in municipalities and national government, researchers, and civic groups. Participation arises within this process, starting with composing adaptation options for each sector and concluding with drawing up and conducting questionnaires (Fig. 1). We conducted ten expert workshops over two years from 2018, and the sample size of experts who participated in the water management sector survey was 65.

2.1. Constructing evaluation criteria and a list of adaptation options in the sector

In contrast with mitigation policies, which are usually focused on only one index, such as emission reduction, adaptation policies must consider criteria of various aspects (e.g., importance, no regret, feasibility) to maximize their effects (de Bruin et al. 2009; Mcleod et al. 2015). For this study, evaluation criteria were established by reviewing previous research (UK Climate Impacts Programme (UKCIP), 2007; de Bruin et al., 2009; Hallegatte, 2009; Trærup and Bakkegaard, 2015). Positive criteria are divided into "effects" and "validity," while effect criteria are given in a hierarchy ranging from "effectiveness to a sector" (i.e., sector-adaptation effect) to "no regret" (i.e., non-climate change effect in other sectors). Negative criteria are represented by "cost," which includes the initial cost to establish as well as the operational costs of maintaining (Table 1).

"Effect on the sector" of an option refers to the level of adaptation effect that can reduce the overall damage to a specific sector (i.e., in this study, the water resources management sector) caused by climate change. "Effect on the other sectors" of an option is similar, but in this case, refers to this same level of adaptation effect for other sectors (e.g., agriculture, ecology, disaster sector). In one previous study, these two adaptation effects were expressed as "importance," meaning the necessity to implement the option to avoid negative impacts (de Bruin et al. 2009). In this study, the effects criteria were divided into consideration of both the specific sector and other sectors to reflect the difference in the adaptation effects of options. "Synergies with mitigation" refers to an option's level of carbon emissions reduction. Since nearly all adaptation and mitigation options have synergies or

Table 1. Evaluation criteria

Evaluation criteria			Description	References
Positive Criteria	Effects	Effect on the sector	The option's adaptation effect in reducing the damages caused by climate change	de Bruin et al., 2009
		Effect on the other sectors	The degree to which the option is helpful in adapting to other sectors	de Bruin et al., 2009
		Synergies with mitigation	Mitigation effects from carbon emissions reductions	Hallegatte, 2009
		No regret	General positive impacts from implementing the adaptation option regardless of adaptation or mitigation effects	UKCIP, 2007; de Bruin et al., 2009; Hallegatte, 2009
	Validity	Feasibility / Ease of implementation	The degree of ease in implementation of adaptation based on the institutional capacity of national and local governments	UKCIP, 2007; de Bruin et al., 2009
		Urgency	The degree to which adaptation cannot be postponed and action must be taken within the next 5 years	de Bruin et al., 2009
Negative Criteria	Cost	Cost	Total cost, including initial installation and maintenance costs	Traerup and Bakkegaard, 2015

conflicts (Hallegatte 2009), this criterion was used to show the effect of an option concerning climate change mitigation. The "No regret" option manages climate uncertainty, providing non-climate related benefits (Hallegatte 2009), and brings socio-economic benefits, regardless of future climate change (UK Climate Impacts Programme (UKCIP) 2007). "Validity" criteria are related to institutional capacities and the severity of climate impact. "Feasibility" refers to the degree of possibility from the institutional point of view in the implementation of the national and local governments, and "urgency" refers to the degree to which the option may not be postponed to a later timeframe (de Bruin et al., 2009). The evaluation criteria were discussed and examined through ten expert panel meetings, which included representatives from government departments, municipalities, academia, and NGOs. The meetings were held between October 22, 2018, and September 17, 2019.

A list of adaptation options was developed based on one United Nations Environment Programme report (hereafter; UNEP report) (Bertule et al., 2017) and one adaptation option inventory made by Korea Environment Institute (KEI), which runs the Korea Adaptation Center for Climate Change (KACCC) and have compiled an inventory from regional and local adaptation plans across the country. The list of criteria was reviewed with the help of academic experts, who advised on the appropriate sub-sector strategies to categorize, as well as establishing a hierarchy for adaptation options. This process was necessary because adaptation implementation is often carried out under the same name at the national, regional, and local levels. The option names and descriptions were also revised to align with the terms commonly used in practice in Korea.

When creating the adaptation options list, the UNEP report was published in collaboration with island regions and developing countries; therefore, many of the adaptation strategies included were irrelevant to Korea.

Table 2. Structure of adaptation policy measures in order to prioritize

Sector	Strategy	Adaptation options	Code
Water Resource Management Sector	Drought	Seawater desalination technology	D-1
		Expansion of sewage reuse	D-2
		Rainwater management, leak prevention, and reduction technology	D-3
		Emergency measures against drought	D-4
		Strengthen water-saving measures	D-5
		Industrial, agricultural water demand management	D-6
		Groundwater resource management	D-7
	Flood	Flood control measures	F-1
		Expand flood disaster prevention facilities	F-2
		Build a flood safety system at the development stage	F-3
		Establishment of water management infrastructure flood response system	F-4
		Expansion of urban flood prevention facilities	F-5
		Measures to prevent flooding of buildings	F-6
		Expansion of rainwater leakage reduction facilities	F-7
	Water Quality & Ecosystem	Ecological river and wetland creation	W-1
		Management of pollution source	W-2
		Limitations on saltwater intrusion	W-3
		Urban nonpoint source management	W-4
		Water source protection management	W-5
		Expansion of small-scale sewage treatment facilities	W-6
		Water safety plan	W-7

During the expert consultation, all cases that were not associated with ongoing projects were excluded, resulting in the water management sector is divided into three major categories: "drought," "flood," and "water quality & ecosystem," based on the classification system in Korea (Table 2).

2.2. Obtaining stakeholder opinion and conducting the policy evaluation questionnaire

A governing body (which functioned as a statistical population of the questionnaire later) was then formed involving experts from government agencies, local governments, research institutes, and civic groups by utilizing a pool of experts (i.e., stakeholders) from the National Assembly Forum on Climate Change (The National Assembly Forum on Climate Change 2020). This included experts from government departments (e.g., Ministry of Environment, public corporations) and municipalities (e.g., central metropolitan cities, metropolitan) and their affiliated research institutions, academia, civic groups (e.g., water-related environmental groups), and consulting firms. Compared to generating the list of adaptation policies, evaluating, and prioritizing the adaptation options was relatively challenging for the policy practitioners. The solution was to compromise by utilizing expert knowledge.

Five experts participated in each of the expert meetings, including one representative from each institution representing each of these groups. They provided advice on the list of pre-established evaluation criteria and adaptation options, including 1) adding essential options that were initially missed and deleting less-important options; 2) reviewing whether the level of adaptation options established was appropriate for scoring and prioritizing; and 3) deciding whether the questionnaire method was intended to answer all options in both the first and second questionnaires or whether a re-examination should be conducted with only the highest-ranking options of the first questionnaire. Furthermore, experts provided an overall opinion on the adaptation options prioritization framework. Finally, the list of adaptation options for prioritization was drafted via discussion meetings of the governance forum.

An overall questionnaire was drafted combining these expert advisory comments and then divided into two main parts. The first questionnaire determined the evaluation criteria weights and weights of the strategies within the sector, while the second questionnaire assessed the value of each adaptation option according to the criteria. Within the water resources management sector, there were three strategies and seven options for each strategy; therefore, 21 adaptation options were evaluated. There were seven evaluation criteria (Table 1), and all scores were evaluated on a 5-point Likert scale. On the questionnaires, the name of the option and a brief supplementary explanation was provided. The survey targets were limited to experts, and online questionnaires were distributed after confirming the expertise of the field through judgment sampling.

Nationwide surveys were carried out among experts in the water resources management sector, with 65 respondents at the end of the survey. The first survey was conducted from October 22 to November 15, 2018, with 44 participants, while the second survey was conducted from November 20 to December 27, 2018, with 21 participants. After the first survey, a minor explanation was added to the second questionnaire to improve the understanding of the questions according to the opinions of the respondents, and the contents of the other questionnaires were kept the same as in the first survey. The respondents comprised 16 people from government departments, 18 from local governments, 20 from universities and research institutes, and 11 from civic groups. When conducting the survey, it was noted that metropolitan government officials with substantial adaptive capacity had relatively little interest, and therefore researchers from the affiliated research institutes of those cities were contacted.

2.3. Choosing a method to synthesize responses determining the final priority

We applied the TOPSIS method to prioritize options, and as one of the MCDM methods, it can be easily

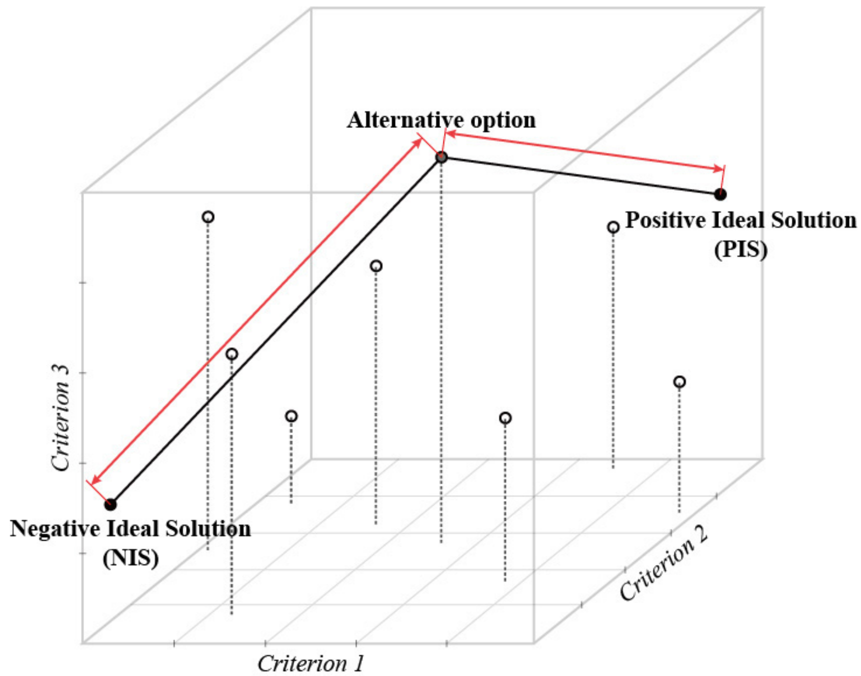

Fig. 2. The conceptual diagram of the TOPSIS method (reproduced from Chang et al., 2010)

explained by comparing it with the Simple additive weighting (SAW) method. SAW is the most used MCDM method, and some decision-makers do not trust the results obtained in this way because of their simplicity (Hwang and Yoon, 1981). To choose an alternative with the largest weighted average, SAW calculates the sum of profit utility and the cost-utility to produce better quality alternatives. In the case of comparing options for monotonic utilities, SAW is a variant of the TOPSIS approach that uses Manhattan distances instead of Euclidean distances (Hwang and Yoon, 1981).

This study aimed to collect the opinions represented by experts, evaluate adaptation options, and interpret the results to determine the priority among options. Therefore, when applying a method for this, the reversal in the result value should not be large while the number of adaptation options increases or decreases due to a change in conditions. In addition, the method should be able to interpret the results of evaluating several adaptation options for criteria with different attributes (Fig. 2).

Equation 1 describes the relative closeness of an option with respect to the ideal solution by TOPSIS, with a decision matrix that contains m alternatives (S_{i^*} is the separation between each alternative from the ideal one, S_{i^-} is the separation from the negative-ideal one. They can be measured by the n-dimensional Euclidean distance). TOPSIS is one of the ways to minimize rank reversal in the case of adding an alternative that is not optimal to the options list (Mukherjee, 2014). In order to compare alternatives, the method calculates the relative closeness to a positive ideal solution (PIS) by regarding the negative ideal solution (NIS) (Equation 1).

$$C_{i^*} = S_{i^-} / (S_{i^*} + S_{i^-}) \quad (0 < C_{i^*} < 1,\ i = 1,2,\cdots,m) \tag{1}$$

TOPSIS can manage with a decision matrix that contains a sizable number of alternatives and attributes (or criteria), but each attribute in the matrix is assumed to take monotonically increasing or decreasing utility (Hwang and Yoon, 1981) Trade-offs and interactions between attributes with different characteristics can also be considered. In addition, both positive and negative items can be used as criteria, and the calculation process is relatively simple and easy to understand (Zavadskas et al., 2016). Further, the priority evaluation values between alternatives provide information to determine their differences and similarities (Yoon and Kim, 2017). The weight of each strategy and the weight of each evaluation criterion were obtained by a questionnaire to apply the TOPSIS method. Each decision matrix was created based on each individual's response in order to consider the individual's opinion on what is most important (through weighting of the criteria). Then in the final step, the matrix was merged with the arithmetic mean of the overall results.

3. Results

3.1. List of adaptation options in the water management sector

The list of adaptation options was first constructed with reference to KEI's climate change risk classification and local government implementation tasks list, and secondly through the UNEP report (Trærup and Bakkegaard, 2015) and and advisory on water management. At the time of the first draft, the subject of the evaluation was attempted as a task level which composes inventory in Fig. 3. But at the second construction, it was decided that the assessment level would take place at the level of the adaptation option itself, which is a level that can be more easily referred to the local government's adaptation planning and serve as a minimum level for actual survey assessment. As a result, an evaluation system of Sector-Strategies-Options (-Tasks) was established, linking options to the inventory of tasks previously implemented by national and local governments (Fig. 3).

As a result of classifying implementation tasks by referring to KEI climate change risk and adaptation inventory, it was possible to classify strategies into "water environment management," "water resource planning," and "flooding/drought." Adapted from the UNEP classification, the water resources sector is divided into "climate change risk," "water shortage," "flood management," "water quality management," and "disaster prevention" strategies. However, since 'climate change risk' is generally addressed across all sectors, it cannot be a specific strategy for the water sector and was therefore excluded. Similarly, the disaster management sector covered' disaster prevention,' so selecting specific risks and strategies for the water sector that can encompass concrete adaptation options was necessary. Consequently, considering the environmental ecosystems' significance in Korea, three strategies were ultimately chosen: drought (i.e., water shortage), flood (i.e., urban flooding), and water quality & ecosystems (Table 2).

3.2. Adaptation options priority result in water management sector

Even if two questionnaires gave identical responses, the result of the adaptation option priority derivation can change significantly depending on how the weight was set and how the score was assigned. In this study, instead of calculating the weights separately, the weights required by the respondents were used intact and different weights were used for each decision matrix. Therefore, the results differed depending on how the respondents were grouped, and different results are shown according to their affiliation as a characteristic of the main stakeholder (Fig.

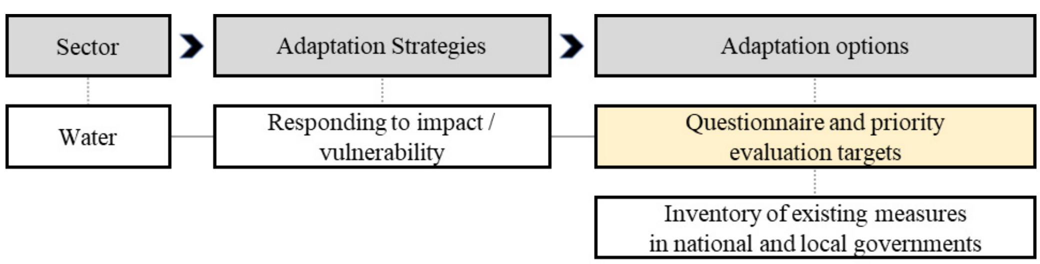

Fig. 3. Hierarchy of adaptation plan elements, the priority evaluation target is adaptation options

Table 3. Mean and standard deviation of evaluation criteria by respondents' affiliation

Criteria \ Affiliation	Government	Municipalities	Academia	Civic Group
Effect on the sector	4.63 (0.62)	**4.61** (0.50)	**4.40** (0.68)	**4.36** (0.67)
Effect on the other sectors	3.81 (0.40)	4.00 (0.69)	3.80 (0.77)	3.64 (1.03)
Synergies with mitigation	3.38 (0.81)	3.61 (0.78)	3.40 (0.88)	3.55 (0.93)
No regret	3.56 (0.51)	3.50 (0.71)	3.20 (0.52)	3.09 (0.83)
Feasibility	**4.69** (0.48)	4.33 (0.59)	4.10 (0.91)	4.36 (0.81)
Urgency	4.56 (0.73)	4.44 (0.62)	**4.40** (0.75)	4.00 (0.63)
Cost	4.19 (0.75)	3.83 (0.92)	3.90 (0.79)	3.36 (0.81)

4). In the case of evaluation criteria, the effect to the sector had the highest weight in almost all groups, followed by feasibility (Table 3). The respondents assigned their own weights to the decision matrix depending on what they deemed more important.

Relative closeness represents how close an alternative is to the PIS and how far it is from the NIS. The PIS was determined by the highest values for benefit utilities (positive criteria) and the lowest for cost utilities (negative criteria), with converse values determining the NIS. PIS and NIS are hypothetical solutions, but they can exist in the possible range of utilities. As a result of calculating relative closeness using TOPSIS, different priorities were derived according to the stakeholder group's interests (Fig. 4, 5). In the case of government departments or academia experts, which show an average point of view for all areas, the variation in closeness value between options was relatively small. In the case of academia, the score of the adaptation option belonging to drought strategies was high. In the case of civil groups, the flood option scores were relatively high, whilst low priorities were drawn for water quality and aquatic ecosystem options. Overall, "Strengthen water-saving measures (D-5)" is identified as the number one priority option to increase water management efficiency to cope with water scarcity. "Building flood safety system at the development stage (F-3)" is vital in addressing disaster risk factors and minimizing the demand for post-disaster recovery through readjusting natural disaster risk. "Emergency measures against drought (D-4)" prepare measures for the efficient operation of dams and wide-area waterworks and to reduce drought damage as the frequency of drought increases due to the impact of climate change.

The positive criteria tend to demote the closeness of most options in the 'drought' and 'flood' strategies while promoting the closeness of options in the 'water quality & ecosystem' strategy (Fig. A2 (a)-(f)). On the other hand, the weight change of the negative criterion, cost, significantly affects the closeness of the 'water quality & ecosystem' strategy (Fig. A2 (g)).

The importance of each criterion varied among different stakeholders. Government departments prioritized feasibility, while the academic sector considered urgency one of the most important criteria. Local governments ranked urgency as the second most important criterion,

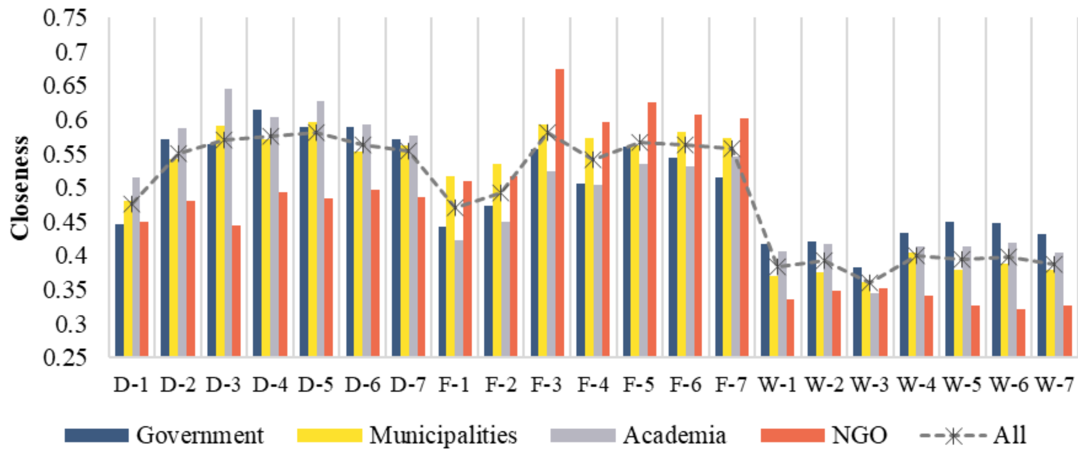

Fig. 4. The closeness of each adaptation option to PIS/NIS by respondent's characteristics identified by affiliation. The Y-axis represents closeness, indicating how close each option is to the PIS of all respondents

while government departments and civil society organizations ranked it third. Based on these findings, government departments prioritize feasible and effective policies in the relevant sector, while local governments focus on both effective and urgent policies. The academic sector prioritizes policies that are effective and particularly urgent, while civil society organizations prioritize policies that are effective and feasible.

Drought policies, which are urgent and effective in the relevant sector, are often customized policies that are high in rank in government departments and academia. However, for D-1 (seawater desalination technology), which is expensive and cannot be applied urgently in the relevant region, its rank is lower even among drought policies. Nevertheless, the policy effects of this technology must be addressed if it is realized, which may explain why it has a slightly higher rank in academia.

High-priority options are ranked at the top by setting sort descending on relative closeness. Therefore, the more similar the alternative and the PIS, the higher the priority of the alternative. There was a difference between groups since the PIS changes according to the decision matrix. These results can inform the process of decision-making with diverse groups of people, such as with governance. Decision-makers can review various opinions, and

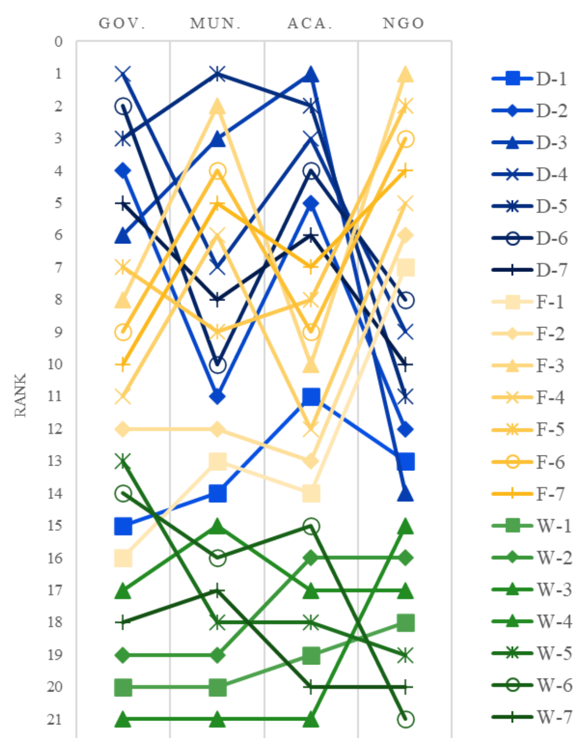

Fig. 5. Change of rank of adaptation options depending on stakeholder groups. A higher rank means high priority. The stakeholder group municipality and NGOs show a similar pattern for the drought and flood sectors

individuals in each group can understand how representative their voices are. Various results can be derived through various configuration methods, such as adjusting the list of options or changing the evaluation index, and this can be used for decision-making. This is possible because pairwise comparison is unnecessary, unlike AHP, therefore the extensive potential range of application. Also, one strength of TOPSIS is that it can handle many attributes and alternatives, so we can freely adjust the number of adaptation options. The priority will change if several adaptation options are added or deleted as the PIS and NIS may modify.

4. Discussions

4.1. Framework for decision-making processes based on varying perspectives using the MCDM approach

MCDM methods can be applied in areas where quantification is difficult but needs to be aligned with urban planning and policy evaluation. As in the case of applying it to ecosystem services (Langemeyer et al. 2016), MCDM can also address conflicting interests in climate adaptation. People assess various options based on their views and values in different contexts, leading to different interests. There is no "correct" answer when discussing adaptation options, and decisions are often made based on preferences and what is "deemed" more appropriate in a particular direction. Because all relevant information cannot be accessed, uncertainty must be addressed, and decision-makers rely on intuition depending on the context (Elbanna and Fadol, 2016). Therefore, we explore various approaches for consensus-building, including systematic methods such as expert meetings, stakeholder discussions, and company consulting, in order to derive analytical results.

Evaluation indicators may vary depending on stakeholders' interests or policy contexts, and there may be volatility in the number of indicators or changes in the indicators themselves as discussions progress or between sectors. In such cases, one solution is the Technique for Order Preference by Similarity to the Ideal Solution (TOPSIS), which offers significant flexibility concerning the size of criteria and alternatives because it does not require pairwise comparisons. The method is easy to use, able to reflect changes in initial conditions, and flexible to change according to user preferences. TOPSIS can be used to assess the vulnerability of a local region to climate change (Kim and Chung, 2013) or prioritize adaptation scenarios in a river basin (Golfam et al., 2019), for example.

The use of AHP among MCDM methods is preferred because its applicability has been demonstrated numerous times in literature and is familiar to policymakers (Vaidya and Kumar, 2006; Behzadian et al., 2012; Mardani et al., 2015). In addition to this, TOPSIS has also confirmed that it has the flexibility of additional options and user considerations as an appropriate model for quickly collecting and reflecting various opinions using weight simulation.

4.2. Understanding stakeholder perceptions: A prerequisite for promoting participation and addressing different preferences

In adaptation, governance requires various actors' joint efforts to influence climate change (Huitema et al., 2016). There is a wide range of different approaches to conceptualizing governance. One is the institutionalist approach, which shapes the actions of actors (Pahl-Wostl 2009). Thus, adaptive co-management relies on the cooperation of stakeholders through a network of local users to regional and national organizations to help create integrated solutions (Folke et al., 2005; Cash et al., 2006). When there are no clear guidelines and limited resources, adaptation governance is a powerful means of potential consideration through higher-level decision-making (Keskitalo et al., 2016).

In this study, the method was applied to prioritize 21 adaptation options in the water resources management sector on a national scale; however, it can also be applied to other sectors in the same way, using the adaptive options inventory, and as a result, priorities for most adaptation options can be established. However, obtaining high-quality and reliable responses through a series of information-gathering processes, including surveys, would be essential to derive a valid result. The reliability of results would be ensured if high-quality values were obtained in the early stages from strategy classification, brainstorming, and selection of survey items through the investigation of various experts and stakeholders and assurance of their participation.

In addition, as adaptation may have ambivalent targets across multiple sectors under information uncertainty, it would be necessary to use enough criteria to take this into account when setting priorities. Otherwise, if key stakeholders are not included, criteria setting is insufficient, or the implementation plan for the established priorities is not properly set up, it may not be possible to present useful findings (Iqbal et al., 2021). The emphasis on adopting a participatory approach in MCDM models beyond what has been previously presented appears here.

4.3. Downscaling approaches to incorporate regional differences within national policy frameworks and address challenges of local application

Even if the results of establishing a climate change adaptation plan have a scientific basis, different socioeconomic conditions will bring different consequences (Liu et al., 2021). Local governments without resources have difficulty setting priorities, but giving them a standard priority would be inappropriate. It is because it is only possible to judge in the local area whether the suggested priorities are most relevant and whether the assigned values would be coherent in the given context. Thus, a method is needed to fully reflect the characteristics of local governments and enable users to adapt the matrix per their priorities.

The ability to derive new priorities even when new expert groups are added, evaluation criteria change, or adaptation option categories differ due to the flexibility of TOPSIS. Through this research, a decision support tool can be organized, allowing users to adjust criteria weights according to local conditions based on the expert evaluation values investigated. This is a significant advantage over traditional WSM and AHP methods and enables a participatory approach. This advantage also serves as a tool to compare and express differing opinions during the deliberation process numerically and to identify the areas of emphasis for each stakeholder, even when the views of experts and citizens diverge. Since there is no definitive answer in determining priorities, it is feasible to consider incorporating weights between participating groups at a higher level, if necessary, through consultations with stakeholders.

The decision support tool will be more effective when it includes the following elements: vulnerability assessments, impact assessments, and risk assessments for

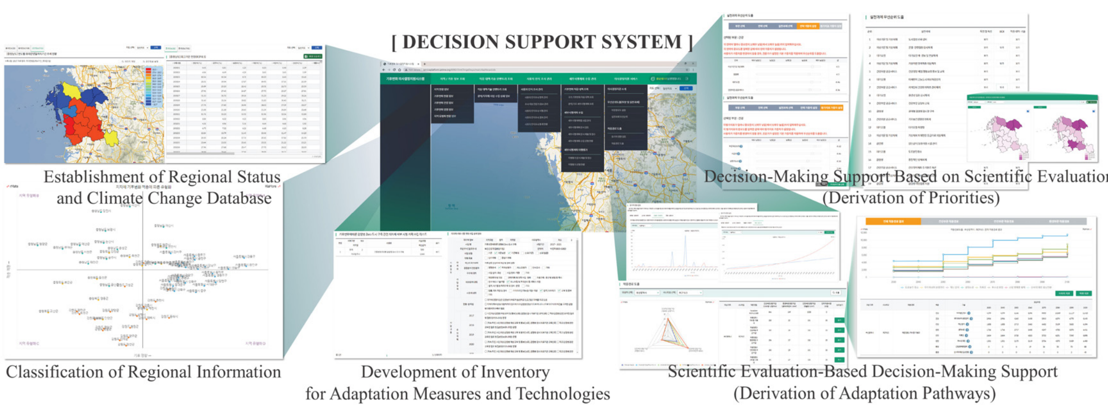

Fig. 6. A decision support system provides access to various climate services, which are categorized into five drop-down menus and displayed on the front page (reproduced from Hyun et al., 2020)

the area, as well as the identification of critical sectors and adjustment of evaluation weights considering future climate change scenarios. In other words, it is necessary to update and adjust information that can be verified at the local level, considering national and regional objectives. By incorporating these elements, the decision support tool can provide a comprehensive framework for stakeholders to make informed decisions about climate change adaptation options. This ensures that local and regional concerns are addressed and that the prioritization process remains flexible and adaptable to changing circumstances. Ultimately, this leads to more effective and targeted adaptation strategies better suited to the unique challenges each community or region faces.

The prioritization method was applied to a developed decision support service that provides accessibility to adaptation information and promotes public disclosure, presented as a single system (Fig. 6, Hyun et al., 2020). This system operates as a decision support service, along with climate information search, adaptation strategy, technology inventory search, user perception survey, and detailed implementation plan management. Stakeholders can establish detailed implementation plans reflecting the characteristics of their regions by changing the default values set by the decision support service to fit their respective regions, obtaining customized prioritization results. Through the function of prioritizing sectors and practice tasks for short-term planning for five years, they can select sectors, strategies, and practice tasks that fit the regional characteristics and set weights for strategies and indicators, resulting in prioritization results of the sectors and their corresponding practice tasks. Anyone can develop regionally suitable detailed implementation plans based on the prioritization results and detailed information.

5. Conclusion

To strengthen the effectiveness of the policy in establishing a climate change adaptation plan and to successfully adapt that plan, it must be able to achieve the maximum effect with a limited budget. Prioritizing itself would be used as a basis for increasing the efficiency of the options and justifying the decision-making process. To prioritize alternatives, the most appropriate and reasonable option-setting is essential, depending on the outcome to be drawn. This study developed a framework for establishing appropriate steps to prioritize adaptation options that were appropriate for the field of climate change adaptation and that were easily understood by various stakeholder groups. The primary screening process was carried out through a review of the UNEP report or the adaptation option at the local government level, which provided the nationwide option typically used and verified by experts. Afterward, discussions were carried out to provide more realistic and easy-to-understand feedback.

Indeed, when this method was applied to the site, additional complementary data, such as impact assessment data, served as an effective, synergistic decision-making tool. When this series of information is provided as a system, users (stakeholders) can increase accessibility to adaptation information and publicly disclose information to the public. This tool is an example of scientific information that can be used to prioritize strategies through a variety of respondent groups and item combinations. The differences in opinion among stakeholders can be identified, therefore, representing the quantitative values of all stakeholders.

With this method, it was possible to integrate opinions from groups with different interests on different criteria and reflect the preferences of individuals while dealing with a decision matrix. Positive indicators (e.g., effects and validity) can be compared to negative indicators (e.g., cost). These results can be used in conjunction with cost-benefit analysis, a quantitative assessment. Priorities derived through this method represent proposed options, not necessarily correct answers, and may be best used as reference data. Since weight selection is very important, comparing the results according to various weight evaluation methods was necessary. This framework can be used to determine policy priorities during the planning process. In particular, as the demand for policy development and implementation at the local level is currently intensifying, involving stakeholders, including citizens, enables this framework to offer flexible policy options through their participation.

In summary, this method was developed to evaluate suitable options for deriving valid priorities and to produce reasonable results. Decision-makers were able to consult with these results, which improved the credibility and validity of the decision-making process. This method would be expected to help evaluate uncertain information under limited resources and choices.

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Appendix

1) Let $\boldsymbol{A} = [a_{ij}]$ be the n × n decision matrix and $\boldsymbol{R} = [r_{ij}]$ be its normalization

2) Constuct the weighted normalized decision matrix $\boldsymbol{T} = [w_j r_{ij}]$

3) Determine positive ideal and negative ideal solutions.

   Let $J_+ = \{j = 1,2,\cdots,n \mid j$ associated with the criteria having a positive impact$\}$ and

   $J_- = \{j = 1,2,\cdots,n \mid j$ associated with the criteria having a negative impact$\}$

   Determine the worst alternative A_w and the best alternative A_b as under:

   $A_w = \{max(t_{ij} \mid i = 1,2,\cdots,n) \mid j \in J_-, min(t_{ij} \mid i = 1,2,\cdots,m) \mid j \in J_+\} \equiv \{t_{wj} \mid j = 1,2,\cdots,n\};$

   $A_b = \{min(t_{ij} \mid i = 1,2,\cdots,n) \mid j \in J_-, max(t_{ij} \mid i = 1,2,\cdots,m) \mid j \in J_+\} \equiv \{t_{bj} \mid j = 1,2,\cdots,n\};$

4) The TOPSIS method evaluates the separation measures by considering $I^2 -$ norm.

   Construct distance metrices and study its effect on ranking.

$$d_{iw}^{p} = \left\{ \sum_{j=1}^{n} \left| t_{ij} - t_{wj} \right|^{p} \right\}^{\frac{1}{p}}, i = 1,2,\cdots,n;$$

$$d_{iw}^{p} = \left\{ \sum_{j=1}^{n} \left| t_{ij} - t_{wj} \right|^{p} \right\}^{\frac{1}{p}}, i = 1,2,\cdots,n;$$

5) The relative closeness to the ideal solution, which will be used for the ranking of options, is calculated as in formula

$$s_{iw}^{p} = \frac{d_{iw}^{p}}{d_{iw}^{p} + d_{ib}^{p}}, i = 1,2,\cdots,n.$$

Fig. A1. Prioritizing alternatives using TOPSIS method (adapted from Dedania et al., 2015)

	c1-0.5	c1-0.3	c1-0.1	c1+0.1	c1+0.3	c1+0.5
D-1	-0.94027	-0.70520	-0.46384	-0.21618	0.03778	0.29383
D-2	-1.33421	-1.19061	-1.04337	-0.89068	-0.73436	-0.57440
D-3	-0.19083	-0.13305	-0.07353	-0.00875	0.05952	0.12955
D-4	-3.02145	-2.88403	-2.73965	-2.59006	-2.43525	-2.27696
D-5	0.35278	0.31836	0.28394	0.24953	0.21511	0.18241
D-6	-0.81464	-0.66167	-0.50159	-0.33262	-0.15830	0.02134
D-7	-1.10621	-0.92546	-0.73747	-0.54045	-0.33801	-0.13014
F-1	-0.46064	-0.78755	-1.12507	-1.47109	-1.82347	-2.18222
F-2	-0.05082	0.10978	0.27851	0.45538	0.63631	0.82131
F-3	-0.56465	-0.40111	-0.22896	-0.04820	0.13772	0.33053
F-4	-1.73887	-1.51921	-1.29031	-1.05218	-0.80667	-0.55378
F-5	-1.46501	-1.29930	-1.12829	-0.95023	-0.76688	-0.58001
F-6	-1.46399	-1.35751	-1.24394	-1.12505	-1.00083	-0.87129
F-7	0.59176	0.56307	0.53617	0.50927	0.48596	0.46444
W-1	3.51347	3.02715	2.51482	1.98169	1.42775	0.85561
W-2	2.40820	1.99878	1.56647	1.11128	0.63829	0.14749
W-3	1.93640	1.65540	1.35214	1.03219	0.69276	0.33943
W-4	2.53563	2.23365	1.91420	1.57977	1.23038	0.86850
W-5	1.15286	0.85895	0.54729	0.22044	-0.11909	-0.47381
W-6	1.67329	1.35625	1.02159	0.66680	0.29692	-0.08807
W-7	0.67557	0.44608	0.19855	-0.06188	-0.33521	-0.62142

(a)

	c2-0.5	c2-0.3	c2-0.1	c2+0.1	c2+0.3	c2+0.5
D-1	-0.78076	-0.60866	-0.43026	-0.24976	-0.06296	0.12383
D-2	-1.22696	-1.12699	-1.02156	-0.91068	-0.79798	-0.68164
D-3	-0.20133	-0.13655	-0.07353	-0.00875	0.05602	0.12080
D-4	-2.53962	-2.58658	-2.63877	-2.69443	-2.75531	-2.81793
D-5	0.22371	0.24264	0.25985	0.27362	0.28739	0.30115
D-6	-0.71859	-0.60120	-0.48025	-0.35396	-0.22589	-0.09605
D-7	-1.11344	-0.93088	-0.73928	-0.53865	-0.33439	-0.12291
F-1	-1.03379	-1.13569	-1.24183	-1.35221	-1.46684	-1.58147
F-2	-0.16467	0.04269	0.25615	0.47774	0.70339	0.93312
F-3	-0.46653	-0.34086	-0.20830	-0.06886	0.07575	0.22552
F-4	-1.40291	-1.31246	-1.21832	-1.12418	-1.02634	-0.92666
F-5	-0.91321	-0.96610	-1.01546	-1.06306	-1.11066	-1.15473
F-6	-1.10376	-1.13570	-1.16941	-1.20313	-1.23685	-1.27234
F-7	0.23491	0.34430	0.46085	0.58638	0.71728	0.85357
W-1	2.80610	2.59284	2.36659	2.13513	1.89327	1.64361
W-2	2.11576	1.81823	1.50290	1.17486	0.83664	0.48825
W-3	1.83346	1.58863	1.32710	1.05723	0.77345	0.48132
W-4	2.56308	2.24862	1.91919	1.57478	1.22039	0.85602
W-5	1.37583	0.99323	0.59290	0.17736	-0.25591	-0.69932
W-6	1.77394	1.41412	1.03920	0.64919	0.24911	-0.16355
W-7	0.96694	0.62142	0.25785	-0.12119	-0.51312	-0.91795

(b)

	c3-0.5	c3-0.3	c3-0.1	c3+0.1	c3+0.3	c3+0.5
D-1	-0.19099	-0.25396	-0.31272	-0.36729	-0.42186	-0.47013
D-2	-0.85615	-0.90159	-0.94521	-0.98884	-1.03246	-1.07609
D-3	-0.25735	-0.17507	-0.08754	0.00525	0.10154	0.19958
D-4	-1.69250	-2.07170	-2.46482	-2.87011	-3.28759	-3.70854
D-5	0.01033	0.10669	0.21167	0.32352	0.44399	0.56961
D-6	-0.58341	-0.52116	-0.45357	-0.38064	-0.30238	-0.22234
D-7	-0.66879	-0.65975	-0.64710	-0.63083	-0.61095	-0.58926
F-1	-0.98285	-1.10597	-1.23334	-1.36283	-1.49444	-1.63030
F-2	0.62818	0.52450	0.41878	0.31104	0.20329	0.09351
F-3	0.24617	0.09640	-0.06025	-0.22035	-0.38734	-0.55432
F-4	-0.57593	-0.80852	-1.04849	-1.29585	-1.54690	-1.80164
F-5	-0.56767	-0.74749	-0.93965	-1.14239	-1.35571	-1.57255
F-6	-0.67077	-0.87129	-1.07891	-1.29186	-1.51012	-1.73017
F-7	0.42499	0.46085	0.50030	0.54693	0.59714	0.65273
W-1	2.30157	2.28337	2.26256	2.24176	2.21835	2.20015
W-2	1.64785	1.53087	1.40627	1.27403	1.13925	0.99939
W-3	2.02543	1.70548	1.36883	1.01550	0.64825	0.26987
W-4	2.16127	2.00404	1.83683	1.65964	1.47496	1.29027
W-5	1.27702	0.93496	0.57263	0.19510	-0.19510	-0.59543
W-6	1.59026	1.30592	1.00146	0.68441	0.35479	0.01510
W-7	1.09845	0.70393	0.28622	-0.14955	-0.60337	-1.06493

(c)

	c4-0.5	c4-0.3	c4-0.1	c4+0.1	c4+0.3	c4+0.5
D-1	-0.78915	-0.61495	-0.43445	-0.24556	-0.05037	0.15111
D-2	-0.73254	-0.82343	-0.91795	-1.01610	-1.11790	-1.22151
D-3	0.08228	0.03501	-0.01576	-0.06828	-0.12080	-0.17507
D-4	-2.30827	-2.44742	-2.59180	-2.74139	-2.89447	-3.04928
D-5	0.34590	0.31492	0.28394	0.25125	0.21855	0.18585
D-6	-0.24724	-0.31305	-0.38242	-0.45357	-0.52649	-0.59942
D-7	-0.41935	-0.50792	-0.59468	-0.68506	-0.77362	-0.86219
F-1	-1.50718	-1.42439	-1.33948	-1.25456	-1.16541	-1.07837
F-2	-0.02846	0.12604	0.28461	0.44928	0.61598	0.78471
F-3	-0.10329	-0.11706	-0.13256	-0.14805	-0.16354	-0.17904
F-4	-1.30323	-1.25339	-1.19986	-1.14264	-1.08172	-1.01896
F-5	-0.71047	-0.83917	-0.97139	-1.10713	-1.24641	-1.38568
F-6	-0.96002	-1.04875	-1.13925	-1.23152	-1.32202	-1.41252
F-7	0.37299	0.43037	0.49134	0.55589	0.62224	0.69397
W-1	2.82170	2.60064	2.37179	2.12993	1.87767	1.61760
W-2	2.15390	1.83857	1.51053	1.16977	0.81630	0.45265
W-3	1.62201	1.45508	1.28259	1.10453	0.91812	0.72337
W-4	2.25112	2.05645	1.85430	1.64217	1.42504	1.20043
W-5	1.21367	0.89442	0.55996	0.21030	-0.14949	-0.52196
W-6	1.67581	1.35625	1.01907	0.66680	0.30195	-0.07800
W-7	0.95405	0.61369	0.25527	-0.12119	-0.51312	-0.91795

(d)

Fig. A2. Sensitivity analysis for each criterion. The color shows the rate of closeness change compared with the criteria weight set by a median value of 3.0. (a) criterion 1 is 'effect on the sector,' (b) criterion 2 is 'effect on the other sector,' (c) criterion 3 is 'synergies with mitigation,' (d) criterion 4 is 'no regret,' (e) criterion 5 is 'feasibility,' (f) criterion 6 is 'urgency,' and (g) criterion 7 is 'cost.' Only (g) shows a different pattern, as the cost is applied as a negative criterion

	c5-0.5	c5-0.3	c5-0.1	c5+0.1	c5+0.3	c5+0.5
D-1	0.32741	0.06926	-0.20149	-0.48273	-0.77446	-1.07459
D-2	-1.03974	-1.01247	-0.98339	-0.95067	-0.91613	-0.87796
D-3	0.13831	0.06653	-0.00525	-0.07703	-0.14881	-0.21884
D-4	-3.42326	-3.12929	-2.82315	-2.50657	-2.17781	-1.84209
D-5	0.27878	0.27362	0.27018	0.26501	0.25985	0.25469
D-6	-0.54250	-0.49270	-0.44290	-0.39309	-0.34151	-0.29171
D-7	-0.91280	-0.80616	-0.69590	-0.58203	-0.46634	-0.34705
F-1	-1.66002	-1.52203	-1.37556	-1.21635	-1.05078	-0.87883
F-2	0.71559	0.57939	0.43911	0.29274	0.14027	-0.01423
F-3	-0.60080	-0.42349	-0.23584	-0.04132	0.16182	0.37012
F-4	-1.72964	-1.51367	-1.28846	-1.05218	-0.80852	-0.55747
F-5	-1.20410	-1.14063	-1.07540	-1.00312	-0.92908	-0.84974
F-6	-1.59708	-1.43737	-1.27056	-1.09843	-0.92098	-0.73820
F-7	0.36761	0.42678	0.48955	0.55769	0.62762	0.70294
W-1	3.45626	2.99334	2.50442	1.99209	1.45896	0.90763
W-2	1.79280	1.61988	1.43678	1.24352	1.04008	0.82647
W-3	2.14785	1.78338	1.39666	0.98767	0.55922	0.11129
W-4	2.95241	2.48821	2.00155	1.48993	0.96084	0.41179
W-5	1.01857	0.77533	0.51942	0.25084	-0.03041	-0.32432
W-6	1.66323	1.34870	1.01907	0.66932	0.30698	-0.06794
W-7	0.31974	0.22691	0.12377	0.01289	-0.10830	-0.23722

(e)

	c6-0.5	c6-0.3	c6-0.1	c6+0.1	c6+0.3	c6+0.5
D-1	-1.04311	-0.75977	-0.47853	-0.20149	0.07346	0.34211
D-2	-1.06882	-1.02701	-0.98702	-0.94703	-0.90704	-0.86523
D-3	0.13130	0.06653	-0.00525	-0.07878	-0.15756	-0.23810
D-4	-3.18148	-2.98144	-2.77270	-2.55875	-2.33958	-2.11693
D-5	0.64361	0.49389	0.34245	0.19102	0.03958	-0.11186
D-6	0.10672	-0.10139	-0.31127	-0.52294	-0.73460	-0.94627
D-7	0.02531	-0.23859	-0.50430	-0.77543	-1.04656	-1.31950
F-1	-3.71487	-2.75325	-1.78314	-0.80878	0.16558	1.13781
F-2	0.14231	0.22972	0.32120	0.41269	0.50620	0.59972
F-3	0.97092	0.53022	0.08435	-0.36324	-0.81082	-1.25841
F-4	-0.91928	-1.02450	-1.12418	-1.21832	-1.30692	-1.39184
F-5	-1.48793	-1.30987	-1.13005	-0.94847	-0.76512	-0.58177
F-6	-1.43382	-1.33977	-1.23862	-1.13037	-1.01326	-0.89081
F-7	0.96654	0.78901	0.61148	0.43575	0.26181	0.08966
W-1	3.70332	3.13898	2.55123	1.94788	1.32633	0.68917
W-2	3.05666	2.38531	1.69362	0.98413	0.26193	-0.47045
W-3	2.58743	2.04490	1.48290	0.90143	0.30604	-0.30048
W-4	3.21446	2.64544	2.05146	1.44002	0.81360	0.17220
W-5	1.32769	0.96536	0.58277	0.18496	-0.22804	-0.65371
W-6	1.82427	1.44683	1.05178	0.63661	0.20885	-0.23401
W-7	1.38982	0.87670	0.34294	-0.20886	-0.77613	-1.35372

(f)

	c7-0.5	c7-0.3	c7-0.1	c7+0.1	c7+0.3	c7+0.5
D-1	1.04941	0.49322	-0.06296	-0.61495	-1.16274	-1.70214
D-2	-0.63984	-0.77798	-0.90704	-1.02519	-1.13426	-1.23423
D-3	-0.14006	-0.10504	-0.06303	-0.01751	0.03151	0.08578
D-4	-2.79706	-2.75183	-2.69617	-2.63355	-2.56223	-2.48569
D-5	-0.12218	0.02753	0.18585	0.35106	0.51970	0.69351
D-6	-0.27214	-0.33973	-0.39487	-0.43756	-0.46780	-0.48914
D-7	-0.46996	-0.54407	-0.61095	-0.66698	-0.71578	-0.75555
F-1	0.35663	-0.29082	-0.95737	-1.63879	-2.33294	-3.02921
F-2	1.77882	1.22789	0.65664	0.07115	-0.52246	-1.12015
F-3	-0.37184	-0.28060	-0.18764	-0.09296	0.00344	0.09813
F-4	-0.50948	-0.76606	-1.03373	-1.31062	-1.59120	-1.87547
F-5	-0.61880	-0.77923	-0.95199	-1.13005	-1.31164	-1.49851
F-6	-0.90678	-1.01326	-1.12683	-1.24572	-1.36639	-1.49060
F-7	0.82308	0.70832	0.58638	0.45906	0.32816	0.19546
W-1	-3.97379	-1.46156	1.02465	3.46666	5.85405	8.18163
W-2	-4.88251	-2.37005	0.11443	2.55569	4.94355	7.27546
W-3	-4.92725	-2.45389	-0.01113	2.38711	4.72693	7.00832
W-4	-4.45482	-1.94914	0.52659	2.95989	5.33829	7.65929
W-5	-5.66043	-3.21534	-0.80320	1.56333	3.87666	6.12917
W-6	-5.17840	-2.74269	-0.33969	2.01802	4.32540	6.56988
W-7	-5.91769	-3.49905	-1.10876	1.23769	3.53515	5.77330

(g)

Rate of closeness change (%)

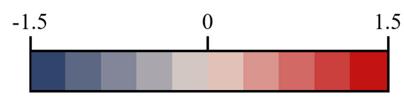

Fig. A2. Sensitivity analysis for each criterion. The color shows the rate of closeness change compared with the criteria weight set by a median value of 3.0. (a) criterion 1 is 'effect on the sector,' (b) criterion 2 is 'effect on the other sector,' (c) criterion 3 is 'synergies with mitigation,' (d) criterion 4 is 'no regret,' (e) criterion 5 is 'feasibility,' (f) criterion 6 is 'urgency,' and (g) criterion 7 is 'cost.' Only (g) shows a different pattern, as the cost is applied as a negative criterion (Continued)