Approaching the Climate Crisis with Multi-Criteria Decision Making Techniques and Novel Software

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Introduction

In recent years, the Climate Crisis has gained much attention. Transitioning to a sustainable society is necessary and urgent, yet quite complex. All types of organizations – civic organizations, state and local governments, commercial firms, national governments, etc. – must decide which policies to implement to yield a sustainable way of life. Choosing these policies can be a daunting and challenging task due to the diversity of options – from transitioning to electric vehicles to utilizing Low Embodied Carbon Concrete. One aspect of this project intended to introduce a small set of candidate policies and detail them at great lengths.

Another large aspect of this project was providing support for decision makers. When presented with multiple policies and much information about them, it still is difficult for decision makers to choose the best options for them. For this, we turned to a multi-criteria decision making technique titled PROMETHEE. The PROMETHEE method outlines a set of mathematical steps to determine the best option(s) out of a set of choices based on the decision maker's preferences on evaluation criteria.

In this project, we fully analyzed the PROMETHEE method for multi-criteria decision making, applied it to a set of sub-national programs and policies, and finally developed novel software for decision makers to use to assist them in their decision making processes.

PROMETHEE method

The Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE) is a method developed by Professors Jean-Pierre Brans and Bertrand Mareschal, and is used for multicriteria decision making problems. Starting from a list of "options" or "alternatives" evaluated on a number of criteria, PROMETHEE ranks the options from best to worst in terms of the goal of the decision maker.

The decision maker or third-party group begins by assigning a score to how each alternative performs on each criterion. This data can be organized on an *n x k* table where there are *n* alternatives and *k* criteria. Below is an example format of a *2x3* table. Our version of such a table is seen in a different section.

	Criterion 1	Criterion 2	Criterion 3
Alternative 1	5	5	6
Alternative 2	3	1	4

In this basic example, we assume a higher score is better. Then, Alternative 1 is the best choice because it outperforms Alternative 2 on all criteria.

PROMETHEE Method Formulae

The PROMETHEE method develops a ranking system for the set of alternatives by sorting a quantity called net outflow (Φ_{net}). Below are a set of equations detailing how to obtain Φ_{net}:

$$\phi_{net}(a) = \phi^{+}(a) - \phi^{-}(a)$$

$$\phi^{+}(a) = \frac{1}{n-1}\sum_{x \in A} \pi(a, x)$$

$$\phi^{-}(a) = \frac{1}{n-1}\sum_{x \in A} \pi(x, a)$$

$$\pi(a, b) = \sum_{j=1}^{k} P_j(a, b) \cdot w_j$$

$$P_j(d) = \begin{cases} 0 & d \le q \\ \frac{d-q}{s-q} & q < d < s \\ 1 & d > s \end{cases}$$

The full details of the PROMETHEE method can be quite complex. For a full explanation of the method, watch the following self-made video tutorial: https://www.youtube.com/watch?v=SkbHgOicAeQ

Policies and Criteria

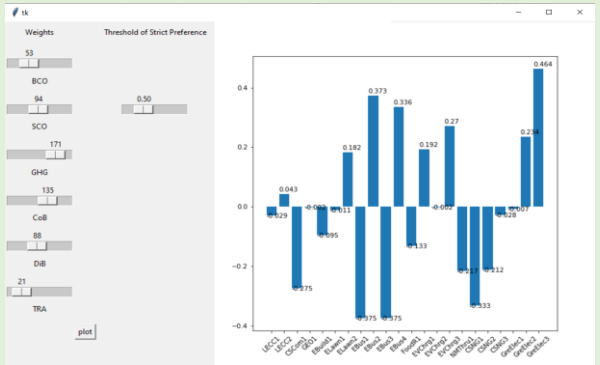
To lessen the abundance of possible policies that relate to creating a more sustainable future, our group focused on a few categories including composting, green electricity, low embodied carbon concrete, etc. For each category, we proposed a few specific policy recommendations. Each policy was then evaluated on a 1-7 scale for the following six criteria: Budget Expense Cost (BCO), Social Expense to Relevant Stakeholders (SCO), Greenhouse Gas Emission Reductions (GHG), Co-benefits (CoB), Disbenefits (DiB), and Transition Effects (TRA).

The decision maker, or user of our software, is tasked with providing 7 values to obtain a ranking of the policies. They must first provide 6 numeric values indicating how important they deem each criterion. And lastly, they must specify the value for a certain parameter used in PROMETHEE calculations. With these seven data points, our software handles all calculations and outputs the best choices.

Software Development and Usage

Program	BCO	SCO	GHG	CoB	DiB	TRA
LECC1	6	3	5	3	1	6
LECC2	1	6	6	5	4	6
CSCom1	7	3	3	5	3	6
GEO1	7	3	4	5	1	5
EBuild1	1	7	7	3	5	7
ELawn1	3	3	4	5	2	6
ELawn2	1	5	5	6	2	6
EBus1	2	3	2	3	2	4
EBus2	2	3	6	7	4	6
EBus3	2	3	2	3	2	4
EBus4	3	3	6	7	4	6
FoodR1	5	3	2	6	2	5
EVChrg1	1	6	6	6	4	7
EVChrg2	3	3	4	4	1	6
EVChrg3	3	1	5	5	2	6
NMThru1	7	2	2	6	5	4
CSNG1	1	3	3	2	2	3
CSNG2	2	3	4	3	2	3
CSNG3	3	3	5	4	2	3
GreElec1	3	3	5	4	2	5
GreElec2	4	3	6	5	2	6
GreElec3	6	3	7	6	2	7

The policies, criteria, and scores are presented in the table above. A decision maker can then use this table to assist them in choosing policies that best match their preferences. Below is a visual of the software for a certain decision maker. The user inputs their seven data points on the left, and the software outputs a graph of all policies and their PROMETHEE score. In general, a higher score is considered to be better.



For this particular decision maker, we may suggest them to consider the policies GreElec3, EBus2, and EBus4, as these are the policies that received the best scores from the preferences specified. Our group thoroughly researched these policies and wrote individual reports for each policy for decision makers to read and learn more about the policy.

Final Notes

The data we collected is quite preliminary in nature and is also noisy. Going forward, we wish to optimize the method of obtaining data from volunteers by avoiding confusing PROMETHEE terminology. The software is sensitive to data presentation, so the data table containing the scores of alternatives and criteria must follow an established format. Finally, I would like to extend much gratitude to Professor Kimbrough and the other talented students I worked with this summer for making this project enjoyable and successful.

Preliminary Data & Results

After researching policies, scoring them on the criteria, and developing software, we decided to gather some preliminary data from volunteers. These volunteers were asked to specify their preferred weights for the six criteria (BCO, SCO, GHG, CoB, DiB, TRA), and we used that data to run the software. In Figure 1, we see a table of the five volunteers and the weights they specified, and Figure 2 graphs the final scores for each policy for the participants.

	BCO	SCO	GHG	CoB	DiB	TRA
V1	60	40	80	25	20	10
V2	15	17	35	10	25	27
V3	24	34	40	22	17	10
V4	52	40	100	10	17	36
V5	30	15	40	2	3	10

Figure 1

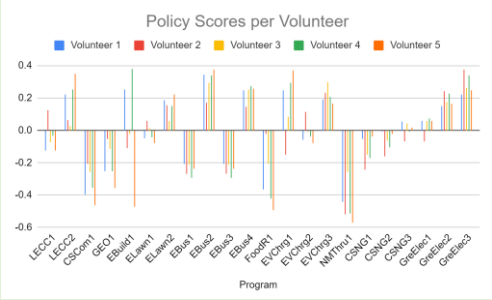


Figure 2

From our data, we can begin to form some conclusions. There were seven policies that received a positive PROMETHEE score for all volunteers. Four of these policies derive from Green Electricity and Electric Buses programs. The policy titled Ebuild1 is the most polarizing amongst the volunteers. Additionally, Volunteer 2's scores across the policies were often quite different than the rest of the group. In the future, we intend to allow discussion between volunteers and monitor how these discussions change an individual's opinions of criteria weights. Such analysis would require additional research.