MULTICRITERIA ANALYSIS FOR THE PRIORITIZATION OF CLIMATE CHANGE ADAPTATION MEASURES OF TRANSPORT SECTOR IN URBAN ENVIRONMENT

SKIADA M. and PAPADOPOULOU M.P.

Laboratory of Physical Geography and Environmental Impacts, School of Rural and Surveying Engineering, National Technical University of Athens, 9 Iroon Polytechniou, University Campus, 15780 Zografou, Greece
E-mail: mara_skiada@hotmail.com

ABSTRACT

Global climate change consists a major overriding environmental problem and one of the most important challenges that environmental regulators are facing with not only economic but also social dimensions. As climate change impacts pose growing challenges to many aspects of life such as infrastructure facilities, agriculture, fishery, ecosystems and human health, many countries and cities are beginning to incorporate climate change adaptation measures/actions into their planning. It is known that climate change effects on regional level mainly depends on the ability of different social and environmental systems to be adapted so it is essential that adaptation will be mainly addressed in a city level.

The current study is focusing on prioritizing adaptation measures/actions to climate change in the transportation sector in Attica Region, Greece. The aim of this study was to first investigate and then hierarchy the most appropriate measures/actions that will serve the purpose of climate adaptation in the Attica region. More specifically, in order to evaluate the adaptation measures found in the literature and obtain their desired hierarchy, a multi-criteria analysis was performed. Thus, a total of four scenarios were developed (i.e environmental, economic, social and equal scenarios). A sensitivity analysis was also performed for each scenario, in order to determine the reliability of the results and whether they are susceptible to possible changes in the performance evaluation process. The final results were quite satisfactory and highlighted the hierarchical relationships of those measures, the implementation of which could contribute to the adjustment of climate change adaptation measures of transportation sector in urban environment.

Keywords: Climate change, Adaptation measures and actions, Transportation sector, Multi-criteria analysis (MCA), Urban environment.

1. Introduction

"Climate change" refers to changes in global climate conditions and especially to changes in weather conditions for extended periods. According to the UNFCCC, climate change is defined as "the change in climate, owing directly or indirectly to human activities", differentiating the term by climate variability, which is owed solely natural causes (European Parliament, 2014). Sea level and temperature rising in conjuction with the increased frequency and intensity of extreme weather events are expected to have significant impacts on transport infrastructure and on distribution of traffic flows. The consequences of climate change in the transport sector vary from a region to another, while they differ in type and intensity (European Commission, 2013).

In this analysis, the Attica Region in Greece is selected in order to first investigate and then prioritize the most appropriate climate change adaptation measures in order to improve the performance of transport sector. So as to examine all the different points of view of the problem, it was chosen to investigate the hierarchy for four alternative scenarios: one scenario where all criteria were considered equal, the environmental, the economic and eventually the social scenario. Finally, it was considered appropriate to assign a sensitivity analysis for each of these scenarios.

The Attica Region is located in the central part of Greece and covers a total area of 3,808km^2. For the purposes of this analysis the administrative boundaries and the identity of the spatial entity, both in elements of natural environment as well as of technical features were considered. Attica's road network is divided into three distinct areas: the small ring area (city center), the remaining urban area and the sub-urban area in the greater metropolitan region. The road network is estimated to have a total length of 14,000 km, 80% of which is local roads with little involvement in transport public service and the remaining 20% consists of the main roads. 43.6% of the country's vehicles are locating in this region. The network of public transportation serving Attica region is primarily consisting of lines of buses, trolley buses, metro lines and a tram network.

2. Methodological approach

For the evaluation and prioritization of climate change adaptation measures in the transport sector in the Attica region, a multi-criteria analysis, a systematic and standardized mathematical effort to resolve problems arising from conflicting objectives was held (Ministry of Agriculture, Natural Resources and Environment of Cyprus, 2005). In this analysis, multi-criteria theory was chosen based on the preferences expressed by the utility function, according to the following formula:

$$u\ (g1,\ g_2,\ \ldots,\ g_n) = u[u_1,\ g_1,\ u_2\ g_2,\ \ldots,\ u_n\ g_n] \quad (1)$$

Where u () sets the overall usefulness defined as the value that the decision maker yields as a function of partial utility u_1, u_2, etc., attached to each criteria.

In particular, the adaptation measures under examination were chosen based on the list in the EU platform (Centre for Climate Adaptation, 2014)

Table 1: Climate change adaptation measures in the transport sector

	Adaptation Measures
M1	Use of non-conventional fuels
M2	Development of a pedestrian network
M3	Development of cycle networks
M4	Expansion of public transport network
M5	Transfer coastal roads
M6	Flood protection works on road network
M7	Implementation of tax incentives

Subsequently, the required evaluation criteria were defined as:

1. Implementation cost of each measure
2. CO_2 emissions reduction which refers to the contribution of each measure to emission levels,
3. The degree of realization, associated with the current state of implementation of adaptation measures,
4. The public acceptance in the implementation of each adaptation measure.

Based on the above criteria the 'Table of Impacts' is properly determined (Table 2).

Table 2: Adaptation measure 'Table of Impacts'

Criteria	Scale	Adaptation measures						
		Non-conventional fuels	Pedestrian network	Cycle networks	Public transport network	Transfer coastal roads	Flood protection works	Tax incentives
Implementation cost	0-6	3	4	4	5	6	5	2
Reduction of CO2	---/+++	++	+++	+++	++	0	0	++
Degree of realization	0-3	1	2	2	3	0	3	1
Public acceptance	---/+++	-	++	+	+++	---	+	-

The adopted multi-criteria analysis (MCA) requires an estimate of the weighting coefficient for each evaluation criterion in order to properly rank the proposed measures. In this analysis, Analytic Hierarchy Process (AHP) method was chosen, which is a structured technique used to organize and analyze a multi-criteria decision and it is characterized by clarity and easiness of implementation (Saaty, 1994).

Table 3: Weighting coefficients for all evaluation criteria

Evaluation Criteria	Environmental Scenario	Economic Scenario	Social Scenario
Reducing CO_2 emissions	51%	5,5%	29,5%
Public acceptance	28,8%	11,8%	51%
Degree of implementation	16,3%	26,2%	13%
Implementation Cost	3,9%	56,5%	6,4%

The consistency is the main advantage of AHP, through which is ensure that the final decision is the proper one. Specifically, the Consistency Ratio (CR) should be less than 10%.In this analysis, the CR is estimated less than 2-4% for all scenarios.

3. Results

Based on the proposed methodology the analysis obtained the following results for the seven adaptation measures under consideration (Table 4). The scale for each one is set from 0 to 1.

Table 4: Results for all scenarios

Adaptation Measures/Actions	Equal criteria scenario	Environmental scenario	Economic scenario	Social scenario
Expansion of Public Transport Network	0,75/1	0,88/1	0,55	0,90/1
Development of cycle networks	0,71/1	0,87/1	0,52/1	0,83/1
Development of a pedestrian network	0,67/1	0,82/1	0,52/1	0,74/1
Flood protection works on road network	0,58/1	0,62/1	0,50/1	0,63/1
Implementation of tax incentives	0,54/1	0,60/1	0,46/1	0,50/1
Use of non-conventional fuels	0,50/1	0,59/1	0,42/1	0,49/1
Transfer coastal roads	0,13/1	0,26/1	0,03/1	0,15/1

Focusing on environmental scenario, the multi-criteria analysis with respect of the examined adaptation measures showed the following performance considering the specific evaluation criteria (Figure 1).

The hierarchy of adaptation measures for the environmental scenario showed a clear preference in the measures/actions of “Expansion of Public Transport Network”, “Development of cycle networks” and “Development of a pedestrian network”, while the measures/actions of “Flood protection works on road network”, “Implementation of tax incentives” and “Use of non-conventional fuels” were less favorable. The measure of ”Transfer coastal roads” came in the last place of the hierarchy due to the significant impacts in the coastal landscape.

Based on these results, it is concluded that the scenario of equal criteria, environmental and social scenario, give the same hierarchy of measures with slight variations, while the economic scenario differs markedly in comparison with the other scenarios. It is also noted that the measure of coastal roads’ transfer occupies the last ranking place for all scenarios.

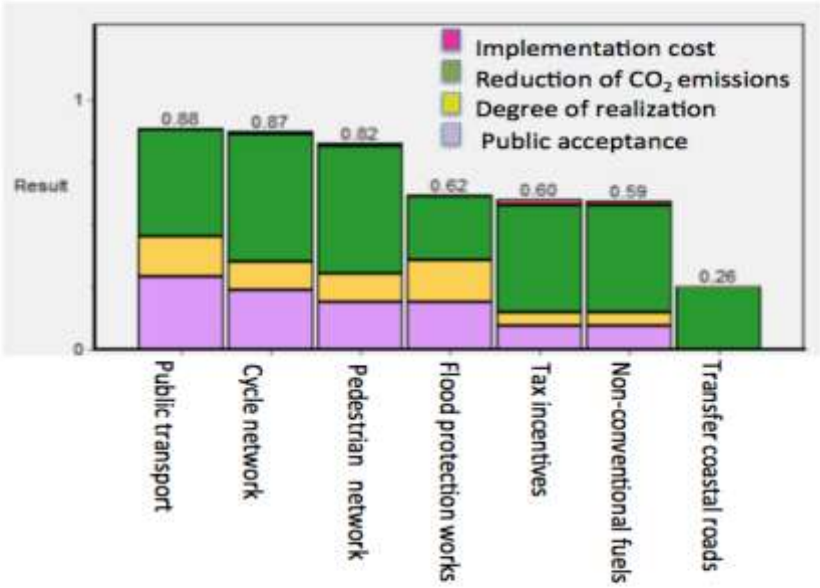

Figure 1: Environmental scenario results

4. Conclusions

Prioritization of climate change adaptation measures was performed in urban environment based on a MCA. The choice of this method was based on the complicated nature of the problem under consideration. The multi-criteria analysis is considered satisfactory as an evaluation method. Successful representation of the multidimensional problem of climate change adaptation, flexibility of the overall process, ability to simultaneously measure the effect of all the different factors of the problem in the final outcome as well as the simplification of the process, are some of the major MCA's advantages. However, a fundamental weakness of the methodological approach is the assignment of the weighting factors that should be followed a more unbiased approach. The overall approach is basically non-quantitative and the obtained results are characterized not as optimal, but as "compromise" solutions.

REFERENCES

1. Saaty, T.L. (1994), Fundamentals of Decision Making and Priority Theory with the AHP, RWS Publications, Pittsburgh, PA, U.S.A.
2. Centre for Climate Adaptation (2014), URL: http://climateadaptation.eu (last access 20/5/2015)
3. European Commission (2013) URL: http://ec.europa.eu (last access 20/5/2015)
4. European Parliament (2014) URL: http://europarl.europa.eu (last access 20/5/2015)
5. Ministry of Agriculture, Natural Resources and Environment of Cyprus (2005) URL: http://moa.gov.cy (last access 20/5/2015)