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Optimal location decision of wind generators in urban areas using multi criteria techniques.

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Abstract: *Powering the urban grid including wind turbines within urban boundaries. Cuenca, Ecuador, was analysed as a case study in this city and its surroundings possess an average annual wind speed of 4 to 5 m / s, depending on the specific characteristics of different locations. The PROMETHEE method was used to identify the best suitable area to take advantage of the wind source for electric power in ranges less than 10KW (micro-scale). Four sites are determined as suitable alternatives, and they are evaluated based on sets of technical, economic, environmental and social criteria. For a more reliable solution, we propose three different scenarios based on different weighting methods. As consequence, the Turi location turns out to be the best option because geographical and wind conditions at the zone. However, it is necessary to analyze aspects related to visual and environmental impact for an adequate implementation of this type of projects.*

The adoption and implementation of ERs on Urban Environments (UE) has attracted attention because more than promoting clean and inexpensive energy, covering the growing energy consumption. Urban environments are characterised by concentration of buildings, industrial areas and a large number of dwellings and diverse infrastructure with a high population density. Continuous improvements in development of ERs integrated on UEs are: solar thermal, photovoltaic and biomass. However, there is growing interest in wind urban integration.

1. PROMETHEE method

It was developed in 1982 by Brans, assesses the strengths and weaknesses of the alternatives. It is based on a pairwise comparison. This method is suitable for selection of alternative tracks based on multiple criteria, allowing a direct comparison of alternatives regarding specific criteria. The process followed by the PROMETHEE method, can be seen in Fig.1.

2. Case study

PROMETHEE in this study is implemented for determining optimal conditions for the implementation of micro wind generation equipment in the urban area of the city of Cuenca (3665 km2). Cuenca is located in the south-central region of the Republic of Ecuador. The urban population is 329,298 inhabitants corresponding to 65.3% of the total population.

Four places in Cuenca have been considered for this study: Turi, Baños, El Vecino and Yanuncay. Baños, is an urban zone emplaced at the south west of the city (2580 m); then Turi located south, in a higher zone (2600 m altitude), Yanuncay located southwest (2560 m altitude) and finally El Vecino, a more dense urban area located northeast of the city of Cuenca (2530 m altitude).In **Fig. 2** shows the location of the city of Cuenca-Ecuador and in **Fig. 3** some images of the study locations are presented.

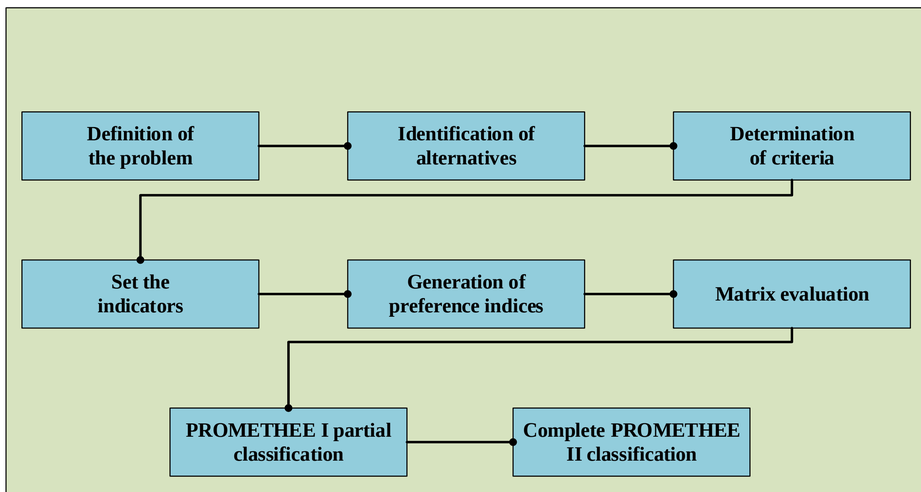

Fig.1. Process method PROMETHEE

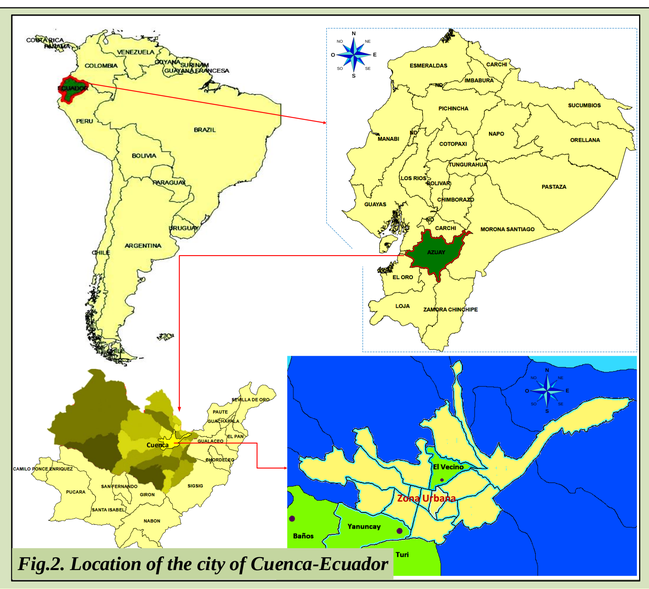

Fig.2. Location of the city of Cuenca-Ecuador

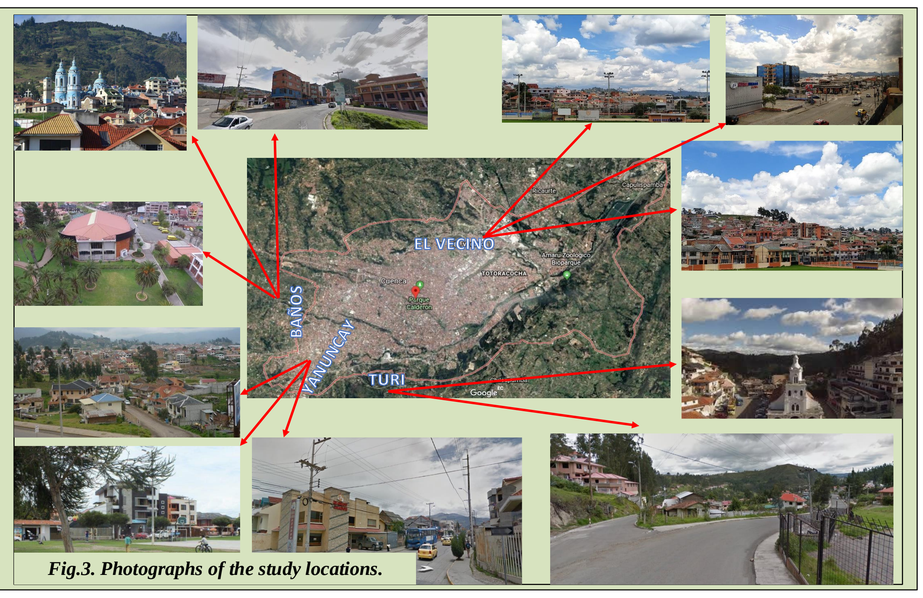

Fig.3. Photographs of the study locations.

3. Criteria grouping

Sub-criteria are established based on a literature review. Four sets of criteria are identified: technical, economic, environmental and social.

Technical criteria:
Turbulence intensity (C1)
Wind power available (C2)
Maximum permitted height for buildings (C3)

Economic criteria:
Annual financial savings (C4)
Economic benefit (C5)

Environmental criteria:
Changes and impact in animal behaviour (C6)
Visual impact (C7)
The collision risk of birds with turbines (C8)

Social criteria:
Availability area (C9)
Social acceptance (C10)

4. Indicators for each sub-criterion

The sub-criteria should be evaluated by quantitative or qualitative indicators.

Table I indicators for each sub-criterion is applicable areas. Also, it indicates whether the sub-criterion should be maximized or minimized.

5. Scenarios

Three scenarios are analysed, each with a different weighting method.
First scenario: "Equal weight allocation". Second scenario: "Points allocation" was used. Third stage:" Critic weighting method " method is used. (Diakoulaki in 1995).
The weights obtained for each scenario are shown in Table II. These values define the final level of importance given to each sub in different scenarios.

In (Fig. 4), wind speed availability in each urban spot is measured.

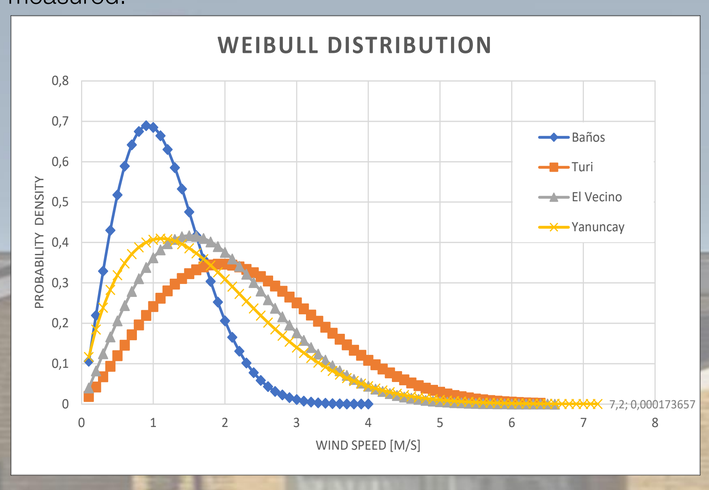

Fig.4. Distribution of Weibull of each study area

Table I. - Complete list of indicators for each sub-criteria analysis

CRITERIA and SUB-CRITERIA					
CRITERIA		Baños	Turi	El Vecino	Yanuncay
Technical	C1	0.42	0.50	0.58	0.64
	C2	259.192	1963.78	1205.73	1959.06
	C3	2	2	6	9
Economic	C4	163.66	1000.36	641.36	572.34
	C5	2.25	2.33	2.00	2.00
Environmental	C6	2.33	2.42	1.92	2.25
	C7	2.50	2.92	2.92	2.92
	C8	3.00	3.00	2.08	2.42
Social	C9	2.92	3.50	2.67	3.00
	C10	3.50	3.42	2.75	2.83

Table II. - Weights for each sub-criteria

SUB-CRITERIA		SCENARIO 1	SCENARIO 2	SCENARIO 3
Technical	C1	0.10	0.11	0.08
	C2	0.10	0.13	0.17
	C3	0.10	0.12	0.35
Economic	C4	0.10	0.11	0.17
	C5	0.10	0.11	0.03
Environmental	C6	0.10	0.09	0.03
	C7	0.10	0.09	0.03
	C8	0.10	0.08	0.06
Social	C9	0.10	0.09	0.03
	C10	0.10	0.08	0.05

6. Results

PROMETHEE method performs a pairwise comparison of alternatives, integrating jointly all sets of criteria. As a result, the net flow is delivered for each alternative. With net flows shown in Table III for each alternative, a partial classification could be done for different scenarios. Alternatives more net flow will be considered more appropriate for solution, while those have a negative net flow will not be considered as a viable solution.

The PROMETHEE II classification allows full comparison of alternatives in terms of weights and preferences established by decision makers.

Alternatives are located hierarchically based on their net flux a rating scale from -1 to 1. As can be seen in Fig. 5, Turi is positioned as the only alternative in Scenarios 1 and 2. While the Stage 3 has giving higher preference to the technical and economic criteria, then Yanuncay is positioned as best alternative followed by Turi and El Vecino.

Table III. - Net flows for every alternative

SOLUTION	ALTERNATIVE	SCENARIO 1	SCENARIO 2	SCENARIO 3
1	Turi	0,2	0,2475	0,1275
2	Yanuncay	-0,0333	-0,0264	0,2684
3	Baños	-0,0667	-0,1155	0,1951
4	El Vecino	-0,1	-0,1056	0,0759

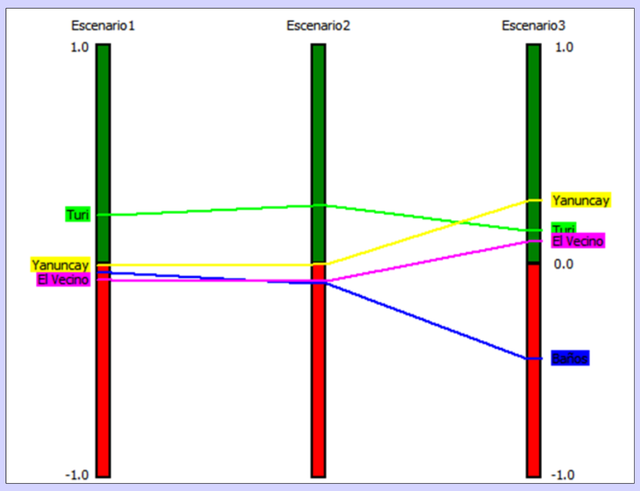

Fig.5. Complete Classification PROMETHEE II

Turi is an area on urbanisation process, maintaining some rural characteristics. The density of buildings is low and the turbulence intensity is less than in Yanuncay. Besides larger empty area is observed that allows to place wind turbines. It is located at a higher altitude place, so Yanuncay has a higher power density, which would provide a greater economic benefit.

Fig.6. Perspective of the TURI area with wind turbines.