Sustainable urban model through fuzzy logic weights

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Abstract— The scope of this work is to assign, by fuzzy logic, the weights to the different indicators that can be taken in consideration in an environmental impact, so to obtain a significant homogeneity and objectivity. In this paper is illustrated the calculation of the assigned weights that uses a procedure based on fuzzy logic and to define a model that allows us to estimate the sustainability of a city. The environmental indicator choice process for studying a specific context results from a fundamental analysis of the objectives, with the consideration that a good indicator must be specific, sensitive, practical and pertinent to the case under study and carefully defined. The sustainable indicators are characterized by a low degree of aggregation and a high amount of information.

Keywords— Environment, Sustainability, Urban plan, Fuzzy logic, Weighting process

I. Introduction

The environmental indicator choice process for studying a specific context results from a fundamental analysis of the objectives, with the consideration that a good indicator must be specific, sensitive, practical and pertinent to the case under study and carefully defined. One of the environmental observation methods that is increasingly prominent proceeds by the use of indicators, which concur "to read" the state of environment in its several aspects, selecting - among all information available - those characterized as meaningful to explain a particular situation, with a descriptive, valuable, predictive or decisional aim [1]. To this point the problem is to define the meaning of an environmental indicator: an indicator furnishes a synthetic description of an environmental reality, by a value or a parameter. However, the information that follows is wider than the value itself and it must be specified in relation to the type of indicator and to the context in which it is placed.

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II. Sustainable Indicators: Uncertainty in the Definition

An International and European agreement on sustainable indicators has not been found because sustainability is not always easily measurable.

A perspective that can be misleading in the selection of environmental indicators is to consider the environment as measurable in a single way. The risk of generating confusion by using an indicator for environmental and sustainability measurement frequently occurs. The relationship between environmental and human decisions is interconnected and it is now impossible to assert that there exists a difference between objective and subjective indicators.

The way in which the indicators are used (it can often depend on the customer) can define the objective or, in other words, the indicators themselves can satisfy objectives and answer various criteria. For example the identification of a pathological condition (diagnostic objective) induces for itself the identification of an environmental standard (management objective), but at the same time it can carry out a descriptive function of the environmental state.

However it remains to be explained the way the environmental information is carefully prepared so as to allow for synthesis evaluation. Since, the codification in categories of environmental indicators, encloses in itself some elements of arbitrariness, the technical definition of an indicator justifies its use and purpose based on its characteristics.

Some essential terms for the predisposition of environmental indicators are the following:

a) identification of the space and temporal context that is taken as reference for the survey of the data base;

b) decision on the type of information that it must be transferred and choice of a synthesis method of the information;

c) check of some property that would characterize the definition of an environmental indicator.

Therefore it will be possible to equip the policy maker with information for "ready consultation", to provide him the information that puts him in situation to attend and to estimate the effects of the intervention.

III. Applications of Fuzzy Logic for Evaluating Environmental Plans

The scope of this work is to assign, by fuzzy logic [2], the weights to the different indicators that can be taken in consideration in an environmental impact, so to obtain a significant homogeneity and objectivity. The indicators arranged by the scientific community are commonly characterized by a low degree of aggregation and a high amount of information, while an increase in the degree of aggregation and a lessening of the amount of information would be necessary to policy makers. Since the different indicators are not homogeneous, as a result of their various structures, it is possible to assign a weight to each indicator to allow for possible aggregation. Typically the base structure for an environmental plan is a matrix (1):

$$\begin{array}{cccc} & G_1 & \cdots & G_J \\ A_1 & \varphi_{11} & \cdots & \varphi_{1J} \\ \vdots & \vdots & & \vdots \\ A_I & \varphi_{I1} & \cdots & \varphi_{IJ} \end{array} \tag{1}$$

where G_j indicates an objective or an environmental characteristic; $G=\{G_1, G_2, \ldots, G_j\}$ is a set of J environmental characteristics, A_i is an alternative or option and $A=\{A_1, A_2, \ldots, A_i\}$ is a set of mutually exclusive plans; φ_{ij} indicates the result of the plan A_i regarding the objective A_j. Generally weights $w=\{w_1, w_2, \ldots, w_j\}$ are introduced to represent the different value of various opportunities.

The following method allows for the assignment to m alternatives $A_1,\ldots, A_m$ their weights. Therefore n experts or judges $J_1,\ldots, J_n$ are used to provide information based on the $C_1,\ldots, C_k$ criteria. The information assigned by judges is fuzzy trapezoid numbers (2):

$$(\alpha / \beta, \gamma / \delta) \tag{2}$$

where a, b, g, d are the real numbers that satisfy the relation a≤b≤g≤d, [3] (Fig. 1).

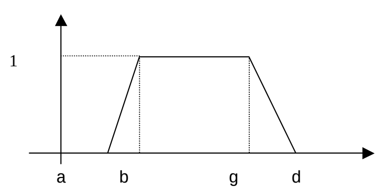

Fig. 1 Typical membership of fuzzy number

The weights of the indicators are given by the followings steps:

1. The judges express their opinion both in terms of the criteria of evaluation of the indicators and in terms of indicator's importance relative to every criterion in the interval of values [0, L]. The matrix of criteria obtained is:

$$T = \begin{array}{c|cccc} & J_1 & J_2 & \ldots & J_n \\ \hline C_1 & & & & \\ C_2 & & & & \\ \vdots & & \bar{b}_{kj} & & \\ C_k & & & & \end{array} \tag{3}$$

where:

$$\bar{b}_{kj} = (\varepsilon_{kj} / \zeta_{kj}, \eta_{kj} / \theta_{kj}) \tag{4}$$

and the alternatives matrix is (5):

$$T_k = \begin{array}{c|cccc} & J_1 & J_2 & \ldots & J_n \\ \hline A_1 & & & & \\ A_2 & & & & \\ \vdots & & \bar{a}_{ij}^{k} & & \\ A_m & & & & \end{array} \tag{5}$$

for every criterion C_k (1≤k≤K), and where (6):

$$\bar{a}_{ij}^{k} = (\alpha_{ij}^{k} / \beta_{ij}^{k}, \gamma_{ij}^{k} / \delta_{ij}^{k}) \tag{6}$$

2. The weight can be determined in two ways:

a) For every judge J_i the indicator weight is obtained by criteria (7):

$$\overline{w_{ij}} = \left(\frac{1}{KL}\right) \otimes \left[\left(\bar{a}_{ij}^{1} \otimes \bar{b}_{1j}\right) \oplus \cdots \oplus \left(\bar{a}_{ij}^{K} \otimes \bar{b}_{Kj}\right)\right] \tag{7}$$

and so on for all judges; then the average value of fuzzy weight $\overline{w_{ij}}$ is (8):

$$\overline{w_i'} = \left(\frac{1}{nL}\right) \otimes [\overline{w_{i1}} \oplus \cdots \oplus \overline{w_{in}}] \tag{8}$$

this is again a fuzzy number.

b) The judge Ji makes fuzzy number $\bar{a}_{ij}^{k} = (\alpha_{ij}^{k} / \beta_{ij}^{k}, \gamma_{ij}^{k} / \delta_{ij}^{k})$ and $\bar{b}_{kj} = (\varepsilon_{kj} / \zeta_{kj}, \eta_{kj} / \theta_{kj})$ then the average values are given by (9):

$$\alpha_{ik} = \sum_{j=1}^{n} \frac{\alpha_{ij}^{k}}{n} \tag{9}$$

to obtain:

$$\bar{m}_{ik} = (\alpha_{ik} / \beta_{ik}, \gamma_{ik} / \delta_{ik}) \tag{10}$$

$$\bar{n}_k = (\varepsilon_k / \zeta_k, \eta_k / \theta_k) \tag{11}$$

then the indicator weight can be considered by the relation (12):

$$\overline{w_i} = \left(\frac{1}{KL}\right) \otimes \left[\left(\overline{m}_{i1} \otimes \overline{n}_1\right) \oplus \cdots \oplus \left(\overline{m}_{iK} \otimes \overline{n}_K\right)\right] \qquad (12)$$

3. Once the value $\left(\overline{a}_{ij}^{k}, \overline{b}_{kj}\right)$ or $\left(\overline{m}_{ik}, \overline{n}_k\right)$ is obtained, the weights can be expressed as (13)

$$(W_i[L_1, L_2]/X_i,\ Y_i/Z_i[U_1, U_2]) \qquad (13)$$

where the diagram of the membership function is:

- zero to the left of Wi,
- $L_1y^2+L_2y+W_i=x$ in $[W_i, X_i]$,
- horizontal line by $(X_i, 1)$ to $(Y_i, 1)$,
- $U_1y^2+U_2y+Z_i=x$ in $[Y_i, Z_i]$,
- zero to the right of Z_i.

with:

$$W_i = \sum_{k=1}^{K} \frac{\alpha_{ik}\varepsilon_k}{KL} \qquad (14)$$

$$X_i = \sum_{k=1}^{K} \frac{\beta_{ik}\zeta_k}{KL} \qquad (15)$$

$$Y_i = \sum_{k=1}^{K} \frac{\gamma_{ik}\eta_k}{KL} \qquad (16)$$

$$Z_i = \sum_{k=1}^{K} \frac{\delta_{ik}\theta_k}{KL} \qquad (17)$$

$$L_1 = \sum_{k=1}^{K} \frac{\left(\beta_{ik} - \alpha_{ik}\right)\left(\zeta_k - \varepsilon_k\right)}{KL} \qquad (18)$$

$$L_2 = \sum_{k=1}^{K} \frac{\alpha_{ik}\left(\zeta_k - \varepsilon_k\right) + \varepsilon_k\left(\beta_{ik} - \alpha_{ik}\right)}{KL} \qquad (19)$$

$$U_1 = \sum_{k=1}^{K} \frac{\left(\delta_{ik} - \gamma_{ik}\right)\left(\theta_k - \eta_k\right)}{KL} \qquad (20)$$

$$U_2 = -\sum_{k=1}^{K} \frac{\theta_k\left(\delta_{ik} - \gamma_{ik}\right) + \delta_{ik}\left(\theta_k - \eta_k\right)}{KL} \qquad (21)$$

The terms W_i, X_i, Y_i, Z_i represent the weight components (fuzzy number), while the terms L_1, L_2, U_1, U_2 are the coefficients of a 2nd order polynomial, that represents the membership of the fuzzy number weight (Fig. 2).

The membership functions are:

$$\overline{m}_{ik} = \left(\alpha_{ik} / \beta_{ik}, \gamma_{ik} / \delta_{ik}\right) \qquad (22)$$

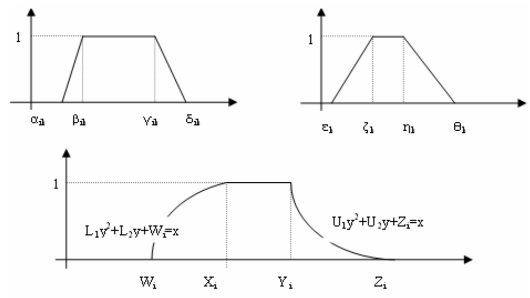

Fig. 2 Membership of fuzzy number weight.

$$\overline{n}_k = \left(\varepsilon_k / \zeta_k, \eta_k / \theta_k\right) \qquad (23)$$

they are equal to: 0 for x≤a and x≥d and x≤e and x≥θ respectively; equal to 1 for b≤x≤g and z≤x≤h respectively. In the average range, as between ai and bi the membership functions are linear and can be expressed by:

$$x_i = (\beta_i - \alpha_i)y + \alpha_i \qquad (24)$$

Considering that the fuzzy products, the membership functions of the weights obtained, are expressed by following relations:

$$L_1y^2+L_2y+W_i=x$$
$$U1y2+U2y+Zi=x \qquad (25)$$

consequently the weights $\overline{w_i}$ are expressed [6],[7] by (Wi[L1, L2]/Xi, Yi/Zi[U1, U2]), [4].

4. Once the weights, that are fuzzy numbers, are obtained, it is necessary to obtain a real number or "crisp" number by a "defuzzification" method. One of these methods is based on the average values using the following relation [5]:

$$F(A_i) = \int_0^1 (1/2)\left[g_1\left(y\,|\,A_i\right) + g_2\left(y\,|\,A_i\right)\right]dy = \\ = \frac{1}{6}\left(L_{1i} + U_{1i}\right) + \frac{1}{4}\left(L_{2i} + U_{2i}\right) + \frac{1}{2}\left(Z_i + W_i\right) \qquad (26)$$

IV. Sustainable Urban Model

The example considers a possible sustainable city model. It is obtained using 5 judges, 4 criteria (economy, environment, energy and urban plan) and 18 indicators. For giving the indicators homogeneity as indicators, so as to compare them, their weights are calculated with fuzzy logic [6].

The methodology is the following: judges express by fuzzy numbers their opinion on the criteria and evaluate the indicators with respect to all evaluated criteria. The criteria and indicators matrix obtained for the urban plan criteria are reported in Table I, respectively Table II.

The resulted database is used for calculating the weights from the averages values of the criteria and by indicators given by the judges. The fuzzy average values n_k obtained by criteria and the values m_{ik} obtained by i-th indicator for k-th criterions are reported in the Table III, respectively Table IV.

TABLE I. CRITERIA MATRIX

CRITERIA	J1				J2				J3				J4				J5			
Economy	4	5	5	6	5	5	5	5	6	7	7	8	4	5	6	7	6	6	7	7
Environment	6	7	7	8	5	5	5	5	7	8	8	9	5	5	7	7	7	8	8	8
Energy	8	8	9	9	6	7	8	9	6	6	7	7	7	7	8	9	6	6	6	6
Urban plan	4	5	6	7	5	5	6	6	4	6	7	7	5	5	6	6	5	6	6	7

TABLE II. INDICATORS MATRIX, EVALUATED BY URBAN PLAN CRITERIA

	Urban plan criteria																			
	J1				J2				J3				J4				J5			
1	1	1	2	2	2	2	3	3	1	1	1	1	2	2	2	2	1	1	2	2
2	3	3	3	3	2	2	3	3	2	2	2	2	2	2	3	3	1	1	2	2
3	3	3	3	3	2	2	3	3	2	2	2	2	2	2	3	3	1	1	2	2
4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
5	3	3	3	3	2	2	3	3	2	2	2	2	2	2	3	3	1	1	2	2
6	6	6	7	7	7	7	8	8	5	6	7	8	7	7	8	8	7	7	9	9
7	7	7	7	7	7	7	8	8	7	7	9	9	6	6	8	8	6	7	8	9
8	3	4	5	5	4	4	6	6	2	2	3	3	2	2	4	4	3	3	3	3
9	7	7	8	8	6	6	8	8	6	7	8	8	8	8	9	9	8	8	8	8
10	7	8	8	8	8	8	9	9	6	6	8	8	7	7	7	8	7	7	9	9
11	5	5	6	6	4	4	5	6	5	5	5	5	6	6	6	6	4	4	6	6
12	9	9	9	9	6	6	8	8	7	7	8	8	6	7	8	9	5	6	7	8
13	6	6	6	6	6	6	7	7	6	6	8	8	5	5	9	9	5	6	6	7
14	2	2	3	3	3	3	4	4	1	1	2	2	2	2	2	2	3	3	3	3
15	2	2	2	2	1	1	2	2	2	2	3	3	1	1	1	1	1	1	2	2
16	2	2	3	3	3	3	3	3	1	1	3	3	2	2	2	2	3	3	3	3
17	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
18	5	5	6	6	5	5	6	6	4	4	6	6	6	6	6	6	5	6	7	7

TABLE III. CRITERIA AVERAGE VALUE

n1=	5	5.6	6	6.6
n2=	6	6.6	7	7.4
n3=	6.6	6.8	7.6	8
n4=	4.6	5.4	6.2	6.6

The weights components are obtained as in Table V. For obtaining the crisp number of the weight, the "defuzzification" is made using the average value method and then normalized as average weight as reported in Table VI. The analysis of the weight results shows that based on the opinion expressed by the judges, the sustainable city is particularly influenced by public transportation, fuel, household GWh and cars, while a low sensitivity is associated with hydro consumption and ISO 14000 certified companies.

TABLE IV. INDICATORS AVERAGE VALUE

m14=	1,4	1,4	2	2
m24=	2	2	2,6	2,6
m34=	2	2	2,6	2,6
m44=	1	1	1	1
m54=	2	2	2,6	2,6
m64=	6,4	6,6	7,8	8
m74=	6,6	6,8	8	8,2
m84=	2,8	3	4,2	4,2
m94=	7	7,2	8,2	8,2
m104=	7	7,2	8,2	8,4
m114=	4,8	4,8	5,6	5,8
m124=	6,6	7	8	8,4
m134=	5,6	5,8	7,2	7,4
m144=	2,2	2,2	2,8	2,8
m154=	1,4	1,4	2	2
m164=	2,2	2,2	2,8	2,8
m174=	1	1	1	1
m184=	5	5,2	6,2	6,2

TABLE V. WEIGHTS COMPONENTS

	W	X	Y	Z	L1	L2	U1	U2
1	2,152	2,582	3,224	3,479	0,015	0,415	0,003	-0,258
2	2,69	3,089	3,771	4,064	0,011	0,388	0,002	-0,295
3	2,58	2,995	3,646	4,031	0,014	0,401	0,01	-0,395
4	1,764	2,165	2,609	2,907	0,017	0,384	0,006	-0,304
5	2,72	3,155	3,776	4,101	0,014	0,421	0,005	-0,33
6	2,54	3,098	3,959	4,528	0,017	0,541	0,017	-0,586
7	2,683	3,224	3,995	4,565	0,014	0,527	0,017	-0,587
8	2,342	2,718	3,562	4,056	0,011	0,365	0,017	-0,511
9	3,394	3,915	4,883	5,435	0,017	0,504	0,013	-0,565
10	2,205	2,65	3,398	3,799	0,017	0,428	0,013	-0,414
11	1,847	2,214	2,83	3,127	0,013	0,354	0,007	-0,304
12	2,66	3,131	3,961	4,418	0,015	0,456	0,011	-0,468
13	3,459	3,924	4,918	5,362	0,011	0,454	0,006	-0,45
14	3,108	3,527	4,402	4,892	0,013	0,406	0,011	-0,501
15	3,211	3,673	4,418	4,801	0,016	0,446	0,004	-0,387
16	2,345	2,673	3,444	3,878	0,007	0,321	0,012	-0,446
17	1,413	1,62	2,149	2,371	0,006	0,201	0,006	-0,228
18	2,326	2,663	3,517	3,85	0,011	0,326	0,008	-0,341

TABLE VI. DEFUZZIFICATION

	Defuzzification	Weight normal
1	2,858	0,48
2	3,402	0,57
3	3,311	0,56
4	2,359	0,4
5	3,436	0,58
6	3,528	0,59
7	3,614	0,61
8	3,167	0,53
9	4,404	0,74
10	3,011	0,51

11	2,503	0,42
12	3,54	0,59
13	4,414	0,74
14	3,98	0,67
15	4,024	0,68
16	3,083	0,52
17	1,887	0,32
18	3,087	0,52

V. Sustainability Indices

In this section a classification of some Italian cities is made in order to verify their sustainability. Analysis of the sustainability when the values are weighted is conducted [10].

1. Air pollution monitoring (efficiency of measuring equipments and monitored parameters)

There are about 80 fixed or mobile stations in 80 municipalities (in 7 cases only mobile) on the 91 areas for which you have answers.

The parameters more monitored are NO_2 (76 municipalities), CO (75), SO_2 (72). There is also the measurement of ozone (68 municipalities), while less frequent observations for benzene (31 municipalities), for the fine particles PM10 (30 municipalities) and for the aromatic hydrocarbons (7 municipalities) [8, 9].

The monitoring system has undoubtedly consolidated over the years and in 1998 at least in all major centers were installed a monitoring system.

2. NO_2 (μg NO_2, annual average weighted on the number of stations)

Emissions of nitrogen oxides, derived from combustion processes and, in particular for urban areas, from traffic and residential heatings, have not suffered a reduction that has characterized other pollutant emissions (more severe for sulfur dioxide, and less severe for the carbon monoxide). The Urban Ecosystem found in 4 municipalities (Trieste, Syracuse, Sassari, Naples) the value of 98 % of NO2 above the threshold of 200 $\mu g/m^3$ in at least one station; a value greater than 150 $\mu g/m^3$ is obtained in 29 municipalities.

3. CO (exceeding the quality level of 10 mg of CO, weighted on the number of stations)

For the first time, Urban Ecosystem considers also the indicator of carbon monoxide, the classic indicator of pollution from traffic. For carbon monoxide are measured the exceeding in 8 hours of the 10 mg/m^3 concentration value; the total number of exceeding is weighted on the number of stations where measurements are conducted. In 9 municipalities exceeding of the 30 mg/m^3 level are registered, while the maximum acceptable quality level (10 mg/m^3) is exceeded in 29 municipalities. The frequency (weighted on the number of stations) is particularly high in Milan (49 overruns), Syracuse (75) and Vercelli (26).

4. Consumption of drinking water (liters delivered/inhabitant/day)

The number is based on the amount delivered for drinking within the municipal boundaries. 80% of municipalities declare consumptions of drinking water below 400 liters daily. Situations of water shortages are still registered in 9 municipalities, mainly in Calabria (120 days in Vibo Valentia, 70 in Reggio, 60 in Catanzaro, 14 to Crotone).

5. NO^3 (mg/l NO^3, average of nitrates)

34 municipalities have a value below the level of 5 mg/l and 80% of the municipalities is below 15 mg/l. No municipality reaches the maximum admissible concentration.

6. Efficiency of water purification (% of population connected to water purification plants operating day*operating days*efficiency of the purification system)

The indicator considers the people connected to the service of purification, the number of days of operation and the efficiency of treatment process. A purification efficiency above 90% was considered equal to 100%.

The situation of the purification system remains preoccupant. In 6 municipalities is even declared a share of population connected to the sewage system below 50%.

The municipalities without any purification system were reduced from 8 in 1995, to 3, 1998. Among these stands out the city of Milan, while the first amount of purification plants came into operation in Palermo and Catania. A purification capacity (as residents delivered) less than 50% of the population is still declared in 17 municipalities (they were 25 in 1995). A percent of purification above 80% is registered in 56 municipalities.

7. Production of municipal solid waste (kg/inhabitant/year of municipal solid waste (MSW) gross collection)

The production per inhabitant of municipal waste, even in recent years, is generally grown on average between 1994 and 1998 there was an increase of 12%. In the last year is increasing production of waste in 72% of the municipalities.

One municipality declares a production per inhabitant below 350 kg/inhabitant, while 24% of the municipalities have productions between 350 kg/inhabitant and 450 kg/inhabitant, 48% between 450 kg/inhabitant and 550 kg/inhabitant and 27% above the 550 kg/inhabitant. Maximum levels are found in areas with strong tourists or where there is a strong mixing with industrial wastes.

8. Separated littery (% of total MSW production)

The growth of the separated littery is the most obvious sign of positive urban ecosystem. In almost all cities there is a further improvement. In 10 municipalities there is a separated littery above 25%, in 23 municipalities above 15%. Unfortunately, the separated littery is still below 5% in 32 municipalities - all in the center-south of Italy.

9. Public transportation (travels/inhabitant/year)

In some areas in southern Italy, the public transportation is formally or virtually absent, in 42 municipalities, the average travels (per inhabitant) with the public transportation is less than 1 per week. Excluding the tourist cities like Venice and Florence, only in Milan and Trieste have a public transportation system with superior performance to 1 travel/inhabitant per day. What is more worrying is the fact that in comparison with 1994, the number of passengers annually transported is decreasing in 57 municipalities and increases in 37. Even compared to recent years, the overall negative sign is: decreases in 57 municipalities, increases in

42.

The situation is particularly critical in large cities with more than 200000 inhabitants, where the urban public transport is generally a viable alternative to much of the private traffic. In 8 of these 16 cities, there is a decrease compared with 1994 to 1997, only 5 have increased and in 3 there are stable values.

10. Pedestrian areas (m^2/inhabitant)

In 67 municipalities, there is the presence of pedestrian area. Again, the data quality is probably not completely homogeneous. On a national scale is an average of about 0.1 m^2/inhabitant and in no case the maximum is greater than 1 m^2/inhabitant. Florence, Rome and Turin are the cities with the largest pedestrian areas.

11. Cycle lanes (m/inhabitant)

There is a presence of cycle lanes in 56 cities, for a global development of 841 km. For comparison, the National Sustainable Development Plan of 1993 set a target of 2000 km of cycle lanes overall hundred Italian cities. Turin (89 km), Modena (71 km), Ferrara and Reggio Emilia (over 40 km) are the cities with the largest absolute cycle lanes.

12. Green areas (m^2/inhabitant)

The data on the availability of urban green areas (excluding both areas of the park or protected areas that fall within the municipality) continue to present a discontinuous quality. In some cases, the values declared as "parks and gardens" include areas not properly configured as urban green spaces (such as cemetery areas), if not all "green areas". There are 5 municipalities have less than 1 m^2/inhabitant, 57 municipalities have an area of 1 to 10 m^2/inhabitant, 17 municipalities have between 10 and 20 m^2/inhabitant and 10 municipalities have more than 20 m^2/inhabitant.

Park areas and reserves are present in 56 municipalities, although an extension of more than 100 ha is found only in 13 municipalities.

13. Cars (cars /100 inhabitants)

Over the period 1989-1995 there is an average increase of 11%. The growth triggered by incentives for motorization has probably caused a further surge.

Only in 16 municipalities the rate of motorization is less than 50 cars for every 100 inhabitants, while 45 municipalities exceed the value of 60 cars for every 100 inhabitants.

Available data show some distortions induced by insurance mechanisms with major variations of cars circulating in some municipalities.

14. Consumption of electricity for domestic use (kWh of domestic use/inhabitant/year)

The demand for electricity for domestic purposes, which in Italy is traditionally large, is recording a continuous growth (1.4% in 1998).

The cities usually are situated between 800 and 1200 kWh/ inhabitant, with an average value of about. 1000 kWh/ inhabitant.

The consumption is higher in Aosta, Grosseto, Rome, Sassari and Trieste (all with more than 1200 kWh/inhabitant). The lowest consumption is in Avellino, Benevento, Foggia, Potenza and Matera.

In the large cities, in 1998, was a decrease in all southern cities (Bari, Catania, Naples, Palermo, Taranto) and an increase in all cities of the center-north, with major cities in the north east of Italy.

15. Fuel consumption (kgep/inhabitant/year of gasoline and diesel)

The fuel consumption per inhabitant (in kg of equivalent oil) showed an average of 615 kg/inhabitant, ranging from a minimum of 313 and a maximum of 1043 kg.

16. Respiratory deaths (No for every 10000 inhabitants)

17. ISO 14001 certification (No of sites ISO 14001/1000 billion in added value)

The 168 Italians sites are distributed in 52 districts. In absolute terms, the maximum concentration was found in Milan (49 sites out of a total of 168 sites, Turin (12), Bergamo (10), Chieti (7), Como (6), Venice (5) and Verona (5).

18. Agenda XXI (Participation at Local Agenda XXI)

The subscription is considered as a sign that the municipality actively pursues a sustainable policy.

For the cities Pavia, Bergamo, Como, Salerno, Cremona, Roma, Foggia, Rieti, Milan, Naples has been applied the previous method of calculation. The results are shown in Table VII. The first column is the classification of the cities without using the weights of indicators, in the second column was reported the classification conducted by “Ambiente Italia” using the own elaborated weights, while in the third one the classification is done using the weights above reported.

TABLE VII

Classification without weights		Classification with weights “Ambiente Italia”		Classification with fuzzy weights.	
Pavia	0,67	Pavia	0,69	Pavia	0,68
Bergamo	0,62	Bergamo	0,67	Bergamo	0,63
Como	0,62	Como	0,67	Como	0,62
Salerno	0,58	Salerno	0,57	Salerno	0,6
Cremona	0,56	Cremona	0,62	Cremona	0,56
Rome	0,55	Rome	0,56	Rome	0,56
Rieti	0,48	Rieti	0,50	Rieti	0,50
Naples	0,45	Naples	0,47	Naples	0,47
Foggia	0,5	Foggia	0,46	Foggia	0,47
Milan	0,42	Milan	0,46	Milan	0,43

It can be observed that the final results are little affected by the system of weights, both as regards the higher or the lower values of the classification, while the weights have a significant influence on the center classification group. This result was expected since the cities situated at the top values the indicators are large, while for the cities situated at the bottom values the indicators have low values and thus the scores are always at limits. The cities situated in the center of the classification have just some of the indicators with enough high values; if in correspondence to these values the weights were high, the cities will go up in the classification; if the weights are low, those cities lose positions.

Ultimately it is true that the three systems bring little variations of the values, considering that the values obtained through the weights calculated with fuzzy logic was more "untie" from the personal opinions, which is not occurring the first system.

Thus, using only the “opinions” could come to conclusions very far from those to which they could reach through a more objective system.

It has been carried out an application for the cities of Milan and Naples, Italy through the weights calculated with fuzzy logic, then it allows us to estimate the sustainability of the city connected to the goals prefixed. For every indicator it was determined a ‘‘sustainable goal’’ or ‘‘environmental quality’’, equal to 100, without to attribute the weights. Therefore, every indicator can to assume a value between 0 (min) to 100 (max).

Figs. 3 and 4 show the outline of the environmental conditions and the ‘‘real’’ outline of sustainability, in this case equal to 100, without considering the weights for the city of Milan, respectively Naples. The grey area shows the ‘‘real’’ values of the chosen 18th indicators. The values were supplied by [10]. The edges are weighed for an ‘‘ideal’’ but not utopian city. Fig. 3 and Fig. 4 highlight how the sustainability objective changes weighting the chosen indicators. For the specific cases of the city of Milan (Italy) and Naples (Italy) it is emphasized how some parameters widely respect the sustainability and how others parameters need work for limiting them inside the sustainability area. It can be seen as only some parameters do not respect the sustainability, while others respect totally the goals.

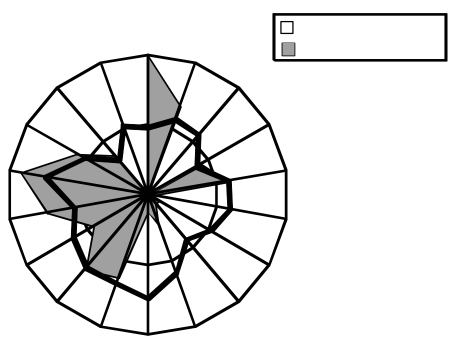

Fig. 3 Environmental conditions and ‘‘real’’ outline of sustainability, considering the weights for the Milan city.

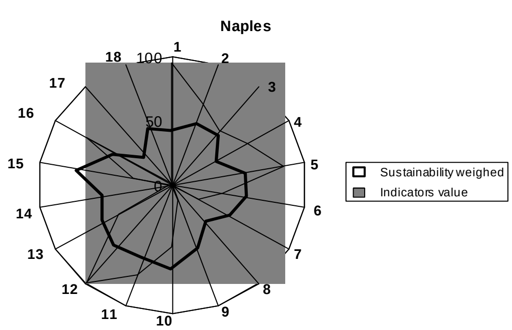

Fig. 4 Environmental conditions and ‘‘real’’ outline of sustainability, considering the weights for the Naples city.

VI. Conclusion

The applied methodology for calculating indicator weights for selected criteria, points out the importance of decision maker’s subjectivity. In fact, assigning the weight of an indicator with regard to another indicator, every decision maker is brought to reason in a less objective way. The proposed systems, even starting from subjective evaluation, permit the combination of different opinions on various indicators, by means of different criteria. Moreover, the final results will be a combination of values assigned by different judges for various criteria by fuzzy number which translates verbal expression in a numerical quantity. The example reported in this paper is on a hypothetical sustainable city and the evaluation of the weight; criteria and indicator have not been carried out by experts of the specific fields. In order in case of a real city to establish the just values will be necessary the contribution of the experts in the various chosen fields.

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