10/2001-UHE/UAB-11.12.2001

Version November 2001

Indicators and Evaluation Tools for the Assessment of Urban Sustainability

Giuseppe Munda
Universitat Autonoma de Barcelona
Dept. of Economics and Economic History
08193 Bellaterra (Barcelona)
Spain
giuseppe.munda@uab.es

Abstract. This paper attempts to provide an explanation of why reductionistic approaches are not adequate to tackle the urban sustainability issue in a consistent way. Concepts such as urban environmental carrying capacity and ecological footprint are discussed. Multicriteria evaluation is proposed as a general multidimensional framework for the assessment of urban sustainability.
This paper deals with the following main topics:

- *definition of the concept of urban sustainability,*
- *discussion of relevant sustainability indicators,*
- *multicriteria evaluation as a framework for the assessment of urban sustainability,*
- *an illustrative example.*

KEY WORDS: URBAN ENVIRONMENTAL CARRYING CAPACITY, ECOLOGICAL FOOTPRINT, MULTICRITERIA EVALUATION, NAIADE METHOD

JEL CLASSIFICATION: R10, Q20, Q30

1. URBAN SUSTAINABILITY AS A MULTIDIMENSIONAL CONCEPT

Sustainable development has of course a global dimension, however it is also increasingly recognized the mutual interactions between local and global processes. In particular, cities are open systems impacting on all other areas and on the earth as a whole. There is actually much work on this issue (under Agenda 21), extending the experience made in some cities under the UNESCO MAB programme.

For example in the European context, the reinforced focus on the city seems warranted, as the European countries are facing a stage of dramatic restructuring and transition (Cocossis and Nijkamp, 1995; Nijkamp and Perrels, 1994). However, the aim to make Europe more competitive in economic terms may beat odds with its environmental sustainability. At the institutional level, EUROSTAT for instance, proposes a set of urban pressure indicators to deal with the urban sustainability issue (European Commission, 1996)[1].

Why so many different indicators - it may be asked - when there could be a unique physical *index* of whether human impact on the environment is excessive, simply by using the concept of carrying capacity, as defined in ecology, i.e. the maximum population of a given species (frogs in a lake for instance) that can be supported indefinitely in that given territory, without spoiling its resource base. Begon et al. (1996) clearly state that even for animals, carrying capacity is "An idealized concept not to be taken literally in practice". Authors who come from a background in biology and from an emphasis on population growth, such as Paul Ehrlich and his collaborators, have over the years become aware of the shortcomings of the notion of Carrying Capacity applied to humans. This is why they proposed the formulation $\boldsymbol{I = PAT}$, where $\boldsymbol{I}$ is the human impact on the environment, $\boldsymbol{P}$ is human population, $\boldsymbol{A}$ is affluence, and $\boldsymbol{T}$ is technology.

The definition of carrying capacity is irrelevant for humans, for several reasons. First, the human ability to establish large differences in exosomatic use of energy and materials means that one first question should be maximum population at which level of consumption? Second, human technologies change at a much quicker pace than in other species (e.g. in a city transport is of the utmost importance for determining the number of people which can enjoy a reasonable

[1] These indicators are: population density per area, land consumption, roads and parking areas, mono functional areas, derelict areas, inhabitants per green area, accessibility of green areas, emissions of CO2, emissions of SO2 and Nox, emissions of VOC, emissions of PM10, emissions of lead, water consumption per capita, COD/BOD through (non-treated) waste water, non-treated waste water, non-treated waste water discharges to urban surface waters, soil contamination, municipal waste per capita, non-recycled municipal waste, household hazardous waste, energy consumption, share of private car transport, registered motor vehicles, traffic accidents with victims (injured and/or dead), mileage of commuters, people endangered by noise emissions, noise emissions of industry, noise levels of vehicle fleet.

quality of urban life). Third, the territories occupied by humans are not given. We compete with other species, and inside the human species, territoriality is socially and politically constructed. There is still another reason why the notion of carrying capacity is not directly applicable to humans, in any particular territory. This is trade, which may be seen indeed as the appropriation of the carrying capacity of other territories.

Urban growth rests on a trade-off between agglomeration economies (notably economies of scale and scope including higher wages) and diseconomies (e.g. population density and environmental decay). It is likely that environmental quality problems may become more severe with urban size, however factors such as land use, transportation system and spatial layout of a city are also critical factors for determining the “urban environmental carrying capacity”.

Another indicator connected with the idea of urban carrying capacity is the ecological footprint index. Ecological footprint gets around some of the difficulties with traditional carrying capacity simply by inverting the usual carrying capacity ratio. In short, the ecological footprint measures land area required per person (or population), rather than population per unit area (Folke et al., 1996; Wackernagel and Rees, 1995). The ecological footprint starts from the assumption that every category of energy and material consumption and waste discharge requires the productive or absorptive capacity of a finite area of land or water. If one sums the land requirements for all categories of consumption and waste discharge by a defined population, the total area represents the ecological footprint of that population whether or not this area coincides with the population's home region.

More precisely, the ecological footprint of a specified population or economy can be defined as the area of ecologically productive land (and water) that would be required on a continuous basis:

- to provide all the energy/material resources consumed,
- to absorb all the waste discharged

by a given population in a given area.

From an operational point of view, the main categories of land use for the calculation of the ecological footprint would be the following:

1. crop and grazing land required to produce the current diet (the sea area could also be included),
2. land for wood plantations for timber and paper,
3. land occupied, degraded or built-over, as urban land,
4. land needed to absorb CO_2 emissions through photosynthesis, or alternatively land

required to produce the ethanol equivalent to current fossil energy consumption.

In Rees' hometown of Vancouver, the respective figures for these four items, per person, would be 1 hectare, 0.6 hectares, 0.2 hectares., and 2.3 hectares (of middle aged Northern temperate forest), i.e. over 4 hectares per person. One should note that only $C0_2$ is translated into a land requirement, and not other wastes, such as domestic waste, or other greenhouse gases, or radioactive waste; this is so because of difficulties of computation. The water catchment area, and the waste water disposal area, are not included too.

Of course, when considering urban population it becomes particularly important the acknowledgment of the existence of physical constraints on matter and energy flows which are determined by the particular type of society structure. This structure has a huge relevance in determining the consequent ecological footprint for the same unit of human mass sustained, energy consumed or waste generated. Let us consider the case of food supply. A kg of grain consumed per person can have a cost of 2,000 kcal (in a poor society) or 35,000 kcal (in a rich society) according to the characteristics of the society. If one is in a rich society there is a need to produce food with only 5% of the available work force in agriculture (to produce grain at a throughput of 700 kg of grain per hour of labor). Totally different is the situation of a subsistence society which is much more "energy efficient". On the other hand this is paid for by a very low productivity of labor - e.g. 10 kg of grain per hour of labor (basically the population is composed by poor farmers). The same applies to the amount of land one has available (Giampietro, 1997). What I want to emphasize here is the aggregation problem (i.e. the somewhat mysterious conventions one needs to transform all the dimensions of ecological sustainability in a common measurement unit in space terms) connected to ecological footprint and thus the necessary reductionism implied by the use of this index.

From a policy point of view, the urban management suggestions coming from the computations of the ecological footprint sometimes could be very dangerous. For example, given that ecological footprint considers the land used to produce the current diet, this could imply an incentive towards intensive agricultural production systems. These systems will reduce the virtual space occupied by a city but at the same time will imply the use of much more energy and loss of biodiversity, due to the use of fertilizers, pesticides and introduction of exotic species. It is true that in part, these consequences will provoke an increase of the land needed to absorb CO_2[2], but *which is the rate of compensability implied by these transformations?* Are we sure that the decrease of the ecological footprint implied by a more energy intensive agriculture will correspond to an equal increase for the land needed to absorb CO_2? In more technical terms, this will depend on the assumptions about the elasticity of substitution assumed between the different environmental pressures[3]. Unfortunately, in the computations of the ecological footprint index no specification of this elasticity is made and thus the compensation implied is totally unpredictable and non-transparent. But even if the elasticity could be specified, which biological productivity are we considering? Which kind of soil? Which kind of trees and with which age?

To give an other simple policy example, let's consider the issue of the urban form. There is agreement that a compact city has less environmental impact than a decentralized city (see e.g. Frey, 1999). If there is a big population pressure, taking into account the environmental point of view only, it would be better to have the people living in compact cities than spread all around the regional territory. But if we are using the ecological footprint index, this surely will be very big for a compact city and on the contrary quite unpredictable in the case of a decentralized city. In this latter case the computations will depend crucially on what it will be considered to be an homogeneous metropolitan area (by means of which definition criteria?).

When dealing with complex systems operating on several hierarchical levels, the simultaneous existence of contrasting but "correct" scientific assessments has to be accepted (Giampietro, 1994). Connotations of complex urban systems are entities that change their identity according to the particular hierarchical space scale at which they are described, i.e. the study of a block inside a city, or of the administrative unit constituting a "Commune", or of the "metropolitan area" could give completely different and contrasting views and policy suggestions. Thus, if we consider e.g. the hierarchical level "Commune of Barcelona", the statement that quality of life is becoming higher and higher seems to be correct (or at least this perception is shared by most of its inhabitants). If we look at the whole metropolitan area, the same statement is probably not that right (since just to give an example, most of the polluting activities have been transferred from the city center to the periphery).

This is the reason why the ecological footprint is often computed for regions or countries. But are political territories also relevant in ecological terms? And what about trade? The trade issue, along with other criticism of the ecological footprint index have deeply been tackled by van den Berg and Verbruggen (1999). A discussion of the pros and cons of this index can also be found in the Forum on the ecological footprint in Ecological Economics (2000). Here I conclude this

---

[2] This point has been raised to me by Joan Martinez-Alier.

[3] One should note that this is the same issue connected to the use of economic production function measured in money terms, where on the other hand, the elasticities of substitution between different production factors are always clearly specified, e.g. a Cobb-Douglas type.

discussion saying that indeed just computing the inverse of the concept of carrying capacity is not a way of overcoming its shortcomings. On the contrary, by definition an inverse keeps all the properties and limitations of the original concept. This is evident from the above discussion.

At this point, I would like to remind that ecosystems can be divided into three categories (Odum, 1989):

1. *natural environments* or natural solar-powered ecosystems (open oceans, wetlands, rain forests, etc.);
2. *domesticated environments* or man-subsided solar-powered ecosystems (agriculture lands, aqua culture, woodlands, etc.);
3. *fabricated environments* or fuel-powered urban-industrial systems (cities, industrial areas, airports, etc.).

It is clear that fabricated environments are not self-supporting or self-maintaining. To be ecologically sustained they depend upon the solar-powered natural and domesticated environments (life-supporting ecosystems). Thus, from a pure ecological point of view, cities are *unsustainable by definition* and the ecological footprint is a good *metaphor* of that.

From the above discussion one main lesson can be learned: it is impossible to find scientific sound conversion factors that can transform all ecological, economic and social dimensions in land as well as in energy, money or whatever common term one would like to use. The concepts of urban environmental carrying capacity and ecological footprint are an example of ecological reductionism, i.e. socio-economic and cultural aspects are completely neglected (e.g., to transform the “Colosseo” in a wooded area would improve the ecological footprint of Rome!).
Even if we take into account the environmental point of view only, it is impossible to use just one single aggregate index, when dealing with “urban sustainability”, thus a wider analysis is needed.

City' s overall sustainability depends at least on of four types of capitals*: man-made*, *natural, human and social capitals*, and on the way in which these capitals are combined, i.e. on their mutual relationship. The challenge of urban sustainable development is the challenge of matching these different dynamics in a co-evolutive perspective. Therefore, one needs monetary indicators in order to control the processes of planning sustainability, but one also needs indicators that can be expressed in different physical and ordinal units. Thus a multidimensional framework is of paramount importance for a correct framing of urban sustainability (Archibugi and Nijkamp, 1990; Archibugi, 1997; Fusco-Girard and Nijkamp, 1997; Norgaard, 1994).

There have been various attempts to develop multidimensional systems of urban sustainability indicators (e.g., CEROI, ICLEI, and many others). There is no unanimous consensus on pros and cons of any specific system. However, here I want to tackle another issue, relevant for the policy making process, connected with the use of various indicators simultaneously: *often some indicators improve while others deteriorate when they are computed for a specific city.* Then a question arises, how could such indicators be aggregated? One should note that this is the classical conflictual situation tackled in multicriteria evaluation.

2. MULTICRITERIA EVALUATION AS A FRAMEWORK FOR THE ASSESSMENT OF URBAN SUSTAINABILITY

A typical multicriteria problem (with a discrete number of alternatives) may be described in the following way: ***A*** is a finite set of ***n*** feasible actions (or alternatives); ***m*** is the number of different points of view or evaluation criteria g_i $i=1, 2, \ldots, m$ considered relevant in a decision problem, where the action ***a*** is evaluated to be better than action ***b*** (both belonging to the set ***A***) according to the i-th point of view if $g_i(a)>g_i(b)$. In this way a decision problem may be represented in a tabular or matrix form. Given the sets ***A*** (of alternatives) and ***G*** (of evaluation criteria) and assuming the existence of ***n*** alternatives and ***m*** criteria, it is possible to build a

n x ***m*** matrix ***P*** called evaluation or impact matrix whose typical element p_{ij} $(i=1, 2, \ldots, m; j=1, 2, \ldots, n)$ represents the evaluation of the j-th alternative by means of the i-th criterion. The impact matrix may include quantitative, qualitative or both types of information (Munda, 1995; see also Paruccini, 1994 and Beinat and Nijkamp, 1998 for a collection of real-world case studies).

For example, if one wishes to buy a new car, her/his choice could depend on the economic, safety, aesthetic and driving characteristics of the various cars taken into account. The criteria (indicators) measuring some characteristics can be incommensurable (price in dollars, speed in Km/h, etc.) and conflicting in nature.

The peculiar characteristic of multicriteria models is that an action ***a*** may be better than an action ***b*** according to one criterion and worse according to another. When several criteria are taken into consideration, in general, there is no solution optimising all the criteria at the same time. As a consequence, there is a need to find compromise solutions by means of an aggregation procedure (the so-called “multicriteria method”)[4].

---

[4] One should note that here the concept of a "compromise solution" is used in a technical sense, i.e. a solution as a balance among different conflicting criteria, no compromise among different actors is necessarily implied.

		Alternatives			
Criteria	**Units**	$\mathbf{a_1}$	$\mathbf{a_2}$	$\mathbf{a_3}$	$\mathbf{a_4}$
$\mathbf{g_1}$		$g_1(a_1)$	$g_1(a_2)$	.	$g_1(a_4)$
$\mathbf{g_2}$		.	.	.	.
$\mathbf{g_3}$		.	.	.	.
$\mathbf{g_4}$		.	.	.	.
$\mathbf{g_5}$		.	.	.	.
$\mathbf{g_6}$		$g_6(a_1)$	$g_6(a_2)$	.	$g_6(a_4)$

Figure 1. Example of an Impact Matrix

The impact matrix may include quantitative, qualitative or both types of information. Another feature related to the available information concerns the uncertainty contained in this information. If it is impossible to establish exactly the future state of the problem faced, a stochastic uncertainty is created; this type of uncertainty is well known; it has been thoroughly studied in probability theory and statistics. Another framing of uncertainty, called fuzzy uncertainty, focuses on the ambiguity of information in the sense that the uncertainty does not concern the occurrence of an event but the event itself, which cannot be described unambiguously (Munda, 1995; Munda et al., 1995). This sort of situation is easily identifiable in complex systems. Spatial-environmental systems in particular, a reflexive complex systems characterised by subjectivity, incompleteness and imprecision (e.g., ecological processes are quite uncertain and little is known about their sensitivity to stress factors such as various types of pollution). A great advantage of multicriteria evaluation is the possibility to take these different situations into account.

A method created for economic-environmental policy applications is the so-called NAIADE method (Munda, 1995). NAIADE (**N**ovel **A**pproach to **I**mprecise **A**ssessment and **D**ecision **E**nvironments) is a discrete multicriteria method whose impact (or evaluation) matrix may include either crisp, stochastic or fuzzy measurements of the performance of an alternative with respect to an evaluation criterion, thus it is very flexible for real-world applications. A peculiarity of NAIADE, is the use of conflict analysis procedures to be integrated with the multicriteria results. This to allow policy-makers to seek for decisions that could reduce the degree of conflict (in order to reach a certain degree of consensus) or that could have a higher degree of equity on different income groups.

When one wishes to use multicriteria methods as a framework for the aggregation of a set of different indicators, in my opinion the following properties are desirable.

1. To avoid the aggregation of all the indicators in one single aggregate function. This approach is not desirable because it does not give useful information on the behavior of the single indicators so that its policy usefulness is very limited.
2. To avoid complete compensability, i.e. the possibility that a good score on one indicator can always compensate a very bad score on another indicator. Urban development implies the creation of new assets in terms of physical, social and economic structures. At the same time, like in any process of "creative destruction", traditional physical, social and cultural assets derived from our common heritage may disappear. Complete compensability implies that an excellent performance on the economic dimension can justify any type of very bad performance on the other dimensions, which is exactly what the concept of sustainability tries to avoid.
3. To be as much transparent as possible to the general public. In urban planning distributional issues play a central role. If a given policy option is evaluated to be "good" or to be "bad", key questions are "good" or "bad" for which point of view? For whom? How long? Any policy option always implies winners and losers, thus it is important to check if a policy option looks good just because some dimensions (e.g. the environmental) or some social groups (e.g. the lower income groups) are not taken into account.

To better clarify the previous discussion in the next section, an illustrative example of multicriteria aggregation, based on the NAIADE method, of a set of urban indicators will be presented. The purpose of this example is to make as clear as possible the limitations, the possible mistakes and the positive aspects of the approach proposed.

3. MULTIDIMENSIONAL CITY EVALUATION BY USING A SET OF URBAN INDICATORS: AN ILLUSTRATIVE EXAMPLE

Let's take into consideration 4 cities, 2 belonging to highly industrialized Countries (Amsterdam and New York) and 2 belonging to transitional economies (Budapest and Moscow). The indicators used are taken from the global urban indicators database (Urban Indicator Programme). The profiles (i.e. the score of each city according to each indicator) of these 4 cities are the one described in Figure 2.

Matrix type Impact Case Study

Criteria \ Alternatives	Budapest	Moscow	Amsterdam	New York
Houses owned (%)	50.5	40.2	2.2	10.3
Residential density (pers. /hectare)	123.3	225.2	152.1	72
Use of private car (%)	31.1	10	60	32.5
Mean travel time to work (minutes)	40	62	22	36.5
Solid waste generated per capita (t./year)	0.2	0.29	0.4	0.61
City product per person (US$/year)	4750	5100	28251	30952
Income disparity (Q5/Q!)	9.19	7.61	5.25	14.81
Households below poverty line (%)	36.6	15	20.5	16.3
Crime rate per 1000 (theft)	39.4	4.3	144.05	56.7

Figure 2. Impact Matrix for the 4 Chosen Cities According to the Selected Indicators

By applying the NAIADE method to this impact matrix, the ranking of the 4 cities shown in Figure 3 is obtained.

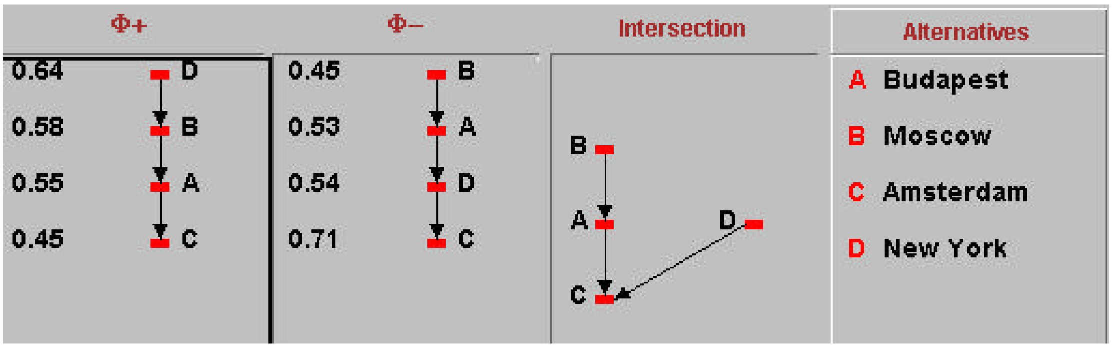

Figure 3. Multicriteria Ranking of the 4 Cities

The final ranking presents Amsterdam in the bottom position (worst than all the other considered cities), Moscow is in a top position (better than Budapest and Amsterdam and incomparable with New York), New York is incomparable with all the other cities, except Amsterdam which is considered in a worse position than New York (Incomparability is a technical preference relation, meaning that according to the information contained in the impact matrix, no preference or indifference relation can be deduced).

At this point a couple of questions need to be answered:

1. From where are these (somewhat surprising) results coming from and what they mean?
2. Are these results of any utility for policy making?

Let's start with the first question. The results obtained depend on:

1. *information available* (in our case the global urban indicators database, where for example the data on the use of private car in Amsterdam are suspicious high),
2. *indicators chosen* (i.e. which representation of reality we are using, e.g. whose interests we are taken into account),
3. *Direction of each indicator* (i.e. the bigger the better or vice versa, e.g. in our example, it has been used the principle that house owners should be maximized, but this could be quite disputable and culturally dependent),
4. *relative importance of these indicators* (in our case all the indicators are considered having the same importance i.e. no weighting coefficient is used),
5. *multicriteria method used* (here the NAIADE method was chosen, but since the information of the impact matrix is all quantitative other multicriteria methods could have been applied).

All these uncertainties have to be taken into account when we state that a given city is "better" than another one. At this stage, it seems also clear why in multicriteria evaluation it is claimed that what is really important is the "decision process" and not the final solution, since this solution has a value only as a construction of the decision process and it is not an ultimate Truth (in Herbert Simon words, we could say that we should move from "substantive to procedural rationality"). Any social decision problem is characterized by conflicts between competing values and interests and different groups and communities that represent them (O'Neill, 1993). As a consequence, the validity of a given approach depends on the inclusion of the several legitimate perspectives as well as the non-omission of the reflexive properties of the system[5], even though these are not easy to deal with (Funtowicz et al., 1999).

When science is used in policy, the appropriate management of quality has to be enriched to include this multiplicity of participants and perspectives. The criteria of quality in this new context will presuppose ethical principles. But in this case, the principles will be explicit and will become part of the dialogue (Funtowicz and Ravetz, 1994). This is the reason why in my opinion

[5] From systems theory it is possible to draw the distinction between systems which are simple or merely complicated on the one hand, and those which are complex. The former are studied by classical physics, and the latter by biology and the human sciences. Complex systems are defined as those which cannot be captured by a

the *transparency of the decision process* is of a fundamental importance.

The second question looks even nastier i.e. is all this effort of any use? Even if we have a very reliable ranking, which is the utility of knowing that Moscow is overall better than Amsterdam or vice versa? Let's try to put some light in this issue. First of all, one should note that for the majority of indicators used in assessment exercises no clear reference point is available, for instance, when GNP (Gross National Product) is used nobody knows the ideal value of a Country GNP, thus it is quite common to compare with other Countries GNP, e.g. the US one. Let's continue the example of our 4 cities to see how the assessment of various indicators can easily be used for policy purposes.

In order to get a set of reference values, an "ideal point" can be defined by choosing the best values reached in any single indicator. This is a well established technique in multicriteria evaluation literature (see e.g. Yu, 1985; Zeleny, 1982) and has the advantage of indicating "real world ideal values". In our case study, the vector defining the ideal value (called "ideal city" is the one presented in Figure 4.

Matrix type Impact Case Study ecolindic2.nd

Criteria \ Alternatives	Ideal City
Houses owned (%)	50.5
Residential density (pers. /hectare)	72
Use of private car (%)	10
Mean travel time to work (minutes)	22
Solid waste generated per capita (t./year)	0.2
City product per person (US$/year)	30952
Income disparity (Q5/Q!)	5.25
Households below poverty line (%)	15
Crime rate per 1000 (theft)	4.3

Figure 4. Multidimensional Representation of the "Ideal City"

single perspective. Among complex systems, the *reflexive systems* are those with the properties of awareness and purpose (Funtowicz et al, 1999).

For example, let's compare New York with the Ideal City. The pairwise comparison supplies the values presented in Figure 5.

These results are given the following policy information: New York is doing perfectly on C2 and C6 (where it meets perfectly the ideal values), more or less well on C8 and C5 (where it is not so far from the ideal values) and very bad on C1, C3, C4, C7 and C9 where it is definitely much worse than the ideal values used, and as a consequence, in our hypothetical situation, the issues connected with these indicators should be considered important policy priorities. However, one should note that these ideal values depend on the cities we are comparing. In this case, the cities are so heterogeneous that probably their comparison is meaningless.

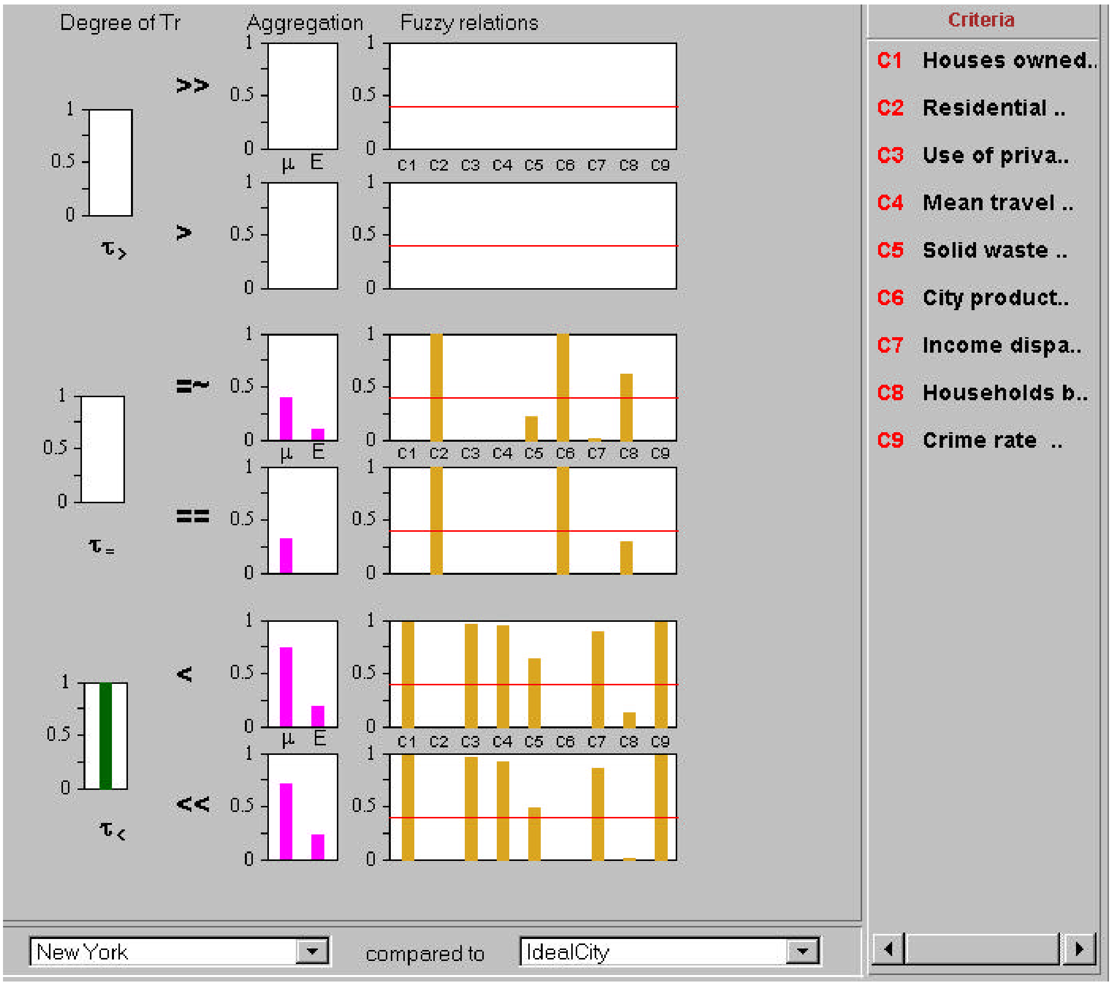

Figure 5. Results of the pairwise comparison between New York and the Ideal City.

4. CONCLUSION

One should note that the construction of an assessment exercise depends on very strong assumptions about (1) the *purpose* of this construction, e.g. to evaluate the sustainability of a given city, (2) the *scale* of analysis, e.g. a block inside a city, the administrative unit constituting a Commune or the whole metropolitan area and (3) the set of dimensions (economic, social, environmental etc.), objectives and indicators used for the evaluation process. A reductionist approach can be defined as the use of just *one measurable indicator* (e.g. the monetary city product per person), *one dimension* (e.g. economic), *one scale of analysis* (e.g. the Commune), *one objective* (e.g. the maximisation of economic efficiency) and *one time horizon*.

According to the discussion developed through this paper, I propose the following procedure based on the NAIADE method for the assessment of urban sustainability by means of a set of multidimensional indicators.

1. To specify clearly the purpose of the assessment exercise.
2. To choose a set of homogeneous cities with respect to the city(ies) one wishes to assess. Of course a key issue here is homogeneity according to what?
3. To choose the spatial scale of analysis (Commune, region, etc.)
4. To choose a set of relevant dimensions/indicators according to which the comparison has to be made.
5. To calculate the scores of the various indicators in all cities.
6. To choose the direction of each indicator (i.e. its maximization or minimization).
7. To define the profile of the ideal city by choosing the best performance in each single indicator.
8. To compare the performance of a given city with this ideal city.

Alternatively, if one wishes to use data on one city only, the procedure can be the following.

1. To specify clearly the purpose of the assessment exercise.
2. To choose the spatial scale of analysis.
3. To choose a set of relevant dimensions/indicators according to which the comparison has to be made.
4. To calculate the scores of the various indicators in the city one wishes to assess.
5. To choose the direction of each indicator.
6. To define some *reference points* considered desirable to be achieved on any single indicator.

7. To compare the real-world performance of the city with the reference points chosen.

Main advantages of these procedures are:

- The immediate usefulness for policy purposes of the information obtained.
- The avoidance of compensability among the different dimensions since the indicators are not aggregated.
- Transparency of the whole process followed.

In this context, the main reason why NAIADE is an adequate multicriteria aggregation procedure are the following.

1. Its ability to tackle an impact matrix with mixed and uncertain information.
2. Its ability to use this information in a homogeneous way to compute pairwise distances as the ones shown in this paper.

Finally, I want to emphasize that the choice of homogeneity criteria for cities and of criteria and indicators, their policy prioritization or the choice of reference points is not a technical issue only; it is mainly a socio-political issue. For this reason it is highly recommended a participatory approach to guarantee the quality of the evaluation process.

REFERENCES

- Archibugi F., Nijkamp P. (1990) – Economy and ecology: towards sustainable development, Kluwer, Dordrecht.
- Archibugi F. (1997) – The ecological city and the city effect, Ashgate, London.
- Begon M., Harper J. L., Townsend C.R. (1996) - Ecology: individuals, population and communities, Blackwell, Oxford (third Edition).
- Beinat E. Nijkamp P. (eds.) (1998) - Multicriteria evaluation in land-use management: methodologies and case studies, Kluwer, Dordrecht.
- Van den Bergh J.C.J.M., Verbruggen H. (1999) – Spatial sustainability, trade and indicators: an evaluation of the ecological footprint, Ecological Economics, Vol. 29, pp. 61-72.
- CEROI- Cities Environment Report on the Internet, http://www.ceroi.org
- Cocossis H., Nijkamp P. (eds.) (1995) – Planning for our cultural heritage, Averbury, London.
- Ecological Economics (2000) – Forum: The ecological footprint, Vol. 32, No. 3, pp. 341-394.
- European Commission - Environmental Indicators and Green Accounting, 1996.
- Folke C., Larsson J., Swetzer J. (1996) - Renewable resources appropriation by cities, in Costanza R., Segura O., Martinez-Alier J.(eds.) - Getting down to Earth, Island Press, Washington, pp.201-221.
- Frey H. (1999) – Designing the city. Towards a more sustainable urban form, E & FN SPON, London.
- Funtowicz S.O., Ravetz J. R. (1994) - The worth of a songbird: ecological economics as a

post-normal science, Ecological Economics, 10, pp. 197-207.

- Funtowicz S., Martinez-Alier J., Munda G. and Ravetz J. (1999) - Information tools for environmental policy under conditions of complexity, European Environmental Agency, Experts' Corner, Environmental Issues Series, No. 9.
- Fusco Girard L., Nijkamp P. (1997) – Le valutazioni per lo sviluppo sostenibile della citta' e del territorio, Franco Angeli, Milan.
- Giampietro, M. (1994). Using hierarchy theory to explore the concept of sustainable development. Futures 26 (6): 616-625.
- Giampietro, M. (1997). The link between resources, technology and standard of living: A theoretical model. In: L. Freese (Ed.), Advances in Human Ecology, Vol. 6. JAI Press, Greenwich (CT), pp. 73-128.
- ICLEI – International Council for Local Environmental Initiatives, 1995.
- Munda G., Nijkamp P. and Rietveld P. (1995) - Qualitative multicriteria methods for fuzzy evaluation problems: an illustration of economic-ecological evaluation, European Journal of Operational Research, 82, pp.79-97.
- Munda G. (1995) - Multicriteria evaluation in a fuzzy environment, Physica-Verlag, Heidelberg.
- Nijkamp, P., Perrels A. (1994) – Sustainable cities in Europe, Earthscan, London.
- Norgaard R. B. (1994) – Development Betrayed, Routledge, London.
- Odum E.P. (1989) - Ecology and our endangered life-support systems, Sinuaer Associates, Sunderland, Massachussetts.
- O'Neill, J.(1993) - Ecology, Policy and Politics, Routledge, London.
- Paruccini M. (ed.) (1994) - Applying multiple criteria aid for decision to environmental management, Kluwer, Dordrecht.
- Urban Indicators Programme, http://www.urbanobservatory.org/indicators/database
- Wackernagel, M. and W. E. Rees (1995) - Our ecological footprint: Reducing human impact on the earth, Gabriola Island, BC and Philadelphia, PA: New Society Publishers.
- Yu P. L. (1985) - Multi criteria decision making: concepts, techniques and extensions, Plenum Press, New York.
- Zeleny M. (1982) - Multiple criteria decision making, McGraw Hill, New York.