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Case study

The Dashboard of Sustainability to measure the local urban sustainable development: The case study of Padua Municipality

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ABSTRACT

The adoption of suitable indicators is fundamental to implement sustainable development at the local level. It helps in the analysis and evaluation; supports the decisional process and helps the communication between the citizens and the society, in general.

Furthermore, the aggregated indexes – by representing the observed context in a simple way – may help the community in the definition of effective improvement goals and also serve as important tools to monitor the fulfillment of the planned objectives.

The Dashboard of Sustainability (DS) is a mathematical and graphical tool designed to integrate the complex influences of sustainability and support the decision-making process by creating concise evaluations.

The city of Padua, Italy, agreed to use the DS in its Local Agenda 21 project, financed by the Italian Ministry of Environment. The available data were sufficient to design 61 useful indicators of environmental protection, economic development, and social promotion.

The results of the analysis were discussed in Padua's community forum on the Local Agenda 21 process. The graphical and numerical results helped Padua reach a consensus on the plan for future sustainability, one that was understood and accepted by all the stakeholders.

In order to adapt this tool to a local context, two changes in the methodologies were necessary: to measure urban sustainability, for which "ad hoc" set indicators were used; and to allow a comparative evaluation, for which the performances of Padua were evaluated over time. These changes were possible, thanks to the flexibility of such tool.

1. Introduction

The need to adopt environmentally sustainable behaviours made the international community commit sustainable development (Meadows et al., 1972; WCED, 1987; WCS et al., 1991; UN, 1992b; UNESCO, 1995; UNDP, 2001).

At the international level, the first World Summit on Sustainable Development at Rio de Janeiro in 1992 established Agenda 21 and suggested that all countries around the world formulate economic policies with a minimum impact on the environment, and encourage social promotion of individuals and the community (UN, 1992a). In the same year, in Europe,

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the European Community suggested that the Members State achieve long-term economic growth respectful of environment, social promotion, and individual welfare (see also EC, 1992, Title I, Art. B; CEC, 1993, Chapter 10; EC, 2000a, Art. 37; EC, 2001; and so on).

There is a fundamental issue in the long path of sustainability, acting at the local level. That is, the economic, environmental, and social objectives of sustainable development may be effectively achieved by acting in the local context and in particular the urban context (see also, at the international level: UNCED, 1992; UNCHS, 1996; WB, 1995; ICLEI and UNDPCSD, 1997; Kirdar, 1997; and at the European level: CEC, 1990; ICLEI, 1994; EC, 1996; CEC, 1997). Agenda 21 involves local authorities and suggests them to adopt policy towards sustainable development through processes of shared governance (see Local Agenda 21) (hereafter: LA21) (UN, 1992a, Chapter 28).

In the international debate concerning sustainable development and its carrying out in an urban context, a particular attention is turned to the necessity of defining suitable measurement tools (see Section 2, paragraph 2.1).

The adoption of an effective monitoring is the sine qua non to undertake in order to face complex issues, and indicators, which represent complex problems in a simple way, and help the sustainable development process in the urban context.

A literature review points out the need for and the difficulty in defining indicators that are able to integrate the economic, social, and environmental issues. The objectives of this integration are: to support the analysis of complex and interrelated problems, support the decisional process and the sharing of objectives according to the principle of LA21 (see Section 2, paragraph 2.1).

Among the different tools available in the literature to measure sustainability, this research considers the Dashboard of Sustainability (hereafter: DS). The DS is a sustainability comparative tool used by the international scientific community in the last few years. Through the use of different indicators and specific aggregations, it supports a synthetic representation of the different dimensions of sustainable development (see Section 2, paragraph 2.2).

Nowadays this tool is internationally adopted to confront the performance of sustainability of different countries of the world and to help the decisional, communication, and sharing process. Nevertheless, it is possible to assume its application to a local urban context (see Section 2, paragraphs 2.2 and 2.3).

This paper presents the results of a research carried out in Padua Municipality, Italy, between 2002 and 2006. This research experiments the application of DS to a local urban context, verifies the validity of such tools in guiding LA21 process and its capability to get over the sustainability measurement problems that emerge in the literature.

Section 2 sums up a literature review concerning the application of sustainability indicators to a local context. Section 3 describes the objectives of the research by giving a synthetic representation of the structure and the functioning of the DS as created by its authors and presents the case study analysed in this research. Section 4 reports the application of the DS tool. Section 5 points out the main results of the application of the DS to the case study. Section 6 discusses on the results achieved in order to verify if DS can be used in a local urban context, the possibility of doing that and its efficacy in measuring sustainability. Section 7 points out the strengths and the limits to the application of the DS as an analysis and evaluation tool to support the local urban sustainability.

2. To measure local sustainability: a literature review

Nowadays, sustainable development is one of the most important commitment engaged by most of the countries in the world. Moreover, the local context is the key dimension to plan and realize sustainability through LA21.

Sustainability indicators are fundamental tools to support LA21 processes: ‘‘indicator of sustainable development need to be developed to provide solid bases for decision-making at all levels and to contribute to a self-regulating sustainability of integrated environment and development systems’’ (UN, 1992a, Chapter 40.4).

The use of indicators is considered as a fundamental step to guide the decisional process: ‘‘there will be no indicators without policies and no policies without indicators’’ (Flood, 1997, p. 1640).

The adoption of indicators to guide the sustainability of local context, meets the needs of the local context managers. To plan sustainable development, the knowledge of the local economic opportunities, local environmental conditions, and of the cultural and social characteristics is fundamental (see also: Giaoutzi and Nijkamp, 1993; Dommen, 1993; Camagni et al., 1998; Bell and Morse, 1999, 2003; Innes and Booher, 1999; Nijkamp and Vreeker, 2000; Valentin and Spangenberg, 2000; Rogers and Ryan, 2001; Annan, 2002; Kratena, 2004; Hezri and Dovers, 2006; Olewiler, 2006; Böhringer and Jochem, 2007; Distaso, 2007; Jollands and Harmsworth, 2007; and so on).

To meet these needs, international organizations, in the last few years, carried out many initiatives aimed at defining sustainability indicators (see also: OECD, 1994, 2001; UN, 1996; Jesinghaus, 1999; Hardi and Zdan, 1997; EC, 2000b; ESCTC, 2000; IISD, 2000; UNEP, 2000; ; UN, 2001; UNCHS, 2001; UNCSD, 2001; UN et al., 2003; WB, 2003, 2005; CEC, 2005; UNDP, 2005; Nardo et al., 2005; and so on). They experimented such indicators in different contexts (e.g., the forest, urban, and waste management, the monitoring of emissions, the assessment of environmental impacts of the economic growth, the repercussions of economic changes on the society, and so on). The abundance of SDI initiatives and metrics is an ‘‘indicator industry’’ (King et al., 2000; Parris and Kates, 2003).

In particular, the local and the urban dimension of sustainability win the interest of international literature and the definition of specific local urban context indicators is of great interest. Even the Johannesburg Plan of Implementation, endorsed at the World Summit on Sustainable Development, encouraged further work on developing sustainability indicators at the local level (UN DESA, 2002). There are also many experiences in the literature (see also: Walter and Wilkerson, 1998; Tsenkova, 1999; Alexander, 2000; Valentin and Spangenberg, 2000; van Kamp et al., 2003; Yuan et al., 2003; While et al., 2004; Mickwitz et al., 2006; Wilson et al., 2007; Hezri and Dovers, 2006; Egger, 2006; Holden, 2006; Olewiler, 2006; Zhang

et al., 2006; Distaso, 2007; Lee and Huang, 2007; Lindholm et al., 2007; and so on).

The definition of effective sustainability indicators is a complex objective due to the complexity of the phenomena concerned and the difficulty to integrate them in a single measure.

By reviewing the literature it is possible to point out the main features that should characterize sustainability indicators:

- multidimensionality: indicators must describe the different dimensions of sustainability – economy, environment, society – with an integrated perspective (Munasinghe and McNeely, 1995; Atkinson and Hamilton, 1996; Nijkamp and Vreeker, 2000; Egger, 2006; Böhringer and Löschel, 2006; Distaso, 2007; Lindholm et al., 2007; Ness et al., 2007);
- guidance to policy-making: indicators must support the decisional processes. They must assess the main problems, guide choices and solutions, and facilitate the verification of the targets achieved (UN, 1992a, par. 40.2; ICLEI, 1995; Hardi and Zdan, 1997; Kates et al., 2001; Capello and Nijkamp, 2002; Olewiler, 2006; Hezri, 2004; Herzi and Nordin Hasan, 2004; Andrada II and Calderon, 2006; Hezri and Dovers, 2006);
- sharing: indicators must support the sharing of local policy general strategies among local communities and the sharing of development goals towards sustainable development. This is possible only through a clear and comprehensible communication of complex information (ICLEI, 1994; Lindholm and Nordeide, 2000; Yuan et al., 2003; Olewiler, 2006; Jollands and Harmsworth, 2007);
- objectivity and relevance: indicators must be significant and also be an exact portrayal of the considered context. In their definition, technical competences are needed (ICLEI, 1995; Harger and Meyer, 1996; Custance and Hillier, 1998; Hezri, 2004; Fraser et al., 2006; Olewiler, 2006; Böhringer and Jochem, 2007);
- on the basis of the objectives and the context: indicators must be coherent with the development goals set down by the LA21 process. This is important to guarantee the efficacy and the utility of the evaluations that follow in every single local context (Hukkinen, 2003; ICLEI, 1995; Hardi and Zdan, 1997; Hezri, 2004; Hezri and Dovers, 2006; Olewiler, 2006; Rosenström and Kyllönen, 2007; Wilson et al., 2007);
- participation: the choice of indicators must be the result of a bottom-up process. This process ensures sharing of the measurement tool and validity of the evaluations that follow to all the stakeholders (Pinfield, 1996; Bouni, 1998; Valentin and Spangenberg, 2000; Morse et al., 2001; Fraser, 2002; Corbiere-Nicollier et al., 2003; Yuan et al., 2003; Hezri, 2004; Andrada II and Calderon, 2006; Mickwitz et al., 2006; Reed et al., 2006; Jollands and Harmsworth, 2007; Rosenström and Kyllönen, 2007).

Although there are many different experiences of use of sustainability indicators, is acknowledged in the literature that sustainable development measurement tools available to local communities, have some limits:

- it is still difficult to measure the multidimensionality of sustainable development; usually, many different specific and heterogeneous indicators are used to get over this problem, but it is difficult to represent them with integrated indexes (van Kamp et al., 2003; Becker, 1997; Kratena, 2004; Heuting and Rejinders, 2004; Wiek and Binder, 2005; Gagliardi et al., 2007; Ness et al., 2007);
- the complexity of the observed phenomena and their interrelationship force the adoption of technical indicators which are difficult to understand to outsiders; this condition hampers the sharing with local communities, which need clear and comprehensible information (Scipioni et al., 2008; Xu et al., 2006; Distaso, 2007; Ness et al., 2007);
- indicators are far from being an effective support to policy-making, although their main purpose is to guide decisions (Dovers, 1997; Bell and Morse, 2001; Kates et al., 2001; Blinc et al., 2006; Scipioni et al., 2008; Distaso, 2007; Wilson et al., 2007);
- peculiarities of every single local context need the use of ad hoc set indicators; however, peculiarities involve consequent difficulties in setting reference parameters to support a comparative evaluation with other local context, and make the evaluation less efficient (Rydin, 2004; Wiek and Binder, 2005; Hezri and Dovers, 2006; Lindholm et al., 2007);
- experts are involved in the definition of technical indicators that are able to acknowledge the complexity of sustainability. This issue often prevents the local community to identify their indicator through a participative process (Riley, 2001; Herzi and Nordin Hasan, 2004; Morse and Fraser, 2005; Andrada II and Calderon, 2006; Reed et al., 2006).

3. Materials and methods

3.1. *The Dashboard of Sustainability for integrate appraisals*

The DS is a tool, developed by the end of the 1990, to measure the different dimensions of sustainability. It helps a concise and synthetic appraisal with great visual impact (Hardi and Semple, 2000; IISD, 2002; Jesinghaus and Hardi, 2002).

The tool was developed by the Consultative Group on Sustainable Development Indices (CGSDI) and the Joint Research Center (JRC). The JRC also designed the free software application that implements this tool. The software allows to synthesize a wide variety of data and environmental, economic, and social information in a single graphical and numerical evaluation form (the software and its user manual are downloadable for free from http://esl.jrc.it/envind/dashbrds.htm; other information on DS are available at http://www.iisd.org/cgsdi/dashboard.htm).

The DS makes a sustainability evaluation by considering the economic, social, and environmental conditions of development and by using ad hoc set indicators. The evaluation involves a comparison between different contexts and allows to classify them on the basis of their economic, social, and institutional performances (Hardi and DeSouza-Huletey, 2000).

The tool is acknowledged to be particularly useful by the scientific community. It facilitates the communication of sustainability, helps the sharing of targets and supports the decisional processes (IISD, 2001; Jesinghaus and Hardi, 2002; O'Connor and Jesinghaus, 2002).

The DS organizes the assessment information into three levels represented by the following concentric rings:

- the outer ring represents the individual indicators used to evaluate sustainability;
- the inner ring represents synthetic indexes, which integrate multiple indicators (Environment, Economy, and Social Care) into a single measure;
- the innermost circle is reserved for a synthetic index of overall sustainability (SDI, the Sustainable Development Index, or PPI, the Policy Performance Index). This synthetic index is obtained by averaging the indexes of the inner ring.

The DS presents information both numerically and graphically by assigning each subject or indicator to a coloured segment of the outer ring.

- The length of a segment is a measure of its relative importance with respect to other indicators in the same category.
- The colour of a segment reports on the performance of the indicator relative to its value in other contexts. This ''policy evaluation'' scale goes from excellent (dark green) to very bad (dark red).

The model uses a software that rescales all the indicators to the same range and represents them mathematically or graphically. The software rates each indicator on a scale ranging from 0 points (the worst case of all contexts being compared) to 1000 points (best case). All intermediate cases are calculated using a linear interpolation between these two bounds (Hardi and DeSouza-Huletey, 2000). The DS software uses the following formula to assign a numerical score to each indicator:

$$(\text{score DS})i = 1000 \times \frac{[(\text{value})i - (\text{value})w]}{[(\text{value})b - (\text{value})w]} \quad (1)$$

Thus, all values range from 0 to 1000 as noted. For a given indicator x, the terms in [F.1] are defined as follows:

- (score DS)i = the DS score assigned to indicator $\times$ for context I;
- (value)i = the value of indicator $\times$ for context i;
- (value)b = the best value of indicator $\times$ among all contexts;
- (value)w = the worst value of indicator $\times$ among all contexts.

This numerical performance evaluation is associated with a scale of 10 colours, corresponding to different performances of sustainability (Fig. 1).

In particular, there are two main applications of DS (Hardi and Semple, 2000):

- the DS can be used at a national and international level to compare the performances of different nations of the world; this application is adopted by many different international organizations (Jesinghaus and Hardi, 2002; Devraj, 2002; OECD, 2002; Glenn and Gordon, 2006; UNESCO, 2006; JRC, 2007);
- the DS can be used at a local level to compare the sustainability of a local context to other local context: this is the direction taken in the last applications of the DS (Känkinen and Oras, 2004; SOE, 2004; Ambiente Italia, 2006a; Ambiente Italia, 2006b; SustainLane, 2006; Tárraga and Ángel, 2006; Beccali et al., 2007; JRC, 2007).

There are many different indicators that can be used in the calculation sheet to build up the DS. The choice depends on the scale of analysis on which the tool is applied:

- indicators, meaningful at the international level, must be used for the application of DS at the national and international level: suitable indicators were designed to meet this purpose (Hardi and Zdan, 1997; Jesinghaus and Hardi, 2002; OECD, 2002; Glenn and Gordon, 2006; JRC, 2007);
- indicators, meaningful at the regional level and diffused at the national level, must be used for the application of DS at the local level (Hardi and Zdan, 1997; Valentinelli, 2001; Känkinen and Oras, 2004; SOE, 2004; Ambiente Italia, 2006b; SustainLane, 2006).

The adoption of DS to measure sustainability implies some significant benefits (IISD, 1999; Hardi and DeSouza-Huletey, 2000; Hardi et al., 2002; Darren et al., 2004):

- the tool is user-friendly and the software application clearly facilitates the communication of complex but important appraisals to those who do not have the training to follow all the steps;
- the DS contemporaneously allows the analysis of numerous sustainability data both with detailed indicators and aggregated indexes;
- the DS helps communicate the sustainability performances and support the Community to share sustainable development goals;
- the DS guides in the definition of new sustainable development policy by pointing out the strengths and weaknesses of the current local development policy.

It is important to underline that, while most recent applications of the DS regards the very local context, does not still exist applications regarding the mean urban contest. Existing projects like ''Ecosistema Urbano'' (Ambiente Italia, 2006b) or ''SustainLane'' (SustainLane, 2006) apply DS in a district, not in the smaller municipal territory, which corresponds at the very urbanized land.

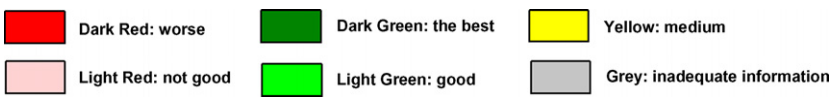

Fig. 1 – The colour scale related to relative performance in the DS.

3.2. Objectives and structure of the research

The theoretical and practical studies have suggested that the existing models have some significant weaknesses:

- it is quite difficult to analyse the many complex and interrelated aspects of sustainability.
- the evaluation loses meaning and credibility over time, so policy decisions made long after the measurements may be ineffective.
- when a measurement tool becomes too specialized, it compromises communication of the results to other parties. Customized local tools are more likely to be misunderstood or used inappropriately in subsequent research, thereby putting the process at risk.

Besides this concept, the international scientific community is going to affirm the DS:

- The diffusion of DS in many initiatives, even institutional, demonstrates the validity of DS to estimate the sustainable development in a synthetic and all-round way.
- The application of this instrument to local scale has already demonstrated its validity.
- It is yet to verify the applicability of the tool to urban scale.

To reply these assumptions, research carried out between 2002 and 2006 has analysed the possibility of adapting the DS to measure the sustainability of a local urban context. This research has two main objectives:

- to discover whether and how evaluation tools such as the DS remain valid when applied to an urban context, that is, a city and its communal bounds;
- to investigate whether and how the DS may be adopted as an instrument to measure the sustainability in an LA 21 process.

In accordance with the defined goals, the research is a quantitative one, whose target is to confirm the method applied within the case study (Corbetta, 1999). This is a widespread methodological choice in literature: in the measurement of urban sustainability, in fact, besides the importance of theoretical contribution, there are many applied research experiences that follow a quantitative approach and use the methodology of a case study (see also: EFILWC, 2003; Yuan et al., 2003; Hezri, 2004; Herzi and Nordin Hasan, 2004; Andrada II and Calderon, 2006; Fraser et al., 2006; Mickwitz et al., 2006; Gagliardi et al., 2007; Jollands and Harmsworth, 2007; Lee and Huang, 2007; Pulselli et al., 2006; Rosenström and Kyllönen, 2007; Wen et al., 2007; and so on).

Clearly, the experimentation of DS at a single case study allows to draw conclusions valid just for the single case, not allowing to formulate general theories about the validity of DS to measure local sustainability and/or support LA21 processes.

An urban local context has been chosen to be the case study in order to fit the research objectives better. We have chosen to investigate the urban context of Padua, where an LA21 process has already been initiated and sufficient supporting information is available to define certain sustainability indicators (see paragraph 3.3).

This research was carried out using statistical data published by local, regional, and national administrations, in order to obtain a holistic vision of the relevant social, economic, and environmental phenomena (Corbetta, 1999).

This choice allows to set the experimental application of DS at the chosen case study keeping the chance to export the experience to other case studies in virtue of the fact that data used in this study come form official statistics.

3.3. The Padua Municipality and its Local Agenda 21

The municipality of Padua is located in Veneto, in northeast Italy. It covers an area of 93 km^2, has a population of 210,000 and each family has an average of 2.2 people. The administrations responsible for Padua have been trying for many years to direct the city towards a state of durable and balanced development.

In 2001, the municipality of Padua started on the path to local sustainable development by agreeing to the Aalborg Charter and approving a Local Agenda 21 (LA21) program named ''Sustainable Padua—PadovA21'' (hereafter PadovA21). The project was designed in collaboration with ARPA Veneto, the University of Padua, and the Ministry of Environment (Padua Municipality, 2001a). As part of this project, Padua published a report on its current environmental state (ARPAV, 2002).

PadovA21 also established a citywide forum to discuss the environment and implemented four thematically organized working groups to identify the most important indicators of sustainability. At the end of 2003, the city had managed to formulate a Local Action Plan (LAP) (Padua Municipality, 2003b).

The PadovA21 project has several interesting features that make it an attractive choice for this research, in particular a working group to design suitable indicators. The indicators chosen by this group assumed an important role in public forum discussions of sustainable growth and effective solutions to local problems (Padua Municipality, 2001b). Padua's solution provides the basis for an experimental application of the DS. In this research, we use the indicators chosen by the municipality of Padua in a DS to represent local urban sustainability.

4. Application of DS in Padua Municipality

4.1. Methodology: the use of DS in the urban context

The DS must be adapted to an urban context before the analysis of Padua's situation begins.

In particular, two modifications have been set.

First, to build a DS with the commonly used indicators (those defined by CGSDI or by UNCSD) a large amount of data is required. This information is usually easy to collect on the national level (from ISTAT or EUROSAT, for example), but may be difficult or even impossible to find on the local level.

The use of indicators different to those commonly used in the model, is required by the application of DS to the local context of Padua.

Futhermore, all the indicators in the dashboard must be significant to the situation examined, and effectively represent the sustainability (IISD, 1999). Similar to other experiences (see also: Valentinelli, 2001; Devraj, 2002; OECD, 2002; Känkinen and Oras, 2004; Ambiente Italia, 2006b; Glenn and Gordon, 2006; SustainLane, 2006; UNESCO, 2006; Beccali et al., 2007, etc.), it is necessary to change the original DS indicators to better fit the urban context.

Anyway, for the screened setting, that is, the communal bounds of a city, other applications of DS do not exist in the literature. Therefore, it is necessary to adopt different indicators, which may have significance even at municipal level, to use DS in the ''PadovA21'' project. In fact, other experiences like ''Ecosistema Urbano'' or ''US Sustainable Cities'' use DS with indicators that have significance at district level and are built with data and information referred to district level. Therefore, is impossible to use such indicators to apply DS to the municipality of Padua. Therefore, in virtue of the originality of the chosen scale for this research (the urban contest), it is necessary to define ad hoc indicators.

At first, this aspect of the project seemed a limitation. As work progressed, however, it evolved into a research opportunity in its own right. We have experimented with several indicators in constructing a DS for Padua's LA21 process carried out in Padua.

In other words, the necessity to define specific indicators for the DS application in Padua allows to choose as indicators the same that the LA21 project planned to produce by an active process.

In fact, the choice of indicators, in the PadovA21 project (Padua Municipality, 2001b), is the results of a bottom-up process and, where possible, of a participative process. The chosen sustainability indicators are coherent with the commitment to sustainability and therefore effective for the municipality of Padua.

A thematic forum to discuss sustainability indicators was established within the PadovA21 project. Its aim was to define suitable indicators to measure Padua's sustainability and to guide the LAP definition (Padua Municipality, 2001c).

The ''PadovA21'' project, in fact, has been set with the constitution of a forum of sharing and discussion about the problems of local sustainability. The forum has been officially set up on November 30, 2002 and dragged about 100 of stakeholders, among which industries, volunteer associations, professional orders, municipal companies which manage territorial services, hospital, university, institutions, mass-media, third sector agencies (Padua Municipality, 2002). The aims of PadovA21 forum were the definition of a common philosophy for local sustainability, the identification of more important problems, analysis, and sharing of possible solutions, definition of middle-long term objective, formulation of the actions to carry out to realize the LA21 (and the drafting of the LAP – Local Action Plan), and at last the management of monitoring activity and evaluation of results coming out from LAP (Padua Municipality, 2002, 2003c).

Between the actions performed from PadovA21 forum, turned out to be especially interesting the choice of new indicators. For this action have been done some thematic meetings to discuss and confront which carried attending people to chose a group of indicators to measure the sustainability in Padua (61 indicators for economic, social, and environmental aspects on local scale) (Scipioni and Mazzi, 2003). Such indicators are the starting point for our research project, the applications of the DS in Padua.

The Thematic forum ended its work by the end of 2003. The forum came to the definition of 61 indicators of local sustainability (Scipioni and Mazzi, 2003). These are the starting points of the DS application to the municipality of Padua.

The second issue to be resolved before applying the DS to Padua, is that no similar application case exists.

In fact, the DS is useful only if Padua's choices can be compared to some other urban context (Hardi and Semple, 2000).

The originality of Padua's program demonstrates the flexibility of the DS, but without a basis for comparison the DS is not useful (Hardi and Semple, 2000). In this case we choose to look back in time, comparing Padua's present program to earlier administrations.

To overcome this limitation, the DS tool was used to evaluate the sustainability of Padua at several points of time.

In this way the tool, rather than being used to get a comparative evaluation in the space (between different local realities) in the same moment (e.g., reference year) has here been used in an original way to make a comparative evaluation of the sustainability along the timeline in the same local reality (municipality of Padua), comparing its performances in different moments (wisely chosen gap of years).

It is necessary to underline that the research work does not intend to express an evaluation of merit for the sustainability of the municipality of Padua but simply to check the possibility to use the DS event in local scale. For this reason, it is wrong to expect a judgement of sustainability or non-sustainability in the municipality of Padua but a judgement on the possibility to apply DS to conduct such evaluation.

4.2. *Choice of indicators and data collection*

As stated previously, we adopted the indicators developed by Padua's civic forum for PadovA21. To insert these into the DS software, the 61 indicators were grouped into four categories: economic (12 indicators), environmental (12), social (22), and indicators related to the health board and justice department (15). Table 1 presents all 61 indicators defined by the PadovA21 project.

The data needed to build these indicators turned out to be available only over a 5-year period, from 1997 to 2001.

Even for this methodological choice it is useful to remember that the aim of the research is n the evaluation of sustainability in Padua because the time gap of 5 years is clearly insufficient; the research wants to experiment the use of DS in an original way, running a temporal comparison of a municipal reality with itself; to do this the time arch is sufficient.

Many public documents, whose editing is done by institutional agencies, were used to build the indicators (Padua Municipality, 1998, 2003a; ARPAV, 2002; ACI, annual redaction; Ambiente Italia, annual redaction; Padua Municipality, annual redaction; ULSS 16, annual redaction).

Table 1 – Indicators of sustainability defined by the PadovA21 project

Environmental indicators		Economic indicators		Social indicators		Health board—justice indicators	
Code	Name of indicator	Code	Name of indicator	Code	Name of indicator	Code	Name of indicator
A 1	Potable water consumption	E 1	Unemployment rate	S 1	Population density	G 1	Hospital admissions
A 2	Air temperature	E 2	Inflation	S 2	Nature balance	G 2	Average stay in hospital
A 3	Annual rainfall	E 3	Poverty thresholds	S 3	Migratory balance	G 3	Causes of death
A 4	Average humidity (%)	E 4	Entrepreneurial attitude	S 4	Immigration rate	G 4	No. of inhabitants per doctor
A 5	Sulphur dioxide (SO_2)	E 5	New companies	S 5	Foreign immigration rate	G 5	No. of inhabitants per hospital attendant
A 6	Particulate Matter	E 6	Insolvent companies	S 6	Chief town attraction rate	G 6	No. of health issues
A 7	Nitrogen dioxide (NO_2)	E 7	GDP	S 7	Birth rate	G 7	Old age rate
A 8	Ozone (O_3)	E 8	Visitors to museums	S 8	Nationalized foreign residents	G 8	Dependence rate
A 9	Carbon monoxide (CO)	E 9	Tourist arrivals	S 9	Motorization rate	G 9	Number of persons with substandard lodging
A 10	Waste	E 10	Tourist presence	S10	Bicycle lanes	G 10	Number of persons without fixed abode
A 11	Recyclable waste	E 11	Hotel use rate	S 11	Pedestrian areas	G 11	Murders
A 12	Electrical energy consumption	E 12	Average stay	S 12	Road accident rate	G 12	Thefts
				S 13	Death rate	G 13	Bag-snatchings and pickpocketings
				S 14	Injury rate	G 14	Suicide rate
				S 15	Riskiness rate	G 15	Juvenile criminality
				S 16	Public transport coverage		
				S 17	Seats available on public transport		
				S 18	Variation in the number of subscriptions		
				S 19	Public transport services		
				S 20	Habitable space		
				S 21	Sport and recreation facilities		
				S 22	Public parks and gardens		

Source: authors elaboration from the indicators selected by PadovA21 Forum.

Table 2 – Indicators of sustainability defined by the PadovA21 project and their trends over the period 1997–2001

Environmental Indicators			Economic Indicators			Social Indicators			Indicators of Health & Justice		
Code	Trend	Sustainability	Code	Trend	Sustainability	Code	Trend	Sustainability	Code	Trend	Sustainability
A 1	↘	☺	E 1	↘↗	☺☹	S 1	↘	☹	G 1	↗	☹
A 2	↗↘	☹☺	E 2	↘	☺	S 2	↗	☺	G 2	↗	☹
A 3	↗↘	☹☺	E 3	↘	☺	S 3	↗↘	☺☹	G 3	↗↘	☹☺
A 4	↗↘	☹☺	E 4	↗↘	☺☹	S 4	↗↘	☺☹	G 4	↘	☹
A 5	→	☹	E 5	↗	☺	S 5	↗↘	☺☹	G 5	↗↘	☺☹
A 6	↗↘	☹☺	E 6	↗	☹	S 6	↘	☹	G 6	↘	☹
A 7	↗↘	☹☺	E 7	↗	☺	S 7	↗↘	☺☹	G 7	↘	☺
A 8	↘	☺	E 8	↘	☹	S 8	↗	☺	G 8	↘	☺
A 9	↗	☹	E 9	↗	☺	S 9	↘	☺	G 9	→	☹
A 10	↗	☹	E 10	↗	☺	S10	↘	☹	G 10	↗	☹
A 11	↗	☺	E 11	↗	☺	S 11	↗	☺	G 11	↗↘	☹☺
A 12	↘	☺	E 12	↗	☺	S 12	↗↘	☹☺	G 12	↗↘	☹☺
						S 13	↗	☹	G 13	↘	☺
						S 14	↗	☹	G 14	↘↗	☺☹
						S 15	↗	☹	G 15	↘↗	☺☹
						S 16	↗↘	☺☹			
						S 17	↗↘	☺☹			
						S 18	↗↘	☺☹			
						S 19	↗	☺			
						S 20	↗	☺			
						S 21	↘	☹			
						S 22	↘	☹			

Source: authors elaboration from Padua Municipality data.

4.3. *Trends and sustainability assessments*

In order to use the DS, it is necessary to associate a sustainability measure with every single indicator. This measure has the exact meaning of whether an indicator is expected to improve or worsen the local sustainability over time.

Every indicator built from the data over the 5 years of study was therefore associated with two symbols:

- a ↗, →, or ↘ represents the trend of the indicator itself over time, which is either increasing, stable, or decreasing, respectively;.
- it then becomes possible to link this trend to a trend in the sustainability using the symbols ☺, 😐, and ☹.

For example, the combination ↗☹ means that the value of the indicator is increasing and that this trend is expected to have a negative impact on sustainability. When a trend is marked ↗↘, it means that the indicator is fluctuating over the 5-year period.

Table 2 presents the 5-year trends (1997–2001) in the indicators chosen by the PadovA21 forum.

4.4. *Using the DS software*

Once the indicators are chosen and built on the available data, it is necessary to insert them in the DS software in order to give a comprehensive sustainability evaluation at a local level.

In order to use the indicators in the DS software it is necessary to assign different weights for them. The weight is proportional to the importance of the aspect evaluated by each indicator (Hardi and DeSouza-Huletey, 2000).

Therefore, following the principle of participation of sustainable development adopted by the PadovA21 project, the LA21 Forum has to determine the importance of the different aspects.

Even though the Civic Forum discussed about the weight to assign to each indicator during the PadovA21 project, no consensus emerged. Therefore, it decided to assign the same unitary weight to every indicator and give the same importance to every aspect. The research followed by inserting all of the indicators in the DS software and by assigning them the same unitary weight.

After calculating all the indicators and entering them into the DS software, a score between 0 and 1000 is assigned to each indicator. As we are comparing the sustainability of Padua at

Table 3 – Synthesized indexes of the DS for each category of indicators over the period 1997–2001

Year	Environment index	Economy index	Society index	Health board—justice index	Policy performance index
1997	577 (4)	345 (5)	372 (4)	605 (3)	474
1998	704 (1)	371 (4)	429 (3)	655 (1)	539
1999	674 (2)	409 (3)	434 (2)	650 (2)	541
2000	416 (5)	551 (2)	353 (5)	436 (4)	439
2001	590 (3)	743 (1)	587 (1)	Not available	640

Source: authors elaboration using DS software for Padua Municipality.

different points in time, for each indicator, the value 0 is always assigned to the worst performance in the 5 years, and the value 1000 is always assigned to the best performance. The values of the intermediate years are obtained by a linear interpolation as described in [F.1].

After rating each indicator in this manner, an annual global index for each aspect (Environment, Economy, Social, and Health/Justice) is calculated. These four synthesized indexes are obtained by calculating with DS the average score of all the indicators within each group for each year of analysis.

Table 3 gives the values obtained for each aspect of sustainability and for each year of the analysis (1997–2001). The numbers in brackets rank the five performance results for each aspect.

The last column of Table 3 gives the overall policy performance index (PPI), which is simply the arithmetic mean of the four synthesized sustainability indexes obtained in the same year.

5. Results

5.1. *Graphical results*

The application of the DS to the municipality of Padua, returned numerical and graphical results. These can be used to compare the sustainability of Padua over time.

Presenting the results gained from this application is useful to remember that the aim of the research was not the evaluation of the sustainability for the local reality considerate, instead the verification of the applicability of the DS tool in a local contest like the considered one. As a consequence, results reported below have not the claim to demonstrate if Padua accomplished results in the considered years, rather they demonstrate in which way is possible to apply DS at municipal level, suing indicators created *ad hoc* to obtain a comparative evaluation in the space which delivers, at he end, numerical values and graphics which are meaningful because immediately interpretable.

Fig. 2 shows the graphical result obtained using the indicators chosen by the PadovA21 forum. For each year considered, the DS is divided into four quadrants representing the four categories of indicators. Each quadrant is subdivided into a number of equally sized segments, one for every indicator in the category. The colour of each segment varies from dark green (ideal situation) to dark red (very bad situation), depending on its interpolated score. The colour grey is used in situations where no data are available. The colours in the inner ring represent the synthetic index for each category of indicators.

The PPI sums up all estimated aspects of the DS, giving an indication of the overall sustainability of the territory (which is presumably partly due to the political choices of the community). This value is the arithmetic mean of the other four synthesized indexes in the same year. The PPI index is plotted from 1997 to 2001 in Fig. 3.

Fig. 4 shows the final output of the DS application. There are five ''dashboards,'' one for each year of analysis. The PPI is represented by the position of a needle in the centre. This figure is called a Dashboard of Sustainability because it looks like the speedometer on the dashboard of a car (Hardi and Semple, 2000). The colour scale of the DS again runs from dark red (0) to dark green (1000). Each dashboard is accompanied by four circles representing the synthetic index of each category for the year. The overall situation in Padua is best during the last period considered in the analysis (2001); the needle of that dashboard is on the darkest shade of green.

5.2. *The adoption of the results in PadovA21 process*

Results gained using DS in Padua allows us to obtain some significant advantages.

First, the PadovA21 forum took in consideration the result of this experimentation dedicating appropriate plenary sessions: this allowed the attendant people to know the DS tool and to understand its potential well.

The PadovA21 forum decided to use the results to identify the main themes which intervene with the LAP. In fact, although the application of DS in Padua had not the aim to couch judgement about sustainability, the Forum acknowledged that the tool shows a clear picture of the main problems of sustainability of the city, confirming the impressions emerged from the Forum.

PadovA21 forum also decided to continue to use DS in future years to verify the accomplishment of the LAP and to monitor improvements of sustainability in the middle-long period. In the matter of the weights to be assigned to each indicator in the DS software, the Forum decided to organize appropriate meetings to discuss and decide in a shared manner.

In conclusion, the use of DS encouraged discussion and sharing inside the Forum and permitted the forum to recognize the importance of objective and synthetic tools to decide correctly.

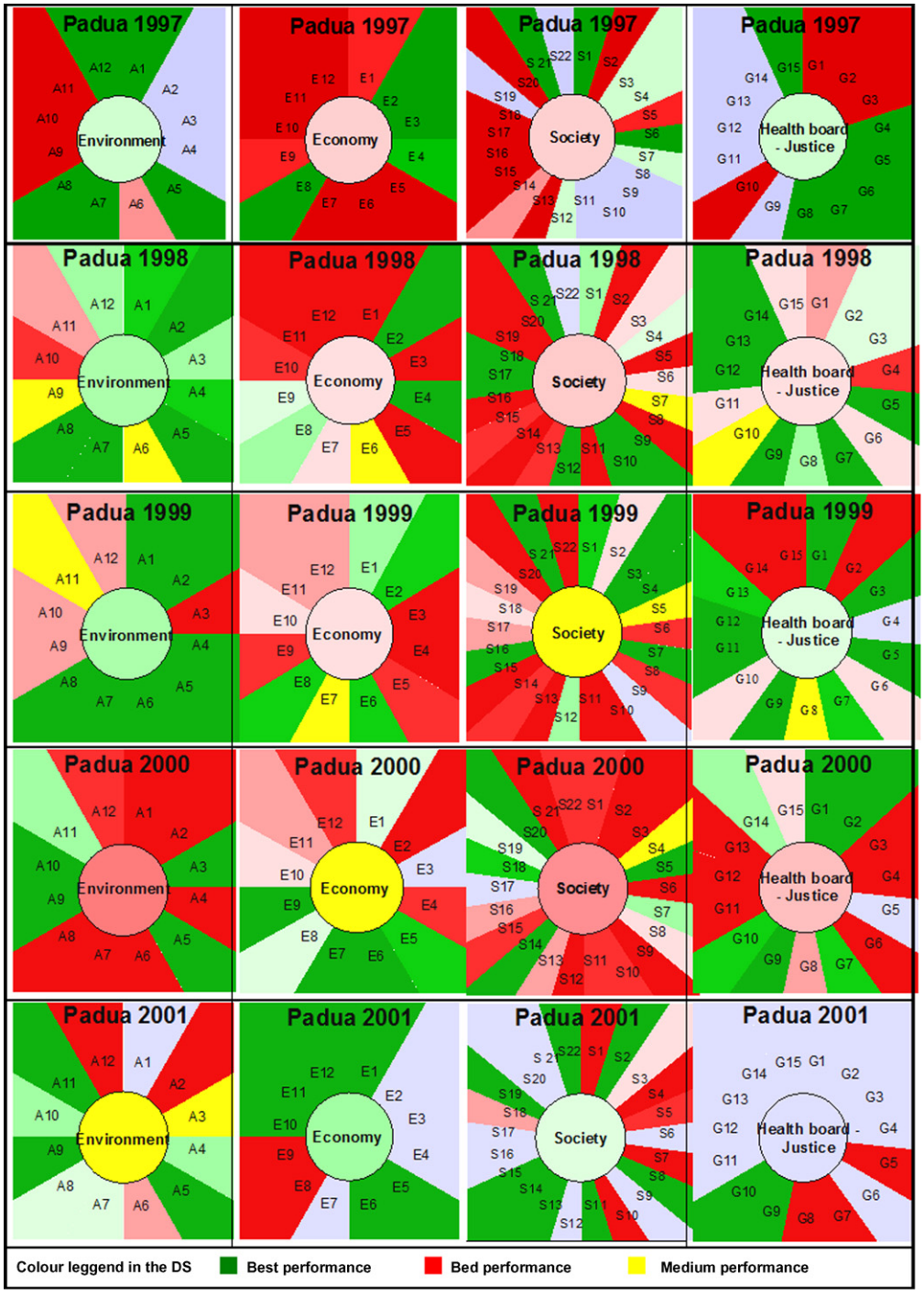

Fig. 2 – Graphical representation of the DS indicators for the Municipality of Padua (years 1997–2001).

6. Discussion

6.1. *Reliability and validity of the research*

The DS application can be analysed in terms of the reliability and effectiveness of its results. No special statistical techniques are needed for this experiment.

Note that the terms 'reliability' and 'effectiveness' assume a special meaning in the social sciences (Corbetta, 1999):

- A reliable result is reproducible under identical or equivalent starting data and measurement tools.
- Effectiveness concerns the degree to which an application's results correspond to their predetermined purpose. Effectiveness can refer either to the method (internal validity) or to the results obtained (external validity).

The reliability and validity (both internal and external) of the DS approach are easily confirmed. The calculation is linear, therefore similar circumstances will always lead to

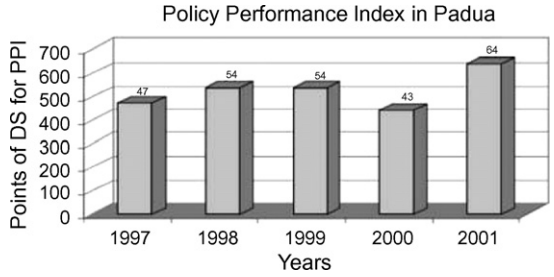

Fig. 3 – Bar chart of the PPI for Padua Municipality (years 1997–2001).

similar solutions. In addition, the DS software was applied to five independent datasets and always returned comparable results for both single indicators and the synthesized indexes.

The tool is reliable and valid in the case of Padua but may not be the same elsewhere. In fact, a single case study has been analysed. However, the results suggest its valid and reliable transferability.

6.2. *Criteria for discussion*

According to the objectives of the research, the discussion follows two main directions: the results are analysed and discussed depending on their capability to measure sustainability and to help sharing.

According to the standards set by the principal international organisms, a useful support tool has to both measure sustainability (by one indicator or a group of associated indicators) and accomplish certain actions in the LA21 process (Bossel, 1999; CEC, 2005).

A. An evaluation tool should fulfill the following criteria in order to be considered effective in measuring the urban sustainability:
   - Significance, sensitivity, and comparability. The tool should correctly describe the situation, indicate the direction in which the situation is evolving, and identify which characteristics have the greatest influence on the situation and its direction.
   - Synthesis, simplicity, and clarity. The tool should effectively communicate its evaluations and facilitate the transmission of information.
   - Feasibility, timeliness, and continuity. It should be possible to apply the method in a reasonable time and with reasonable costs. Useful results should be obtained rapidly, to allow for continuous monitoring.

B. An evaluation tool provides useful support to an LA21 process, if it accomplishes at least one of the following:
   - Description and analysis of the environmental, social, and economic needs of the context.
   - Quantifying and sharing the environmental, social, and economic conditions and the sustainability of the context, as well as determining the relative priority of intervention.
   - Aid in planning interventions with a mid- or long-range perspective.
   - Monitoring the progress and effectiveness of any actions undertaken.

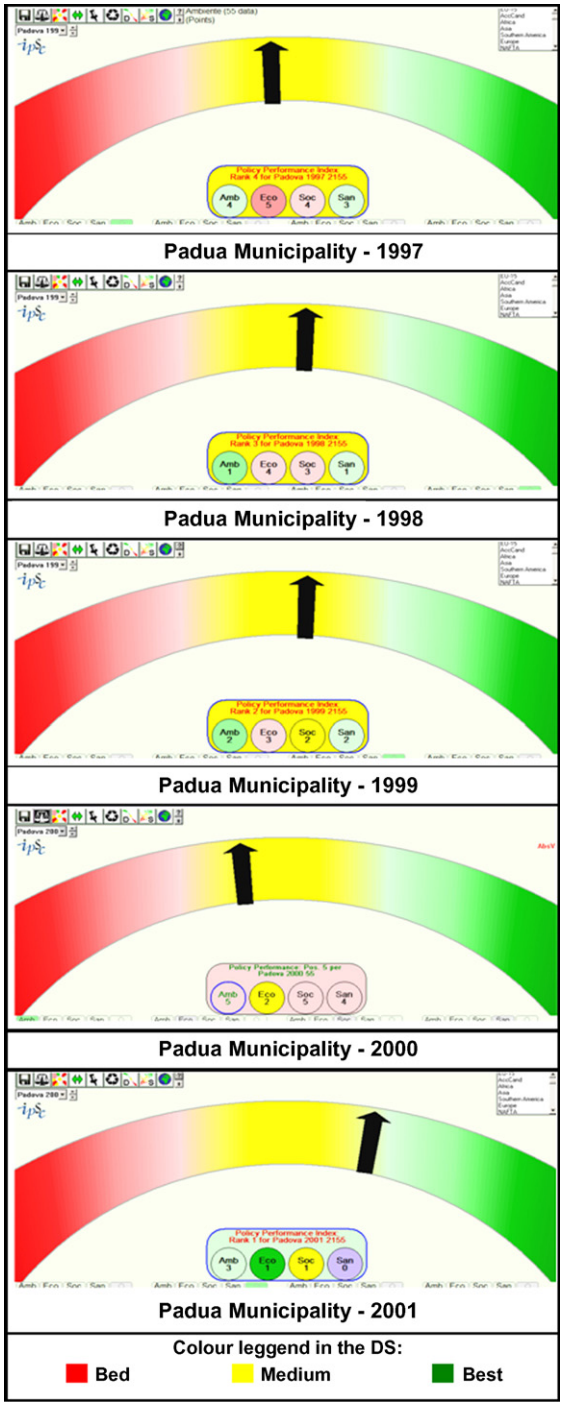

Fig. 4 – The Dashboard of Sustainability for Padua Municipality: overall results (years 1997–2001).

6.3. *Efficacy of the DS in measuring local context sustainability*

The DS proved to be a valid tool in measuring sustainability:

- The DS was built using indicators chosen by the municipality of Padua within its PadovA21 project. Therefore, it is able to give significant information.

- By using DS software, it was possible to investigate trends in sustainability of Padua Municipality over time, through single indicator and aggregated indexes.
- By using clear and concise indicators, the tool facilitates the comprehension of complex problems and the sharing of intervention priorities to experts and common citizens.
- The tool is of great visual impact. By using graphical synthesis it facilitates the sharing of problems and solutions within the PadovA21 forum.
- Thanks to the graphical and mathematical representation of indicators, useful evaluations are always and promptly available.

However, the adoption of the DS in the case of the Padua Municipality, points out some unresolved issues. These aspects must be considered when measuring local sustainability:

- the application of DS to a local urban context avoid a complete comprehension of the causal relationships between the different dimensions of sustainability. The structure of DS itself avoids this information;
- the availability and relevancy of the information depends on the availability of the data needed by the relative adopted indicators, and on the relevancy of the collected data and the adopted indicators.

The DS is effective in measuring urban local sustainability:

- The DS is flexible enough to analyze many indicators simultaneously.
- The DS permits meaningful, sensitive, and comparable evaluations of the sustainability over time, at least in a single examined case.
- The DS provides a concise, simple, and clear summary of the indicators and their trends. Its principle output is easily understood and shared.
- Thanks to the abundance of available data, the DS was able to provide a continuous history of sustainability performances.

6.4. *Usefulness of the DS within the LA21 process*

In the case of Padua, the DS proved to be capable of supporting the LA21 process:

- The DS allows an economic, environmental, and social analysis of the urban context. Through an over time comparison of the performances of the same context, it also evaluates this analysis.
- Through a clear and immediate communication of the sustainability evaluations, the DS facilitates the sharing process during the context analysis, the definition of priorities and the adoption of an LAP.
- Although it has not been directly experimented in the case of Padua, we infer that the DS can be a valid tool to assess the implementation of the planned actions and the effectiveness of the conducted interventions.

However, it is important to point out some features of such tools, which conditions its applicability and the gained results. These features must be considered when using DS as a support in the LA21 process:

- The effectiveness of the analysis conducted with the DS the of the relative evaluations is closely connected to the relevance, the pertinence, and the completeness of the chosen indicators: the case of Padua shows that the DS can be adapted to a local urban context if built on indicators chosen to be significant to the examined context.
- Results obtained using the DS are strongly influenced by the weight assigned to the different aspects evaluated; the definition of weights is a key issue when the DS is used.
- Adoption of medium-long term actions is not necessarily encouraged by the use of the DS, but solutions depend on the indicators chosen to build the DS.

The DS tool supports the LA21 process as it provides a detailed analysis of individual and collective aspects of sustainability, and can also be used to describe the results achieved over time.

7. Conclusions

The desire to propose an innovative theory of economic development, one consistent with the equilibrium of ecosystems and the promotion of human society, has found its home in the paradigm of sustainable development.

The international debate on sustainable development and its implementation has focused on the need for reliable measurements of sustainability. A valid evaluation tool must be able to provide an objective comparison of the sustainability in different contexts. In addition, a suitable indicator should be sensitive to changes in the economic, social, and environmental context. This allows research to comment on and possibly modify the political choices of the community. A few indicators in current use, however, are evenly spread among all the stakeholders of a region. Due to the complexity of long-term sustainability decisions, there is a strong need for evaluation tools that can integrate multidimensional conditions.

The DS is one such method. It is designed to fairly represent numerous data with complex relationships using a simple, integrated approach. It provides a mathematical and graphical synthesis of all the indicators relevant to the development, even in cases of conflicting data.

While the DS has mainly been used to describe the sustainability of national and international development, the PadovA21 project shows that it can also effectively evaluate sustainability in an urban context.

The success of Padua's experiment proves that the DS is an extremely flexible evaluation tool. After replacing the standard indicators with those appropriate to the context and available data, the DS was able to perfectly describe the specific characteristics of Padua's urban context. Note that other urban regions would probably have chosen a different set of indicators, because they represent the community's compromise between many competing priorities.

In this research, the DS was employed to identify trends in the sustainability performance of the municipality of Padua

itself. This approach may be contrasted with the traditional use of the DS to compare sustainability in different regions.

The tool again demonstrates its flexibility: it can be used to compare different context or the same context at several points in time.

The DS can be used to meet the need of finding measurement tools sensitive to the specific context and significant to evaluate the sustainability of local policies over time.

Another strength of the DS is its capacity to describe and compare factors influencing sustainability in detail. Trends can be identified in single indicators, in the synthesized index of several related indicators, and in the PPI.

From the experience of Padua, some limits emerge relatively in the application of DS at the urban scale.

First, the DS is effective in measuring sustainability in a local urban context only if the chosen indicators are relevant, appropriate, and give a complete description of the local sustainability and if the weights assigned to each indicator are consistent with the examined context. Therefore, the criteria used for the definition of the indicators and their weights are of extreme importance.

Another limit is the impossibility to conduct a comparative evaluation between the examined context and other similar contexts. This limit was overcome by using DS for a comparison of the same urban context at several points of time. The tool was used to compare the economic, environmental, and social performances of the considered context in different years. These are useful information to guide a local context towards sustainability. Anyway, they are still out of benchmarking opportunities with other contexts.

As a consequence, the DS can be adopted by local authorities in order to measure sustainability and facilitate sharing in the LA21 process. However, local authorities must be conscious of its limits. If such limits are considered not to invalidate the results, the DS can be used with efficacy.

The main conclusions drawn by this research may be summarized as follows, in the case of Padua. The DS can be applied to an urban context provided that the most important data are readily available. Its results are relevant to the urban context and can be used to investigate trends in sustainability and its indicators over time.

Furthermore, we have shown that the DS can support an LA21 process. In fact, it is coherent with the data requirements of the local context and are able to facilitate the analysis of problems and the sharing of solutions.

Thanks to these results, we can point out some future directions for this research.

In particular, it would be interesting to verify that Padua's experiences with the tool can be repeated in other urban contexts. These experiences could point out the transferability of the results, enable comparison of different regions and at least, from a methodological perspective, verify the validity of the proposition advanced at a general level.

By using the DS it would also be interesting to measure the sustainability of a local urban context for a longer time (e.g., some decades). In this case the local community policies are evaluated with more efficiency. In fact the development trends can be defined only in the medium-long term.

Than, it would be interesting to evaluate the long-term impact of the DS after the local sustainability policies it helped develop have been active for many years. This is the only way to find out whether the tool can maintain its effectiveness over time and continue its support of local A21 processes.

At the end, another possible direction to lead future researches might be the use of DS to compare results gained from an analysis, which uses ''bottom-up'' indicators (as the PadovA21 ones) with the results of an analysis which uses ''top-down'' ones (as did the project ''Ecosistema Urbano''). To apply this is necessary to use the same observation unit, the municipal contest or the district contest (remember that actually PadovA21 project used DS for the municipal territory while the project ''Ecosistema Urbano'' is referred to the territory of the district of Padua; at the moment it is impossible to compare top-down and bottom-up applications because they are not on the same territory), and the same arch of time (possibly longer than 5 years, because in this case the DS has been used to get sustainability judgments).

From the comparison might result an overall evaluation of sustainability different in the two cases (with different PPIs). The comparison might so proceed investigating the changes of sustainability evaluation for each indicator in the two cases (proceeding with the assumption of zero-weight for all indicators): this allowed to verify the influence of every indicator on the perception of sustainability in a local reality.

REFERENCES

ACI, annual redaction. Annuario Statistico e Autoritratto (Statistical Yearbook and Self-Portrait). Automobile Club Italia (ACI).

Alexander, G., 2000. Information-based tools for building community and sustainability. Future 32, 317–337.

Ambiente Italia, 2006/a. Ambiente Italia 2006 (Italy Environment 2006). Edizioni Ambiente Italia, Milano. http://www.ambienteitalia.it.

Ambiente Italia, 2006/b. L'indice di Legambiente a cura di Ambiente Italia che mostra la performance ambientale dei 103 capoluoghi di Provincia (Ecosistema Urbano: the index of ''Legambiente'' cured by Ambiente Italia which shows the enviromental performances of the 103 countryseats). Edizioni Ambiente Italia, Milano. http://esl.jrc.it/dc/index_IT.htm.

Ambiente Italia, 2008. annual redaction. Ecosistema Urbano: Rapporto annuale sulla qualità ambientale dei Comuni Capoluogo (Urban Eco-system: Year's Report on the environmental quality of Chief Towns). Edizioni Ambiente Italia, Milano.

Andrada II, R.T., Calderon, M.M., 2008. Sustainability Criteria and Indicators for the Makiling Botanic Gardens in Los Baños, Laguna, Philippines. An application of the CIFOR C&I toolbox. Ecological Indicators 8, 141–148.

Annan, K.A., 2002. The Secretary-General's Message on World Environment Day, June 5, 2002. United Nations, New York.

ARPAV, 2002. I° Rapporto sullo Stato dell'Ambiente a Padova (Ist Report on the Environmental Conditions of Padua). Comune di Padova, Padova. http://www.padovanet.it/infoambiente/padova21/rsa.htm.

Atkinson, G., Hamilton, K., 1996. Accounting for progress: indicators for sustainable development. Environment 38 (7), 16–20.

Beccali, G., Federico, G., Iadicola, G., Rizzo, G., Traverso, M., 2007. Integrated approach to the assessment of waste

management systems within SEA framework. International Journal of Environmental Technology and Management 7 (1–2), 68–84.
Bell, S., Morse, S., 1999. Sustainability Indicators: Measuring the Immeasurable. Earthscan, London.
Bell, S., Morse, S., 2001. Breaking through the Glass Ceiling: who really cares about sustainability indicators? Local Environment 6, 291–309.
Bell, S., Morse, S., 2003. Measuring Sustainability: Learning from Doing. Earthscan, London.
Becker, B., 1997. Sustainability Assessment: A Review of Values, Concepts and Methodological Approaches. World Bank Publication, Washington, DC.
Blinc, R., Zidanšek, A., Šlaus, I., 2006. Sustainable development after Johannesburg and Iraq: the global situation and the cases of Slovenia and Croatia. Energy 31, 2259–2268.
Böhringer, C., Jochem, P.E.P., 2007. Measuring the immeasurable—a survey of sustainability indices. Ecological Economics 63, 1–8.
Böhringer, C., Löschel, A., 2006. Computable general equilibrium models for sustainability impact assessment: status quo and prospects. Ecological Economics 60, 49–64.
Bossel, H., 1999. Indicators for Sustainable Development: Theory, Method, Applications. A Report to the Balaton Group. IISD Publications Centre, Ottawa.
Bouni, C., 1998. Sustainable development indicators: theory and methodology. Nature Sciences Sociétés 6 (3), 371–384.
Camagni, R., Capello, R., Nijkamp, P., 1998. Towards sustainable city policy: an economy, environment, technology nexus. Ecological Economics 124 (1), 103–118.
Capello, R., Nijkamp, P., 2002. In search of sustainable human settlements. Ecological Economics 40, 151–155.
CEC, 1990. Green Paper on the Urban Environment. Communication from the Commission to the Council and the Parliament, COM(90) 218 CEC, Commission of the European Communities, Bruxelles.
CEC, 1993. White Paper – Growth, Competitiveness, Employment: The Challenges and Ways Forward into the 21st Century. Communication from the Commission to the Council and the Parliament, COM(93) 700 def., Commission of the European Communities, Bruxelles.
CEC, 1997. Towards an urban agenda in the European Union. Communication from the Commission to the Council and the Parliament, COM(97) 197 CEC, Commission of the European Communities, Bruxelles.
CEC, 2005, Sustainable Development Indicators to monitor the implementation of the EU Sustainable Development Strategy. Communication from Mr. Alumnia to the Commission, SEC(2005) 161 final CEC, Commission of the European Communities, Bruxelles.
Corbetta, P.G., 1999. Metodologia e Tecniche della Ricerca Sociale (Methodology and Methods of the Social Research). Il Mulino, Bologna.
Corbiere-Nicollier, T., Ferrari, Y., Jemelin, C., Jolliet, O., 2003. Assessing sustainability: an assessment framework to evaluate Agenda 21 actions at the local level. International Journal of Sustainable Development and World Ecology 10, 225–237.
Custance, J., Hillier, H., 1998. Statistical issues in developing indicators of sustainable development. Journal of the Royal Statistical Society, Series A 161 (3), 281–290.
Darren, A.S., Pinter, L., Bregha, F., Volkery, A., Jacob, K., 2004. National Strategies for Sustainable Development: Challenges, Approaches and Innovations in Strategic and Co-ordinated Action. IISD Publications Centre, Ottawa.
Devraj, R., 2002. Internet Deshboard Device for Navigating Development. Terra Viva, World Social Forum, Porto Alegre, January 31–February 5.
Distaso, A., 2007. Well-being and/or quality of life in EU countries through a multidimensional index of sustainability. Ecological Economics 64, 163–180.
Dommen, E., 1993. Far Principles for Sustainable Development. Essays on Environmental Policy and Developing Countries. Edwar Elgar Publishing, Aldershot.
Dovers, S.R., 1997. Sustainability: demands on policy. Journal of Public Policy 16, 303–318.
EC, 1992. Treaty on European Union and Treaty Establishing the European Community. European Commission, Maastricht http://eur-lex.europa.eu/LexUriServ/site/en/oj/2006/ce321/ce32120061229en00010331.pdf.
EC, 1996. European Sustainable Cities. Export Group on the Urban Environment, EC—DG XI ''Environment, Nuclear Safety & Civil Protection'', European Commission, Brussels.
EC, 2000/a. Charter of Fundamental Rights of the European Union. The European Parliament, the Council and the Commission, 2000/C 364/01, Nizza. http://www.europarl.eu.int/charter/pdf/text_en.pdf.
EC, 2000/b. Towards a local sustainability profile: European common indicators—Technical Report. Working Group on measuring, monitoring and evaluation in local sustainability, Expert Group on the urban environment, Office for Official Publication of the European Communities.
EC, 2001. A Sustainable Europe for a Better World: A European Union Strategy for Sustainable Development. Communication from the Commission to the Council and the Parliament, COM(2001) 264, European Commission, Bruxelles.
EFILWC, 2003. Monitoring quality of life in Europe—Report. European Foundation for the Improvement of Living and Working Conditions, Office for Official Publications of the European Communities, Luxembourg.
Egger, S., 2006. Determining a sustainable city model. Environmental Modelling & Software 21, 1235–1246.
ESCTC, 2000. Indicators Adoption Agreement. European Sustainable Cities & Towns Campaign, Hannover.
Flood, J., 1997. Urban and housing indicators. Urban Studies 34, 1635–1666.
Fraser, E., 2002. Urban ecology in Bangkok, Thailand: Community participation, urban agriculture and forestry. Environments 30 (1), 37–49.
Fraser, E.D.G., Dougill, A.J., Mabee, W.E., Reed, M., McAlpine, P., 2006. Bottom up and top down: Analysis of participatory processes for sustainability indicator identification as a pathway to community empowerment and sustainable environmental management. Journal of Environmental Management 78, 114–127.
Gagliardi, F., Roscia, M., Lazaroiu, G., 2007. Evaluation of sustainability of a city through fuzzy logic. Energy 32, 795–802.
Giaoutzi, M., Nijkamp, P., 1993. Decision Support Models For Sustainable Development. Avebury, Aldershot.
Glenn, J.C., Gordon, T.J., 2006. Update on the State of the Future: environmental sustainability, global partnership against terror, technology, and drug availability figure in humanity's future. The Futurist 40 (1), 20.
Hardi, P., Zdan, T. (Eds.), 1997. Assessing Sustainable Development: Principle in Practice. International Institute for Sustainable Development, Winnipeg.
Hardi, P., DeSouza-Huletey, J.A., 2000. Issues in analyzing data and indicators for sustainable development. Ecological Modelling 130, 59–65.
Hardi, P., Semple, P., 2000. The Dashboard of Sustainability: from a metaphor to an operationale set of indices. In: Fifth International Conference on Social Science Methodology, Cologne.
Hardi, P., Jesinghaus, J., O'Connor, J., 2002. The Dashboard of Sustainability: a measurement and communication tool. In:

Ninth Session of the Commission on Sustainable Development, 16–27 April. New York. UNCSD, New York.
Harger, J.R.E., Meyer, F.M., 1996. Definition of indicators for environmentally sustainable development. Chemosphere 33 (9), 1749–1775.
Hezri, A.A., 2004. Sustainability indicator system and policy processes in Malaysia: a framework for utilisation and learning. Journal of Environmental Management 73, 357–371.
Hezri, A.A., Dovers, S.R., 2006. Sustainability indicators, policy and governance: issues for ecological economics. Ecological Economics 60, 86–99.
Herzi, A.A., Nordin Hasan, M., 2004. Management framework for sustainable development indicators in the State of Selangor, Malaysia. Ecological Indicators 4, 287–304.
Heuting, R., Rejinders, L., 2004. Broad sustainability contra sustainability: the proper construction of sustainability indicators. Ecological Economics 50, 249–260.
Holden, M., 2006. Urban indicators and the integrative ideals of cities. Cities 23 (3), 170–183.
Hukkinen, J., 2003. From groundless universalism to grounded generalism: improving ecological economic indicators of human–environmental interaction. Ecological Economics 44, 11–27.
ICLEI, 1994. Charter of European Cities & Towns Towards Sustainability—The Aalborg Charter. International Council for Local Environmental Initiatives, Aalborg.
ICLEI, 1995. European Local Agenda 21 Planning Guide—How to Engage in Long-term Environmental Action Planning Towards Sustainability? ICLEI Publication, Policy & Practice Series, ICLEI European Secretariat, Freiburg.
ICLEI, UNDPCSD, 1997. Local Agenda 21 Survey—A Study of Responses by Local Authorities and Their National and International Associations to Agenda 21. International Council for Local Environmental Initiatives in cooperation with United Nations Department for Policy Coordination and Sustainable Development.
IISD, 1999. Beyond Delusion: A Science and Policy Dialogue on Designing Effective Indicators for Sustainable Development. International Institute for Sustainable Development, IISD Publications Centre, Ottawa.
IISD, 2000. Compendium of Sustainable Development Indicator Initiatives and Publications. International Institute for Sustainable Development, http://www.iisd.org.
IISD, 2001. The Dashboard of Sustainability: A Measurement and Communication Tool, in: IISD (Eds), Earth Negotiations Bulletin, A Reporting Service for Environment and Development Negotiations. International Institute for Sustainable Development, IISD Publications Centre, Ottawa, vol. 5, No. 179, Tuesday 24 April 2001, Things to look for today—Side event.
IISD, 2002. The Dashboard of Sustainability: The measure of Progress, Measurement and Indicators Brochure. IISD Publications Centre, Ottawa.
Innes, J.E., Booher, D.E., 1999. Indicators for Sustainable Communities: A Strategy Building on Complexity Theory and Distributed Intelligence. Institute of Urban and Regional Development, University of California, Berkeley (Working Paper 99-04).
Jesinghaus, J., 1999. Indicators for Decision Making. European Commission, Ispra. , In: http://esl.jrc.it/envind/idm/idm_e_.htm.
Jesinghaus, J., Hardi, P., 2002. Doshboard of sustainability: Indicator guidance to the 21st century. IISD Earth Negotiations Bulletin (ENB), ENB on the site, August 30, 2002. http://www.iisd.ca/2002/wssd/enbots.
Jollands, N., Harmsworth, G., 2007. Participation of indigenous groups in sustainable development monitoring: Rationale and examples from New Zealand. Ecological Economics 62, 716–726.
JRC, 2007. The Dashboard online collection. Joint Research Center. http://esl.jrc.it/dc/dc.htm.
Känkinen, K., Oras, K., 2004. 2004 Edition of the UN CSD Dashboard for Europe. Statistical Office of Estonia, Tallinn. , In: http://www.stat.ee/dashboard.
Kates, R.W., Clark, W.C., Corell, R., Hall, M.J., Jaeger, C.C., et al., 2001. Sustainability science. Science 292, 641–642.
King, C., Gunton, J., Freebairn, D., Coutts, J., Webb, I., 2000. The sustainability indicator industry: where to from here? A focus group study to explore the potential of farmer participation in the development of indicators. Australian Journal of Experimental Agriculture 40, 631–642.
Kirdar, U., 1997. Cities Fit For People. United Nation Publications, New York.
Kratena, K., 2004. Ecological value added in an integrated ecosystem–economy model. An indicator for sustainability. Ecological Economics 48, 189–200.
Lee, Y.J., Huang, C.M., 2007. Sustainability index for Taipei. Environmental Impact Assessment Review 27, 505–521.
Lindholm, O., Greatorex, J.M., Paruch, A.M., 2007. Comparison of methods for calculation o sustainability indices for alternative sewerage systems—Theoretical and practical considerations. Ecological Indicators 7, 71–78.
Lindholm, O., Nordeide, T., 2000. Relevance of some criteria for sustainability in a project for disconnecting of storm runoff. Environmental Impact Assessment Review 20 (3), 413–1413.
Meadows, D.H., Meadows, D.L., Randers, J., Beherens III, W.W., 1972. The Limits of Growth. Pen Books, London.
Mickwitz, P., Melanen, M., Rosenström, U., Seppäla, J., 2006. Regional eco-efficiency indicators—a participatory approach. Journal of Cleaner Production 14, 1603–1611.
Morse, S., Fraser, E.D.G., 2005. Making 'dirty' nations look clean? The nation state and the problem of selecting and weighting indices as tools for measuring progress towards sustainability. Geoforum 36, 625–640.
Morse, S., McNamara, N., Acholo, M., Okwoli, B., 2001. Sustainability indicators: the problem of integration. Sustainable Development 9, 1–15.
Munasinghe, M., McNeely, J., 1995. Key concepts and terminology of sustainable development. In: Munasinghe, M., Shearer, W. (Eds.), Defining and Measuring Sustainability. The World Bank, Washington, pp. 19–56.
Nardo, M., Saisana, M., Saltelli, A., Tarantola, S., 2005. Tools for Composite Indicators Building. European Comission, Ispra.
Ness, B., Urbel-Piirsalua, E., Anderbergd, S., Olssona, L., 2007. Categorising tools for sustainability assessment. Ecological Economics 60, 498–508.
Nijkamp, P., Vreeker, R., 2000. Sustainability assessment of development scenarios: methodology and application to Thailand. Ecological Economics 33, 7–27.
O'Connor, J., Jesinghaus, J., 2002. Data from the Rio to Johannesburg Dashboard of Sustainability. Software tool distributed at the 2002 World Summit on Sustainable Development in Johannesburg, South Africa.
OECD, 1994. Environmental Indicators. Organisation for Economic Cooperation and Development, Paris.
OECD, 2001. OECD Environmental Indicators. Towards Sustainable Development. Organisation for Economic Cooperation and Development, Paris.
OECD, 2002. EU Member States experiences with sustainable development indicators. OECD World Forum on Key Indicators, Statistics, Knowledge and Policy, November 10–13, Palermo. Organisation for Economic Cooperation and Development, Paris.
Olewiler, N., 2006. Environmental sustainability for urban areas: the role of natural capital indicators. Cities 23 (3), 184–195.
Padua Municipality, 1998. Profilo della Salute della Città (City Health Profile), Comune di Padova, Progetto Città Sane, Padova.

Padua Municipality, 20 February 2001a. Bando per il finanziamento di programmi di sviluppo sostenibile e di attuazione di Agenda21 Locale—approvazione del progetto ''Padova sostenibile'' (Call for funds for sustainable development programs and Local Agenda21 actions—approval of project ''Sustainable Padua''). Comune di Padova, Deliberazione di Giunta Comunale n.70, Padova.
Padua Municipality, 2001b. Progetto Agenda 21 Locale: ''Padova Sostenibile, PadovA21'' (Local Agenda 21 Project: ''Sustainable Padua, PadovA21''). Comune di Padova, Assessorato all'Ambiente, Settore Pianificazione Urbanistica Ambiente, Servizio Ambiente, Padova.
Padua Municipality, 2001c. Regolamento del Forum Agenda 21 Locale del Comune di Padova (Rules of Local Agenda 21 Forum in Padua Municipality). Comune di Padova, Padova.
Padua Municipality, 2002. Newsletter Dicembre 2002. Foglio di informazione del progetto PadovA21 (Newsletter December 2002. PadovA21 project informative sheet). Comune di Padova, Padova.
Padua Municipality, 2003a. Annuario statistico 2002 (Statistical Yearbook 2002). Sistema statistico nazionale, Comune di Padova, Settore di programmazione controllo e statistica, Padova.
Padua Municipality, 2003b. Piano d'Azione Locale del Comune di Padova (Local Action Plan of the Padua Municipality). Comune di Padova, Progetto PadovA21, Padova.
Padua Municipality, 2003c. Newsletter Febbraio 2003. Foglio di informazione del progetto PadovA21 (Newsletter February 2003. PadovA21 project informative sheet). Comune di Padova, Padova.
Padua Municipality, annual redaction. Bollettino statistico (Statistical bulletin). Sistema statistico nazionale, Comune di Padova, Settore di programmazione controllo e statistica, Padova.
Parris, T.M., Kates, R.W., 2003. Characterizing and measuring sustainable development. Annual Review of Environment and Resources 28, 559–586.
Pinfield, G., 1996. Beyond sustainability indicators. Local Environment 1 (2), 151–163.
Pulselli, F.M., Ciampalini, F., Tiezzi, E., Zappia, C., 2006. The index of sustainable economic welfare (ISEW) for a local authority: A case study in Italy. Ecological Economics 60, 271–281.
Reed, M.S., Fraser, E.D.G., Dougill, A.J., 2006. An adaptive learning process for developing and applying sustainability indicators with local communities. Ecological Economics 59, 406–418.
Riley, J., 2001. Multidisciplinary indicators of impact and change: key issues for identification and summary. Agriculture, Ecosystems & Environment 87, 245–259.
Rogers, M., Ryan, R., 2001. The triple bottom line for sustainable community development. Local Environment 6, 279–289.
Rosenström, U., Kyllönen, S., 2007. Impacts of a participatory approach to developing national level sustainable development indicators in Finland. Journal of Environmental Management 84, 282–298.
Rydin, Y., 2004. Governmentality and sustainability indicators: a good conceptual fit? In: Background paper to the PEER conference: use of indicators for sustainability, 17–18 November, Helsinki, Finland.
Scipioni, A., Mazzi, A., 2003. Osservatorio sulla Qualità della Vita a Padova, Manuale degli Indicatori (Observatory on the Quality of Life in Padua. The Indicators Handbook) Università degli Studi di Padova - Centro Studi Qualità Ambiente and Comune di Padova - Settore Ambiente, Padova.
Scipioni, A., Mazzi, A., Zuliani, F., Mason, M., 2008. The ISO 14031 standard to guide the urban sustainability measurement process: an Italian experience. Journal of Cleaner Production 16, 1247–1257.
SOE, 2004. Indicators of Sustainable Development. Statistical Office of Estonia, Tallinn. http://www.stat.ee/files/eva2004/KK200401.pdf.
SustainLane, 2006. The SustainLane 2006, US City Rankings. SustainLane, San Francisco, CA. http://www.sustainlane.com/us-city-rankings/.
Tárraga, O., Ángel, M., 2006. A conceptual framework to assess sustainability in urban ecosystems. International Journal of Sustainable Development and World Energy 13 (1), 1–15.
Tsenkova, S., 1999. Sustainable Urban Development in Europe: Myth or Reality? Joint Editors and Blackwell Publishers Ltd, Blackwell Publishers, pp. 361–364.
ULSS 16, 2008. annual redaction. Relazione annuale dell'unità Socio-Sanitaria Locale ULSS 16 (Year's report of the Social-Health local unit ULSS16). Unità Locale Socio-Sanitaria n° 16, Regione Veneto.
UN, 1992a, Agenda 21, United Nations, General Assembly, Rio de Janeiro. http://www.un.org/esa/sustdev/documents/agenda21/english/agenda21toc.htm.
UN, 1992b, Rio Declaration on Environment and Development, United Nations, General Assembly, Rio de Janeiro. http://www.un.org/documents/ga/conf151/aconf15126-1annex1.htm.
UN, 1996. Indicators of Sustainable Development. Framework and Methodologies. United Nations, New York.
UN, 2001. Indicators of Sustainable Development. Guidelines and Methodologies. United Nations, New York.
UN DESA, 2002. WSSD Plan of Implementation. United Nations Department of Economic and Social Affairs. http://www.un.org/esa/sustdev/documents/WSSD_POI_PD/English/POIToc.htm.
UN, EC, IMF, OECD and WB (Eds), 2003. Handbook of National Accounting—Integrated Environmental and Economic Accounting. Studies in Methods, Series F, No. 61, Rev.1. United Nations, New York.
UNCED, 1992. A Statement on Behalf of UK Local Government. United Nations Conference on Environment and Development, Local Government Management Board.
UNCHS, 1996. Habitat Agenda. United Nations Organization, Conference on Human Settlements (Habitat II), Istanbul. http://www.unhabitat.org/declarations/habitat_agenda.asp.
UNCHS, 2001. The State of the Worlds Cities 2001. UN, United Nations Centre for Human Settlements, Nairobi.
UNCSD, 2001. Indicators of sustainable development: framework and methodologies. United Nations Commission on Sustainable Development.
UNDP, 2001. Human Development Report. United Nations Development Program, New York. http://hdr.undp.org/reports/global/2001/en/.
UNDP, 2005. Human Development Report 2005. United Nations Development Programme. Oxford University Press, Oxford.
UNEP, 2000. Integrated Environmental and Economic Accounting—An Operational Manual. United Nations Environmental Programme. Oxford University Press, Oxford.
UNESCO, 1995. The Cultural Dimension of Development. Towards a Practical Approach. United Nations Educational Scientific and Cultural Organization. UNESCO Publishing, Paris.
UNESCO, 2006. Indicators of Sustainability, Reliable tools for Decision Making. UNESCO Scope Policy Briefs May (1) United Nations Educational, Scientific and Cultural Organization, UNESCO Publishing, Paris.
Valentin, A., Spangenberg, J.H., 2000. A guide to community sustainability indicators. Environmental Impact Assessment Review 20, 381–392.
Valentinelli, A., 2001. Most frequently used urban indicators. http://esl.jrc.it/dc/urban_indicators.htm.

van Kamp, I., Leidelmeijer, K., Marsman, G., de Hollander, A., 2003. Urban environmental quality and human well-being. Towards a conceptual framework and demarcation of concepts; a literature study. Landascape and Urban Planning 65, 5–18.

Walter, G.R., Wilkerson, O., 1998. Community sustainability auditing. Journal of Environmental Planning and Management 41, 673–682.

WB, 1995. Monitoring Environmental Progress. World Bank Publication, Washington, DC.

WB, 2003. World Bank Report 2003, Sustainable Development in a Dynamic World: Transforming Institutions, Growth and Quality of Life. The World Bank and Oxford University Press, Washington, DC.

WB, 2005. The Little Green Databook 2005. World Bank Publication, Washington, DC.

WCED, 1987. Our Common Future. World Commission on Environment and Development.

WCS, UNEP, WWF, 1991. World conservation strategy: a strategy for sustainable living. World Conservation Strategy, United Nations Environment Programme, World Wide Fund for Nature.

Wen, Z., Zhang, K., Du, B., Li, Y., Li, W., 2007. Case study on the use of genuine progress indicator to measure urban economic welfare in China. Ecological Economics 63, 463–475.

While, A., Jonas, A.E.G., Gibbs, D., 2004. The Environment and the Entrepreneurial City: searching for the Urban 'Sustainability Fix' in Manchester and Leeds. International Journal of Urban and Regional Research 28 (3), 549–569.

Wiek, A., Binder, C., 2005. Solution spaces for decision-making—a sustainability assessment tool for city-regions. Environmental Impact Assessment Review 25, 589–608.

Wilson, J., Tyedmers, P., Pelot, R., 2007. Contrasting and comparing sustainable development indicator metrics. Ecological Indicators 7, 299–314.

Xu, F.L., Zhao, S.S., Dawson, R.W., Hao, J.Y., Zhang, Y., Tao, S., 2006. A triangle model for evaluating the sustainability status and trends of economic development. Ecological Modelling 195, 327–337.

Yuan, W., James, P., Hodgson, K., Hutchinson, S.M., Shi, C., 2003. Development of sustainability indicators by communities in China: a case study of Chongming County, Shanghai. Journal of Environmental Management 68, 253–261.

Zhang, Y., Yang, Z., Yu, X., 2006. Measurement and evaluation of interactions in complex urban ecosystem. Ecological Modelling 196, 77–89.