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DEVELOPMENT OF A MULTRICRITERIA INDICATOR OF VIRTUOSITY IN WASTE MANAGEMENT ADDRESSED TO LOCAL AUTHORITIES

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Abstract

As the percentage of segregated waste, taken as individual indicator, is insufficient to measure the virtuosity of a Municipality waste management, a multicriteria indicator has been developed to broaden the horizon of the analysis of waste management performance. The aim of this study is to experiment a new and easy–to-use methodology for the evaluation of Municipalities virtuosity in waste management, built from Public Administrators to verify the responsiveness between their ideal guidelines and their real applications. The identified criteria are eight: percentage of segregated waste collection, production of unsorted waste per capita, total production of waste per capita, service costs, environmental impact of the waste collection and treatment system, traceability of Municipal Solid Waste's fate, involvement of population, citizen's convenience. Scores given to each criterion were assigned by experts in each field and then normalized [0-1]; weights were determined applying Pairwise Comparison method to Public Administrators of municipalities selected as a case study. For each Municipality, a score for each criterion is assigned and, subsequently, multiplied by the weight given to the criterion itself. The indicator provides a wide spectrum analysis, marking the state of the art, the scope for improvement and deficiencies of each area of analysis; thus to become an effective decision support tool for Administrations. This tool was, applied to a case study, returning results in terms of virtuosity far different from those obtained in terms of percentage of recycled waste alone, thus highlighting the importance of a multidisciplinary approach to the issue.

Key words: Analitic Hierarcy Process, involvement of population, Multi-Criteria Decision Analysis, Municipal Solid Waste Management, Pairwise Comparison

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1. Introduction

The percentage of segregated collection is the only indicator of virtuosity in waste management applied to municipalities so far in order to check their performance. This measurement, however, is incomplete (Matei and Ungureanu, 2014; Simion, 2013): it is now known that, beyond the percentage of segregated collection, other conditions could define the virtuosity of a waste collection system (Simion et al., 2014), for example the amount of waste products, the cost applied for the service or the environmental impact generated by the waste collection and treatment. In the present study were collected these and other criteria relevant to the overall performance assessment of a municipality with respect to the production, collection and treatment of waste, in order to build a more complete analysis of virtuosity of local authorities in waste management. The indicator is proposed with two objectives: first, being a multi criteria indicator, overcoming the contradictions and partiality of the measure of the percentage of segregated collection alone; secondly, providing municipal government

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with a tool to address their investments in the improvement of the waste management system more effectively, in order to reach the European strategic objectives in waste management (Sarkady et al., 2013a, 2013b).

The methodology selected was the Analytic Hierarchy Process, a multi criteria decision analysis method already used in waste management field (Kim et al., 2013; Pires et al., 2011; Soltani et al., 2015). In this study a different perspective is outlined: the target of the Analytic Hierarchy Process is not finding the best alternative, but only giving an evaluation to the Municipalities involved, in order to put in evidence their strengths and weaknesses compared to the theoretical guidelines they give themselves.

Thus resulting in a decision support tool built on the results of the analysis. Another novelty is that the case study Municipalities were directly involved in building the scores and weights system to be applied to the criteria: they were asked to express their point of view on the basis of their decision criteria on which they base their policies. This indicator is built by Municipalities for Municipalities.

The aim of this study is to develop a new methodology for the evaluation of Municipalities virtuosity in waste management: for this reason the focus of the paper is on the building of the indicator, while its application on the case study is summarized as an example, in order to give an idea of the potentiality of this methodology.

The Analytic Hierarchy Process is defined as follows: the goal is the numeric evaluation of the virtuosity of a Municipality; the criteria of evaluation are eight and they were chosen from a pre-selection performed by the authors, in order to evaluate all the main issues connected with waste management, and then they were re-defined by the Municipalities in order to meet the needs of verification of local authorities; finally the alternatives are eight Municipalities of the case study. They were chosen because of their organisation: not only they form a formal Union, but also they organized Municipal Waste collection as a "Smart Area", with the same management and different options of application for all the eight Municipalities.

The indicator of virtuosity was built in relation to the case study of the territory of the Unione Terre di Castelli, a union of eight municipalities of small and medium size, with a total population of about 82 000 inhabitants in a territory extended over an area total of 312.15 km² in the Province of Modena, Emilia-Romagna, in Italy. The involvement of local stakeholders in the definition (including mathematics) of the evaluation model represents a strong element of novelty: service managers, mayors and local administrators, municipal technicians, universities, experts from the sectors involved, associations, and citizens contributed to define the structure of this indicator of virtuosity. These subjects and mayors in particular, were chosen for their public role of decision-makers and they were asked to assess the weights to be assigned to different criteria.

The proposed methodology for the allocation of weights is the Pairwise Comparison (Saaty, 1980), which allows decomposing a multi-dimensional problem in a number of two-dimensional problems and, through a simple matrix calculation, to obtain the weights attributed to each indicator.

Therefore, the virtuosity indicator was applied to the eight municipalities of the case study, showing for each performance for each criterion, and the overall result, how the various management decisions affect the virtuosity of waste management. Finally, the virtuosity indicator proved to be an effective decision support tool, able to mark the state of the art, as well as the scope for improvement and deficiencies in each area of analysis.

2. Materials and methods

The study started with the identification of eight criteria constituting the virtuosity indicator: percentage of waste collection, production of mixed waste per capita, production per capita of total waste, service costs, and environmental impact of the system of waste collection and treatment, traceability of municipal waste fate, involvement of population, citizen's convenience. They were chosen in reference to the environmental, economic and social aspects to promote a systemic approach to the issue of waste

The creation of an indicator of virtuosity has gone through three main phases: deepening of environmental and management aspects associated with waste management and criteria selection; construction of the indicator of virtuosity, with criteria scoring and weighting; application of the virtuosity indicator to the case study.

The evaluation of virtuosity for Municipalities is performed by adding the scores obtained for each criterion, multiplied by the weights assigned to the criteria themselves. The development of the indicator continues with the normalization of the scores given to the criteria, carried out through interviews with key figures in each field, in order to turn these indicators making them dimensionless variables, with values in the range [0-1]. The 0-1 scale was selected because it allows a very simple normalization and convenient calculation of the scores, both in the phase of score definition and in the phase of calculation of the score reached by each Municipality for each criterion.

For the first four criteria, which were not dimensionless, an appropriate utility function was established, requiring interviewed people to assign a score from 0 to 1 to several possible values for each criterion. Through a regression curve were, then, built utility functions that associate univocally a score between 0 and 1 to each value of the criterion. The weighting of the criteria concludes the construction of the indicator. Mayors and directors of the eight municipalities of the case study were interviewed, chosen for their public role of decision-

makers and proficiency in multi-disciplinary analysis. They were then asked to assess the weights to be assigned not just referring to their town, but providing a universal perspective, representative of their ideal priority scale. The proposed methodology for the allocation of weights is the Pairwise Comparison (Saaty, 1980), which allows to decompose a multi-dimensional problem in a number of two-dimensional problems and, through a simple matrix calculation, to obtain the weights attributed by interviewees to each indicator.

The method consists in comparing all possible pairs of criteria by assigning a numerical judgment of relative virtuosity among the criteria considered, according to the scale proposed in "Analytic Hierarcy Fundamental Process Scale for Pairwise Comparison", and then on through a matrix calculation to the exact definition of the weights assigned. Pairwise Comparison was chosen instead of other methodologies (such as Ranking or Rating Analysis), because it ensures a more consistent weight distribution related to interviewee's response, thanks to its mathematical approach. It also allows to measure distance between subsequent choices and the difficulty of responding to the interview does not increase with increasing choices.

In conclusion, the virtuosity indicator was applied to the eight municipalities of the case study, showing for each community, the performance for each criterion and the overall result. In this way, it becomes evident how the various management decisions affect the virtuosity performance of waste management and finally making it an effective decision support tool for waste management, being able to mark the state of the art, as well as the scope for improvement and deficiencies in each area of analysis. The criteria included into virtuosity indicator were:

1) Percentage of segregated waste collected [%SC]: it is obtained, following EU regulation, as the ratio of the sum of the weights of the fractions collected separately, considering both those intended to recovered and those to be disposed, and the total amount of municipal solid waste produced.

*2) Unsorted waste [kg/(ab*y)]:* it provides an indication of the ability of citizens in reducing the more impactful fraction of waste (to be disposed of in landfills or by incineration).

*3) Total waste produced per citizen [kg/(ab*y)]:* used to measure the virtuosity in reducing the overall quantity of waste.

4) Service costs [€ per capita]: it is intended as an administrative indicator, since, with the same environmental performance, the Municipality that uses less economic resource for waste management, freeing cash for other interventions, should be considered the most virtuous. It has been frequently shown that once reached percentages of segregated collection close to 65-70%, reaching higher goals involves a considerable economic effort.

It is believed that a careful administrator should ask what environmental benefit could be gained from further investments in other areas of prevention from environmental damage, such as water management, the insulation of buildings, energy production from renewable sources, the mitigation of the effects of climate change, sustainable mobility etc.

5) Environmental impact of the service: several studies show how different waste management systems produce different impacts in terms of different pollutant emissions (Marini, 2010), or of ecological footprint (Simion et al., 2013). In addition to this, the intended final fate of the waste produces different impacts on the ecosystem: to dispose a waste in landfill, incinerator or recycle it evidently produces significantly different impacts. This indicator has to be taken into account as part of an integrated environmental approach.

6) Waste fate traceability: The presence of a system of traceability of waste allows precise control of the waste fate, promoting proper disposal of waste, checking for any areas of inefficiency and making punctual communications for any difficulties in service. A traceability system allows also making the whole chain of waste management transparent.

7) Involvement of population: it takes into consideration the participation of users and the stimulus that the local administration can give in terms of political awareness and prevention of waste. National experience shows how some governments, while providing citizens with an integrated waste management service and information on how to use it, they do not share with citizens the reasons behind the legislator's requirements.

Thus leaving behind the information related to the environmental issues and the benefits that may result from a more virtuous and effective segregated collection and waste reduction. This criterion therefore takes into account the training proposed to citizens on waste and more generally on environmental issues; then consider actions taken for the prevention of waste and the ability of public administrator in engaging their citizens in the strategic choices of waste management.

8) Convenience for the citizen: the possibility to dispose of waste with the maximum flexibility during the week is a criterion which many citizens take into account. This criterion, however, evaluates even the maximum predicted distance for waste disposal, with the awareness that in most unfavorable territories (such as mountains, or in the presence of a widespread urbanization) the distance to travel to get rid of the waste produced can be crucial in participation of the population to the segregated collection.

The administration that mostly meets the proximity request was accounted to deserve the highest score in this criterion.

3. Experimental

The construction of the indicator was performed in two stages: normalization of scores and

weighting of criteria.

Normalization of scores: in order to compare the above criteria, which are mutually independent and characterized by different units of measure, it is necessary the introduction of the utility functions (FU) to transform these indicators so that the dimensionless variables take values in the interval [0-1].

The definition of the utility functions is independent from the alternative collection systems commonly applied (dumpsters or curbside collection). In order to achieve this goal, the first step taken was an interview with different specialists of the issues involved by different criteria, asked to attach a judgment with respect to certain values verified or verifiable for that indicator. The opinion was expressed in numerical form by an assignment of utilities between 0 and 1, depending on the sensitivity of each respondent. With regression mathematic methods was then assigned an analytic function to each criterion that matches utility values with opinions expressed. For dimensionless criteria, experts were asked to assign scores between 0 and 1 to identified actions replicable by municipality and the sum is always equal to 1.

Identified "countable criteria", i.e. criteria with unambiguous units, are the percentage of segregated waste collected, the amount of unsorted waste, total amount of municipal solid waste and service costs. One-to-one relationships between value and judgment of utility were obtained asking interviewee judgments relating only to small number (4-7) values of all different.

The possible results for each criterion were previously divided into ranges such that the set of values presented a wider step to the extreme values and a denser one for the central values, where often even moving very little can significantly change the information provided.

All respondents were asked to judge the values present in all range, so that the interviewee sensitivity could not determine an excessive subjectivity factor.

In this way a regression curve more faithful to the data was obtained, having a sufficiently dense distribution of points on the ordinate where the opinions expressed were, and having judgments values that, while not the same, are still very close together.

They have always been respected the three axioms of utility functions:

1. U = 0 minimum utilities
2. U = 1 maximum utilities
3. (dU/dNB) ≥ 0 Utilities non decreasing

3.1. Countable Criteria

3.1.1. Criterion n°1: percentage of segregated waste collected (%SC)

Respondents were required to express judgments related to fixed values of percentage of segregated waste collected. Subject involved were Technical Support Manager Administrative Area Ferrara - Modena, Environmental Services Directorate - Hera SpA (waste management company - interview N°1); head of the environmental services of the Unione Terre di Castelli (case study - interview N°2); head of environmental services of Ferrara - Hera Spa (waste management company - interview N°3).

Following the same principle, the same respondents were asked to express an opinion on the criteria of annual per capita production of unsorted waste (criterion n.2) and the annual production per capita of total waste (criterion n.3); the obtained results are stated in Table 1, while the Fig. 1 shows the scores assigned in %SC, kg UW; Kg MSW criteria, and relative regression curves.

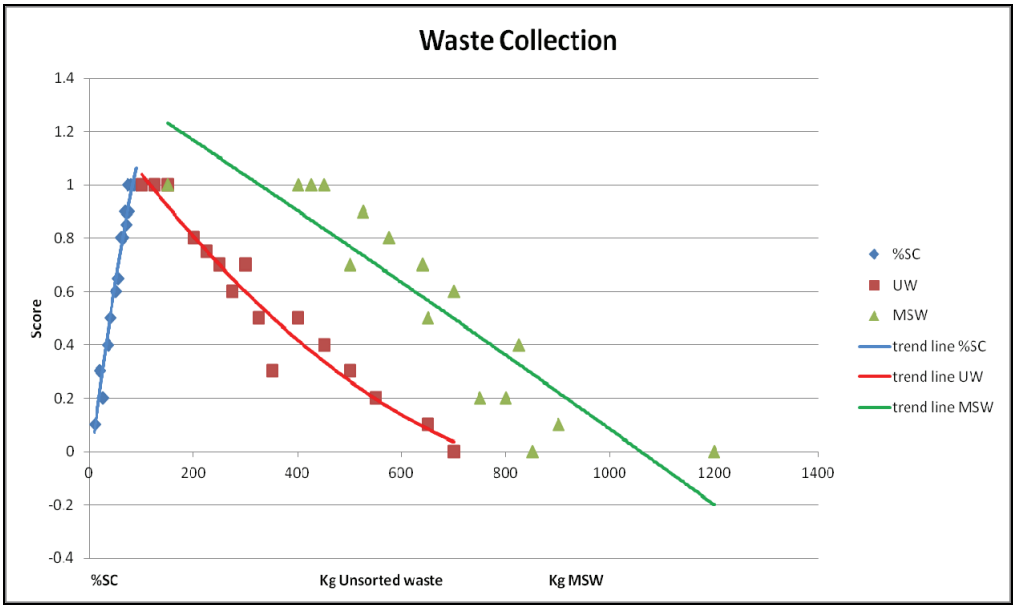

Fig. 1. Graph of the scores assigned in %SC, kg UW; Kg MSW criteria,and relative regression curves

Table 1. Results of the interview about the %SC, UW and MSW Criteria

Performance sector	*% SC*	*Interview n°*	*Score assigned*	*kg UW*	*Interview n°*	*Score assigned*	*kg MSW*	*Interview n°*	*Score assigned*
High	90	1	1	100	3	1	400	1	1
High	85	2	1	125	2	1	425	3	1
High	80	1	1	150	1	1	450	2	1
Middle-High	75	1	0.9	200	2	0.8	500	1	0.7
Middle-High	74	2	0.9	225	3	0.75	525	3	0.9
Middle-High	73	3	1	250	2	0.7	575	2	0.8
Middle-High	70	2	0.85	275	2	0.6	640	2	0.7
Middle-High	67	3	0.9	300	1	0.7			
Middle-High	65	1	0.8						
Lower-Middle	64	2	0.8	325	2	0.5	650	1	0.5
Lower-Middle	60	3	0.8	350	2	0.3	700	2	0.6
Lower-Middle	55	2	0.65	400	3	0.5	750	1	0.2
Lower-Middle	50	1	0.6	450	1	0.4			
Low	40	3	0.5	500	3	0.3	800	3	0.2
Low	35	2	0.4	550	1	0.2	825	2	0.4
Low	25	1	0.2	650	3	0.1	850	1	0
Low	20	2	0.3	700	1	0	900	3	0.1
Low	10	3	0.1						

The utility function for %SC becomes (Eq. 1):

$$y = -4^{0.5} x^2 + 0.0165x - 0.0897 \quad (1)$$

The regression curve choice is a polynomial of the second order, with a value of $R^2 = 0.9695$

3.1.2. Criterion n°2: annual production of unsorted waste per capita (UW)

The regression curve choice is a polynomial of the second order, with a value of $R^2 = 0.9485$. The utility function thus becomes (Eq. 2):

$$y = 1^{-0.6} x^2 + 0.0027x + 1.3028 \quad (2)$$

3.1.3. Criterion n° 3: annual production of municipal solid waste per capita (MSW)

The regression curve choice is a polynomial of the second order, with a value of $R^2 = 0.8932$. The utility function thus becomes (Eq. 3):

$$y = -9^{-0.7} x^2 + 0.0008x + 1.4834 \quad (3)$$

3.1.4. Criterion n°4: service costs

The cost items included in the Economic Financial Plans of Municipalities were considered. To build the utility function for this criterion, all Budget Offices of case study municipalities were surveyed, and as before, were asked to formulate judgments related to specific cost values of service per inhabitant, capable of covering all the cost items related to waste management. The regression curve choice is a polynomial of the second order, with a value of $R^2 = 0.6524$. The value of R^2 is significantly lower than in the previous cases. In particular, as stated in Table 2 and in Fig. 2, one of the interviews reported values significantly distant from other experts involved, and it has significantly influenced the result because of the choice of the boundaries of the system, which provided a limited number of opinions.

It was decided, nevertheless, not to exclude the results provided the above interview because it reflect the qualified opinion of the interviewee. The utility function thus becomes (Eq. 4):

$$y = -4^{-0.6} x^2 + 0.0039x + 1.1773 \quad (4)$$

3.2. Uncountable criteria

The "uncountable criteria" category includes the environmental impact of the service, the traceability of the waste fate, involvement of the population and the convenience of the service. Since the very nature of these criteria substantially differs from the previous ones, experts involved were required to identify some standard actions reproducible by administrations and citizens, and to assign them a score between 0 and 1 according to the importance of each action, the commitment required, the expected results and, in essence, the virtuosity assigned to a specific action.

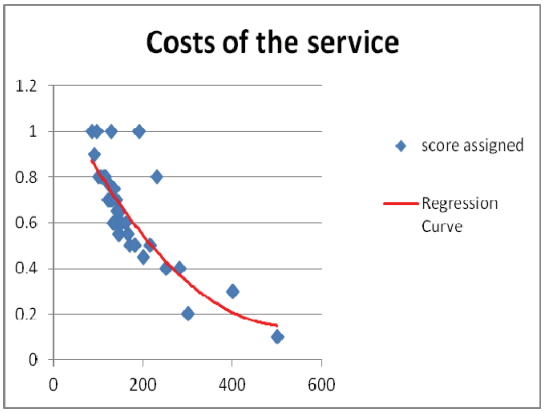

Fig. 2. Graph of the scores assigned and regression curve

Table 2. Reports of interviews with experts on service costs

Performance sector	*cost (€/yr) for inhabitant*	*Interview n°*	*score assigned*
High	80	2	1
High	85	6	1
High	90	1	0.9
High	95	5	1
High	100	2	0.8
High	105	4	0.8
High	110	3	0.8
High	115	1	0.8
High	120	2	0.7
High	122	7	0.77
Middle-High	124	4	0.7
Middle-High	126	3	0.7
Middle-High	128	5	1
Middle-High	130	1	0.7
Middle-High	132	2	0.6
Middle-High	134	6	0.75
Middle-High	136	4	0.6
Middle-High	140	3	0.7
Middle-High	142	7	0.65
Middle-High	144	2	0.55
Lower-Middle	146	6	0.65
Lower-Middle	148	4	0.6
Lower-Middle	150	1	0.6
Lower-Middle	160	3	0.6
Lower-Middle	165	7	0.55
Lower-Middle	170	6	0.5
Lower-Middle	180	1	0.5
Lower-Middle	190	5	1
Lower-Middle	200	2	0.45
Lower-Middle	215	4	0.5
Lower-Middle	230	5	0.8
Low	250	7	0.4
Low	280	6	0.4
Low	300	4	0.2
Low	400	6	0.2
Low	500	5	0.2

This procedure does not necessarily entail the presence of an analytic function representative of the opinions of respondents, but the results are divided into score ranges attributed to the actions taken by the local administrations evaluated.

3.2.1. Criterion n°5: environmental impact of the service (LCA)

The criterion of environmental impact of the service is designed to estimate the virtuosity of Municipalities in the choice of the collection system to reduce its impact on the ecosystem, in terms of pollution and use of natural resources. In building this criterion it is taken into account that very rarely Municipalities submit its waste management system to a comprehensive Life Cycle Assessment. Therefore, this criterion is built by allocating points to some important aspects of waste management, in particular:

1. Type of collection (dumpster, curbside or mixed): on the basis of Life Cycle Assessment provided by literature in waste collection systems (Marini, 2010), a higher score is assigned to the dumpster collection, rather than curbside one.

TYPE OF COLLECTION [MAX 0:25]

- Dumpster points 0.25
- Curbside collection points 0.15

2. Ratio users/inhabitants: a greater number of users means a higher number of stops of the vehicles employed for the collection, and consequent greater pollution. In order to avoid disadvantaging excessively the most populous municipalities, the number of users is normalized the number of inhabitants.

REPORT USERS/POPULATION [MAX 0:25]

- *(Utilities/Inhabitants)< 0.35* 0.25 points
- 0.35*<(Utilities/Inhabitants) <0.45* 0.20 points
- 0.45*<(Utilities/Inhabitants)<0.60* 0.15 points
- 0.60< *(Utilities/Inhabitants)<0.75* 0.10 points
- *(Utilities/Inhabitants)>0.75* 0.05 points

3. Distance traveled: it is the distance of Municipality from the landfill or treatment center used and points assigned are divided into distance bands.

DISTANCE (average distance of landfills and treatment plants) [MAX 0:25]

1. $d \leq 50$ km 0.25 points
2. $50km \leq d \leq 100km$ 0.10 points
3. $100km \leq d \leq 300km$ 0.05 points
4. $300km \leq d$ 0 points

4. Waste destination: as stated in Table 3, for each sorted waste fraction, it is awarded the highest score in relation to the recycling (or quality composting for organic) and a lower one if the waste is destined to incineration or landfill. For unsorted waste, the highest rating is assigned to the incineration for energy recovery and lower to landfill in accordance with the European Community instructions.

DESTINATION OF WASTE (to be weighted on quantities of each fraction) [MAX 0:25].

The allocation of scores, however, ignores the fact that the local administration can not decide the final destination of the waste, which remains exclusive prerogative of the waste manager. For this reason it was decided to give all municipalities a fixed score amounted to 0.3 by the sum of points 3 and 4. The scores due to the type of collection and ratio users/residents are assigned on the basis of strategic choices of each Administration.

3.2.2. Criterion n°6: waste fate traceability

A Councilor for environmental policies of one of the case study Municipalities was interviewed on this issue as carrier of one of the most advanced traceability methods applied in Italy for segregated collection through dumpster along the roads.

An effective traceability system of municipal waste fate associates each user with the amount of waste produced for each waste fraction and it works mainly on two fronts: on one hand, the ability to sanction users who deliberately or carelessly performs an incorrect waste disposal, on the other the opportunity to reward the most virtuous citizens through tax cost discharging. Another significant advantage is the ability to introduce a punctual communication to the users who misapply - or not apply - some or all of segregation fractions for recycling. It is possible, in fact, that these people have not understood how to profit of the waste management system and, verifying this through the traceability system, the administration is, then, able to intervene in time to provide correct information and solve the problem.

From the management point of view, the Municipality and the Managers are also facilitated by the presence of a monitoring system in the definition of strategic choices. Being able to know the usage rate of the service by all users, in fact, they would be better able to develop studies on trends of use, in order to improve the efficiency of the system.

From the citizen's point of view, it is commonly believed that the ability to easily access data about their own contributions as well as aggregates information on the overall management of waste in the municipal area and to their destinations, can be an incentive to users to improve their segregated collection. The awareness of no longer being an anonymous user, but a verified citizen would improve user empowerment.

A disadvantage of traceability systems is clearly the high costs of installation and management, due to the increased complexity in the system and the possible adversity of the users, who do not perceive the benefits and complain about increased discomfort of the system.

The respondent has identified four actions that mark the different degrees of virtuosity of a municipal administration traceability system of waste:

1. The presence of an agreement with Voluntary Ecological Guards or other agencies or organizations for the control and sanction of improper waste disposal.
2. The existence of a traceability system for household waste though which the Municipality is able to recognize precisely the disposal of different users.
3. The transparency of information with the possibility for citizens to access the data of their own contributions and the overall management information of waste in the municipal area.
4. The presence of economic incentives and rebates on the tax for more virtuous citizens.

Each action is assigned a score of 0.25, as it is believed that each of these procedures can produce a benefit of the same order of magnitude. Note that this procedure will only set goals that can be achieved with different instrumentation and perfectly adaptable to any waste management system (curbside or dumpster collection or mixed). It is even not necessary that a municipality implements the action number one to activate subsequent actions and accessing to its benefit, leaving every administration free to implement whatever action it deems most effective or viable, being, nevertheless, able to be rewarded by an improvement in the indicator of virtuosity.

Table 3. Scores assigned for each type of waste according to the destination

UNSORTED WASTE		***PLASTIC***		***GLASS***	
landfill	0.02 points	landfill	0.00 points	landfill	0.00 points
incinerator	0.05 points	incinerator	0.04 points	incinerator	0.00 points
		recycling	0.05 points	recycling	0.05 points
		PAPER		***ORGANIC***	
		landfill	0.00 points	compost quality	0.05 points
		incinerator	0.03 points	landfill	0.03 points
		recycling	0.05 points	anaerobic digestion	0.04 points

3.2.3 Criterion n°7: involvement of population

This criterion was created with the aim of measuring the ability of Municipalities to form their own citizens on the importance and proper use of the waste collection, to reward the strategies put in place by the Administration, by individual citizens or by entrepreneurs, on waste prevention, and, finally to build the real possibility for the users to intervene in the strategic choices regarding waste management.

The significant initiatives in the field of information and waste prevention are evaluated, being taken by individuals or groups of citizens, as the virtuosity of the Municipality is not only meant as a management skill of the Administration, but also and above all as the answer provided by the community to the waste issue. It remains true that, despite the scarcity of resources available, the City Council may provide significant results, creating the network between those who must get rid of a product and others possibly searching it for their own purposes.

This policy aims to support the leading role of citizens in the management of this important environmental issues, seen as a concrete tool of democracy, a facilitating factor and sometimes a prerequisite to the achievement of the expected results, whereas policies and actions widely shared with the users of the service can produce significant improvements.

To develop this criterion, two founders of the Transition Movement in Monteveglio (BO) were interviewed, which is a cultural and environmental movement engaged in "a dedication to the creation of tangible, clearly expressed and practical visions of the community beyond its present-day dependence on fossil fuels. The primary focus is not campaigning *against* things, but rather on positive, empowering possibilities and opportunities" (Hopkins and Lipman, 2009). One of the cardinal principles of the Transition is openness and involvement "bottom-up" of the larger part of the community as possible.

From the interview conducted emerge some pivotal actions, such as systematic information of the population (underlining the ineffectiveness of meetings and conferences organized from time to time), or the creation of a cultural density in which a continuous and pervasive signal would be able to change bad habits. This is not always possible at all levels of society, but in the experience of the respondents, the widespread presence of target educational activity in schools is very effective, which in many cases has led the boys to involve their own families in the activation of virtuous behavior. Another level of strategic actions emerged from the interview covers all initiatives aimed to waste prevention, considered the priority solution rather than the mere segregated collection of waste. It is considered in fact much more virtuous a reduction policy applied in "upstream", capable of greatly reducing the problem of costs and disposal and which can also be made by individuals, rather than a management "downstream" which is not always effective.

Finally, the participation of the population can have a very positive impact if citizens are really involved in management decisions: the involvement can be defined accordingly to the scale of participation provided by Lewanski (2009). It is emphasized that the actions of involvement of the population often have not an immediate a return, but the investment in the formation of a widespread civic and environmental consciousness can bring very convincing results over time, if handled properly. The proposed actions and their scores are as follows:

1) Information:

- Leaflets, illustrating how to differentiate waste;
- Activities in schools, continuous and constant (for example, every year turn of training with all children of a certain class, so in time to meet all the students of the city).

2) Waste prevention:

- Promotion of home composting, while decreasing the percentage of segregated waste of the organic fraction, this initiative produces a significant economic and environmental benefits, producing a local compost to be entirely reused, preventing issue related to transport, treatment and possible rejection by the market.
- Re-use markets.
- Actions for the prevention of disposable items use:
  - agreements with the mass distribution to apply a tax reduction on municipal tax for shops proportional to the area for the distribution of products "on tap";
  - introduction of cloth diapers in kindergartens: in addition to reducing waste from school often produces an effective conviction to families, so that they start to use cloth diapers even in their homes.

Any of these actions or other similar left to the free initiative of citizens are attributed the score shown in Table 4, the presence of more than one action, however, does not increase further the score indicator. Possible agreement between Municipality and a laboratory to perform analysis on tap water with reduced cost to the citizens, encouraging the use of public water instead of mineral water. Always with the goal of increasing the use of public water to the detriment of that bottle, the introduction of tap water distributors, to be placed in areas of passage on the streets normally traveled by users, in order not to improve traffic.

3) Mitigation:

The temporary subscription of the Last Minute Market (www.lastminutemarket.it), born from a Spin off initiative of University of Bologna or similar initiatives (such as the permanent Food Bank) is considered by respondents as an effective reuse of potential food waste, a sort of emergency management. A systematic use of this practice however, it is feared may adversely affect

management practices in the food chain, considering the presence of a significant food waste as a meritorious work to the most disadvantaged population. Coupling, instead, these practices with the actions of waste reduction would close the circle of the food chain in the most virtuous way.

4) Management service:

What makes a Municipality an efficient recycler of their own waste is undoubtedly the willingness of users to participate in the collection. It is believed that the establishment of virtuous solutions for training, feedback collection and involvement of the population in the decisions about waste management practices can greatly increase the susceptibility of the users to the best use of the waste collection service.

The commitment of an administration can be declined on different levels, making citizenship more or less active participant of the decisions, to bring the "ordinary citizens" to contribute with overt behaviors to at least a part of public decisions through processes of participatory politics.

To identify the possible variations of the commitment of an administration towards public participation to decisions, interviewees suggested the use of the Participation Scale (Lewanski, 2009), which identifies five degrees in the actions that the Municipality can activate.

Into virtuosity indicator a score for each level of scale achieved has be assigned and, for simplicity, the different steps of the participation scale have been developed this way:

1. INFORM: it includes, in addition to the normal routine information on how to dispose the waste, the information on the importance of waste reduction and segregation, in a cultural and educational approach to environmental issues.
2. CONSULT: it is the ability to listen to citizens' feedback, to gather information and opinions from the users, such as in public meetings or through devoted offices.
3. INVOLVE: it requires action by the administration in research and involvement, proposing the collection of qualified opinions, so that those who present grievances or new proposals must identify themselves. This is to encourage the user empowerment that can no longer hide behind the anonymity guaranteed by the response to a questionnaire or intervention during a meeting or conference open to the public. In this phase, the Administration is not, however, obliged to answer.
4. COOPERATE: the gathering of opinions qualified is not regarded to be sufficient and it becomes necessary that the public administration fulfills its obligation to reply to all users bringing considerations and evaluations.
5. EMPOWERMENT: the final step in which the public administration decision leaves a window open to the public, which can take any decision in that space.

Score attribution: given the difficulty of assigning scores to actions so different and with so different and uncertain results remaining in a 0-1 scale, a value of 10 was attributed to the first initiative taken into consideration (the presence of leaflets), and then score were assigned for all other actions.

All scores were then rescaled to bring their sum to 1. Below there is a summary table of the scores assigned to different actions, which shows, in line with the previously stated, how waste prevention is the action deemed as the most important.

3.2.4. Criterion n° 8: citizens' convenience

Here are presented the scores assigned on the basis of the distance in the case of dumpster collection and collection frequency in the case of curbside collection. For Municipalities that have both types (in a mixed collection system), an average value weighted on the number of users served is provided, so that the maximum score is always equal to 1.

Table 4. Summary scores for the criterion "Involvement of Population"

Criterion	***Actions***	***Scores***	***Scores in 0-1 scale***	***Relative impact***
Information	Flyers information	10	0.07	28%
	School activity	30	0.21	
Waste prevention	Home composting	20	0.14	38%
	Re-use market	15	0.10	
	Water quality test	3	0.02	
	Prevention of disposable goods	10	0.07	
	Water distribution point	7	0.05	
Mitigation	Last Minute Market or Food Bank	10	0.07	7%
Participatory management of decisions	Inform	8	0.06	28%
	Consult	8	0.06	
	Involve	8	0.06	
	Cooperate	8	0.06	
	Empower	8	0.06	
SUM		145	1	100%

Dumpster collection: Presence of complete dumpster set (for all segregated fraction): 0.5 points to be added to the maximum distance between dumpsters and homes

$d_{max} \leq 100$ 0.5 points
$d_{max} \leq 150$ 0.4 points
$d_{max} \leq 200$ 0.3 points
$d_{max} \leq 300$ 0.2 points
$d_{max} > 300$ 0.1 points

It was then decided, in case of opening of the box through magnetic card, to multiply the result by 0.9, since it could represent an increased discomfort in the waste disposal operation.

Curbside collection: This is calculated on the basis of frequency of collection of each fraction and then applying an average calculation. Scores are estimated on the basis of discomfort experienced keeping waste at home for different intervals (one or two collection shifts, in case unable to deliver it at the first occasion), and presented in Table 5.

3.3. Weighting of criteria

For the delicate process of allocating weights the Mayors of Terre di Castelli Municipalities were involved. They had been chosen for their key role of public decision-makers and because they are considered the figures better able to compare criteria belonging to different policies and disciplines, something that an expert specializing in one area would find more difficult to perform. They were asked to rate the criteria providing a universal judgment as representative of their priority ideal scale.

The methodology chosen is the pairwise comparison as proposed by Saaty in the study of Analytic Hierarcy Process (Saaty, 1980), which allows decomposing a multidimensional problem in a number of two-dimensional problems. The interviewee have been proposed all possible combinations between the criteria and, attributed a score of 1 to one of the two criteria, they were asked to assign a rating of greater or lesser importance to each other on a scale from 1 to 9 if best match or from 1 to 1/9 if lower.

1: EQUAL IMPORTANCE: two elements contribute equally to the objective.

3: MODERATE IMPORTANCE: experience and evaluation moderately favor one element over another.

5: STRONG IMPORTANCE: experience and evaluation strongly favor one element over another.

7: IMPORTANCE VERY STRONG: an element is very strongly favored over the other. His domain is shown in practice

9: EXTREME IMPORTANCE: The evidence that favors an element on the other is of the highest possible order of affirmation.

Scores 2, 4, 6, 8 can be used for intermediate values. The opinions so expressed were placed in a 8x8 square matrix, whose rows and columns represent the criteria considered. The main diagonal is entirely occupied by the value 1, while the other positions host numerical assessments for the various pairs evaluated, according to the table. A weight matrix has been, therefore, produced for each auditor interviewed.

Then, calculating the right eigenvector of the matrix the weight vector is obtained, which provides the weight of each criterion. All the scores are normalized between 0-1: in order to normalize the 1-9 Saaty scale is calculated the right eigenvector of the weights matrix, that automatically normalize the scores from 1-9 scale to 0-1, reporting the weighted scores assigned from each person interviewed. The right eigenvector is defined by Eq. (5), where A is a symmetric matrix, x is the eigenvector right, λ the eigenvalue.

$$A * x = \lambda * x \quad (5)$$

Built the matrix, a verification of its consistency was needed, as the consistency of judgments provided by interviewees: the matrix is perfectly consistent if $\lambda = N$ (number of criteria) and is much more inconsistent, as $\lambda > N$. However, there is a tolerance on the number of criteria analyzed that, starting from the calculation of the coefficient of inconsistency (CI) given by Eq. (6) divided by the Random Consistency Index (RI) provides the Consistency Rate (CR) (Eq. 7).

$$CI(A) = ((\lambda max - N) / N) \quad (6)$$

$$CR(A) = CI(A) / RI(N) \quad (7)$$

The Random Consistency Index represents the consistency of a matrix of pairwise comparison randomly generated. It is derived as the average index of consistency calculated from a sample of 500 randomly generated matrices based on the scale AHP seen previously. The value of RI depends on the number of criteria, as expressed by Saaty (Saaty, 1980).

Table 5. Scores assigned to every type of waste, according to collection frequency

Scores assigned for collection frequency	*Organic Fraction*	*Unsorted fraction*	*Dry fractions (for each fraction)*
1 time / week	0.2 points	0.3 points	0.4 points
2 times / week	0.5 points	0.7 points	0.8 points
3 times / week	0.8 points	0.8 points	1 point
4 times / week	1 point	1 point	1 point

If CR (A) ≤0.1, the pairwise comparison matrix is considered significant enough. In the case where CR (A) > 0.1 the pairwise comparison matrix must be improved by modifying certain ratings. For the pairwise comparison, it was made use of the software tool MakeItRational Decision Tool, which, thanks to a graphical interface easy to understand and the real-time reporting of any inconsistent judgments, allowed to go directly to the definition of the weights that each auditor has determined, immediately creating matrices sufficiently consistent.

Finally, even if the sensitivity analysis is usually used as the confirmation of weighting strength of criteria due to pairwise comparison (Cabala, 2010; Chen and Kocaoglu, 2008; Dalalah et al., 2010), in this study it is considered unnecessary. The reason is that the aim of this paper is not to make a choice among alternatives, but to experiment a complete tool for the Local Administrations to decide how to manage their urban waste, with respect to the their policy's goals.

This function is completely performed by the indicator as described heretofore. In fact in the construction of this indicator the mayors were asked what their guidelines are. Subsequently, the application of the indicator will tell if the Municipalities are following these steps that they have set themselves.

Furthermore, weights given to the criteria would change choosing a different case study providing a serviceable ranking of Municipalities if performed on an extended case study (like a Region). In a broader framework, a sensitivity analysis would be useful as the statistical basis for interview would increase and this new setting would be particularly interesting, as the Italian Region is the competent authority in waste management.

4. Results and discussion

After interviewing the sector managers of all the Municipalities of the Unione Terre di Castelli and having collected weights assigned to each respondent to the eight criteria with the method of Pairwise Comparison, before performing the definitive allocation of weights to the criteria selected to form indicator virtuosity, the results of calculation of Random Consistency Index have been checked. In Table 6 it is shown that every matrix performed with Pairwise Comparison methodology was consistent enough. It was therefore calculated the arithmetic mean of the values obtained from the interviews; it is not a weighted average and no other correction factor is applied, since the results are the fruit of thought and sensibility of administrators, and not necessarily the synthesis of the will or the priorities of residents of the Municipality.

The results thus obtained are shown below in Table 7, "Weight" column, and in Fig. 3.

A substantial lack of a single view of the priorities related to waste management emerges from results presented, although some judgments are common to all respondents. The case of the environmental impact of waste collection and treatment is considered a strategic indicator of a virtuous waste management, while the percentage of recycling has never reached the 10% of the total weight because of the many flaws identified by the respondents on this indicator. No doubt the criterion subject to major contradictions is the traceability of waste fate, sometimes considered a good strategy to improve service and considered a waste of effort and money by other respondents.

Different levels of interest, but still significant, were provoked by the criteria related to costs (essential for a municipal administration) and involvement of the population. Among criteria for waste collection stands out the importance attributed to the amount of unsorted waste, recognized as the component of major concern for the impact it produces both on ecosystem and on municipal budget. To clarify the subject, the graph reporting weights assigned by administrators interviewed is shown below.

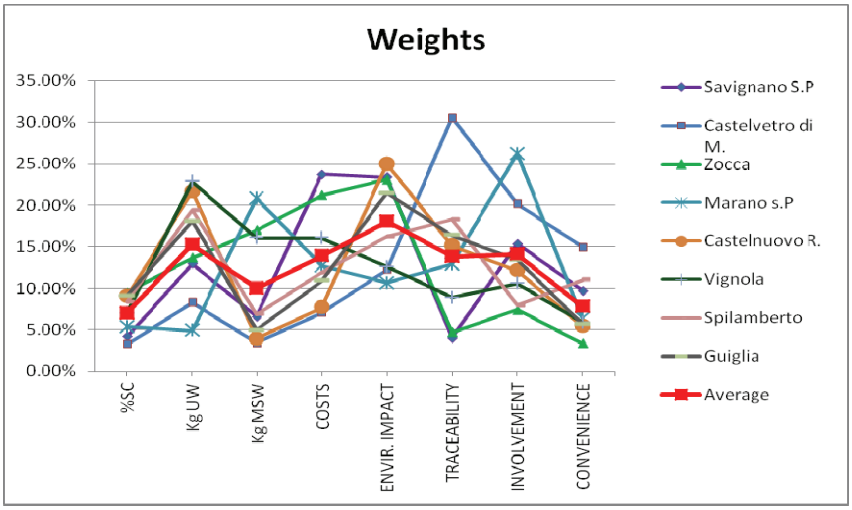

Fig. 3. Chart of weights assigned by the respondents and the average value

Table 6. Random Consistency Index calculated for the weights matrix proposed by each Municipality interviewed

MUNICIPALITY	*CR(A) calculated*	*CR(A) limit*	*RESULT*
Savignano S.P.	0.04	≤0.1	Consistent
Castelvetro	0.1	≤0.1	Consistent
Zocca	0.07	≤0.1	Consistent
Marano S.P.	0.05	≤0.1	Consistent
Castelnuovo R.	0.06	≤0.1	Consistent
Vignola	0.03	≤0.1	Consistent
Spilamberto	0.05	≤0.1	Consistent
Guiglia	0.03	≤0.1	Consistent

Table 7. Weights attributed by respondents and the scores obtained by each Municipality, for each Criterion at the end of the analysis

Municipality	*% SC*		*Kg UW*		*Kg MSW*		*COSTS*		
	Weight %	*Score*	*Weight %*	*Score*	*Weight %*	*Score*	*Weight %*	*Score*	
Savignano S.P.	4.17	0.1078	12.97	0.0805	6.59	0.0648	23.74	0.1102	
Castelvetro	3.26	0.0578	8.33	0.13	3.43	0.0776	7.08	0.1164	
Zocca	9.53	0.0284	13.67	0.0533	16.97	0.0640	21.22	0.1067	
Marano S.P.	5.38	0.0451	4.92	0.1169	20.86	0.0955	12.71	0.1107	
Castelnuovo R.	9.05	0.0565	21.69	0.1028	3.93	0.0428	7.71	0.1032	
Vignola	7.04	0.0449	22.85	0.0790	16.06	0.0541	16.06	0.1039	
Spilamberto	8.37	0.0536	19.44	0.1120	6.87	0.0700	11.89	0.1132	
Guiglia	9.12	0.0537	18.09	0.1175	4.94	0.0768	10.88	0.1130	
Municipality	*Environmental Impact*		*Traceability*		*Involvement*		*Convenience*		*Total score*
	Weight %	*Score*	*Weight %*	*Score*	*Weight %*	*Score*	*Weight %*	*Score*	
Savignano SP	23.37	0.1262	4.04	0.0693	15.39	0.0906	9.72	0.0544	0.7039
Castelvetro	12.23	0.1356	30.54	0.0693	20.18	0.0864	14.95	0.0546	0.7255
Zocca	23.11	0.1085	4.73	0.0693	7.42	0.0765	3.36	0.0546	0.5612
Marano s. P.	10.64	0.1265	12.92	0.0693	26.22	0.0765	6.37	0.0546	0.6953
Castelnuovo R.	24.96	0.1260	15.12	0.0693	12.12	0.1076	5.42	0.0544	0.6626
Vignola	12.61	0.1257	8.88	0.0693	10.58	0.0935	5.91	0.0609	0.6313
Spilamberto	16.20	0.1263	18.26	0.1386	7.99	0.1076	10.99	0.0632	0.7845
Guiglia	21.48	0.1175	16.39	0.0693	13.40	0.0765	5.71	0.0546	0.6789

The mean value obtained is then shown in the following pie chart (Fig. 4).

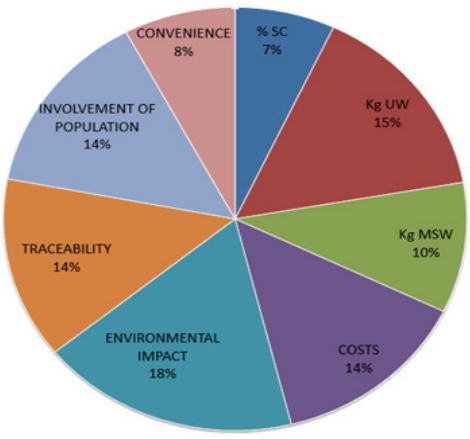

Fig. 4. Average distribution of weights

In summary, the weights assigned by the administrators of the Union of Terre di Castelli, presented in order of importance are given in Table 8.

The results presented in Table 7, "Score" column, derived from the application of the indicator of virtuosity and scores obtained by the Municipalities belonging to the case study, with the aggregated performance data of the Unione Terre di Castelli Municipalities in relation to each of the eight criteria taken into examination. It was decided to use a time interval of 12 months of analysis, covering the period from July 2012 to June 2013.

For each criterion, each municipality received a score as explained above, multiplied by the weight assigned by the mayors interviewed (Table 9, Fig. 5).

As demonstrated by Fig. 5, one of the most interesting potential applications for the method proposed is the support to strategic choices about waste management: reporting for each municipality performance measured by each criterion, the indicator shows clearly the areas where it may be more effective to invest for the overall improvement of the waste management system. The indicator can also be used as a simulator for the actions that the Administration of Spilamberto plans to take, for example viewing if the investments to improve some

criteria are sustainable or if their economic impact can reduce the overall virtuosity. In conclusion, the overall scores are shown in the summary chart below, marking how this ranking differs from a judgment based solely on the percentage of segregated waste collected. This means extending the horizon of the investigation into all areas pertaining to the management of waste, obtaining a measurement of virtuosity that moves beyond from the Italian legislator's present requirement.

All this underlines the importance of a multi criteria approach to the delicate issue of waste management in order to achieve a more accurate estimation of the real virtuosity of Local Authorities and the actions to be taken in order to improve the approach to discipline and to reduce the impact environmental product from municipal waste. Table 10 shows a comparison of the rankings obtained by the exclusive evaluation of the percentage of segregated collection against the indicator proposed. Examples of Savignano and Spilamberto show how this indicator awards the attention to different aspects of waste management and the various actions that can be implemented, increasing the Municipality score of virtuosity.

Fig. 6 shows the overall results, to provide a visual clue to easier and more immediate understanding.

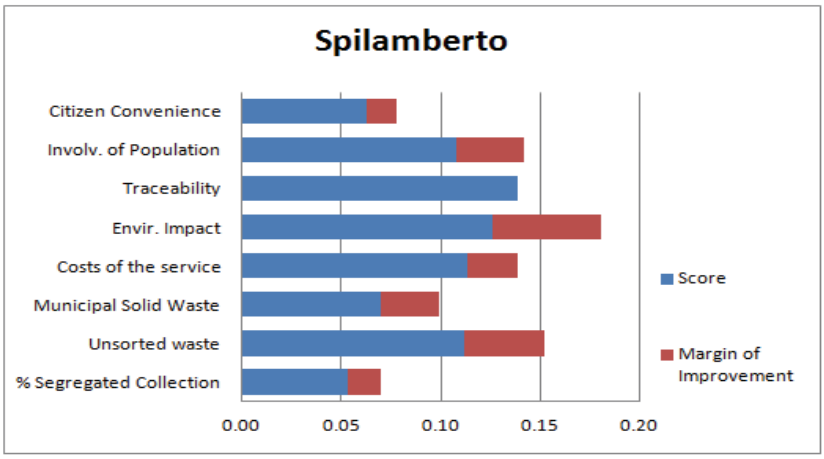

Fig. 5. Performance of Spilamberto

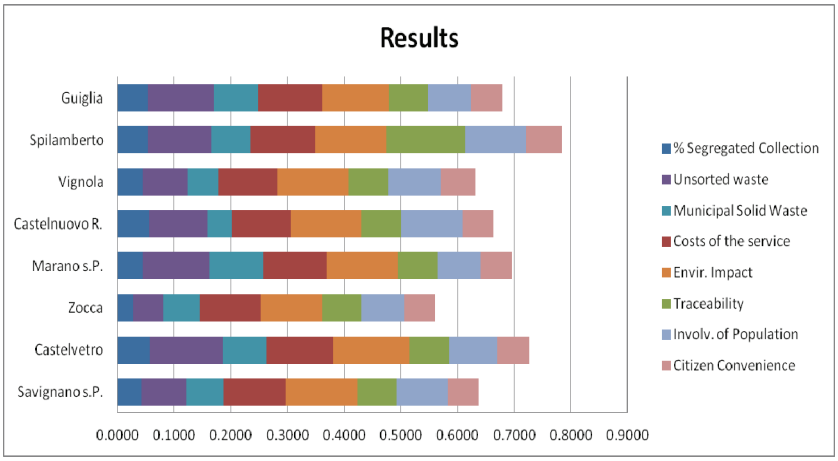

Fig. 6. View of the sums of the partial results obtained by the municipalities with the application of the indicator of virtuosity

Table 8. Weights distribution

Criterion	***Value%***	***Weights***
Environmental impact of the service	18:08%	0.1808
Unsorted waste produced	15:24%	0.1524
Involvementnt of population	14:16%	0.1416
Costs	13.91%	0.1391
Traceability	13.86%	0.1386
Municipal Solid Waste	9.96%	0.0996
Convenience for users	7.80%	0.0780
% Segregated Collection	6.99%	0.0699
SUM		**1.0000**

Correctly the sum of the weights is 1

Table 9. Performance of Spilamberto

% SEGREGATED COLLECTION		***UNSORTED WASTE***	
Segregated Collection [%]	60.86%	UW per capita [kg]	229.92
Score assigned	0.77	Score assigned	0.73
Weight attribuited	0.0699	Weight attribuited	0.1524
Result %RD	0.0536	Result UW	0.1120
Margin of improvement	0.0163	Margin of improvement	0.0404
MUNICIPAL SOLID WASTE		***COSTS OF SERVICE***	1458769
MSW per capita [kg]	587.42	Cost per capita [€]	108.06
Score assigned	0.70	Score assigned	0.81
Weight attribuited	0.0996	Weight attribuited	0.1391
Result MSW	0.0700	Result COSTS	0.1132
Margin of improvement	0.0296	Margin of improvement	0.0259
ENVIRONMENTAL IMPACT OF SERVICE		***WASTE FATE TRACEABILITY***	
Score assigned	0.70	Score assigned	1
Weight attribuited	0.1808	Weight attribuited	0.1386
Result ENV. IMPACT	0.1263	Result TRACEABILITY	0.1386
Margin of improvement	0.0545	Margin of improvement	0.0000
INVOLVEMENT OF POPULATION		***CITIZEN CONVENIENCE***	
Score assigned	0.76	Score assigned	0.81
Weight attribuited	0.1416	Weight attribuited	0.0780
Result INVOLV. POPULATION	0.1076	Result CITIZEN CONVENIENCE	0.0632
Margin of improvement	0.0340	Margin of improvement	0.0148

Table 10. Different classifications of virtuousness of Municipalities examined

RANKING FOR RD%		***RANKING FOR INDICATOR VIRTUOSITY***	
Municipalities	***% RD***	***Municipalities***	***Total scores***
Castelvetro	66.19%	Spilamberto	0.7845
Castelnuovo R.	64.51%	Castelvetro	0.7255
Guiglia	61.07%	Savignano s.P.	0.7039
Spilamberto	60.86%	Marano s.P.	0.6953
Marano s.P.	50.85%	Guiglia	0.6789
Vignola	50.59%	Castelnuovo R.	0.6626
Savignano s.P.	46.92%	Vignola	0.6313
Zocca	32.59%	Zocca	0.5612

5. Conclusions

This application has proved a valid and complete tool for local governments to evaluate the consistency between their own ideals guidelines and the actions they intend to apply. This work has proved a valuable decision support tool for local administrators, showing for each criterion not only state of the art but also the scope for improvement.

The indicator can also be used as a simulator for actions planned by administration, for example verifying sustainability of investments needed to improve performance in specific criteria or if their impact does not affect the overall virtuosity, with a simple and user-friendly tool.

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