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A methodology for assessment of MSWM applied to Southern Europe areas

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A methodology for assessment of MSWM applied to Southern Europe areas

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Abstract. The MED programme is one of the ETCP (European Transnational Cooperation Programmes) in the frame of the ‘Territorial Cooperation’ objective of the EU cohesion policy. The MED project entitled WASMAN was co-financed by ETCP and was launched in 2009 among a set of eight areas from Southern Europe. Detailed investigations were undertaken during three years at each of these areas by local MSWM experts resulting at a thorough state-of-the-art (Med Wasman Team, 2010) which is the starting point of our work. In order to fit the objective of the cohesion policy aimed by ETCP, this paper focuses on a methodology for assessing the overall performances of Municipal Solid Waste Management (MSWM) applied to the eight chosen areas. The performance of MSWM has been assessed through eleven criteria representing various social, economic and environmental factors. For each criterion and each area, (Med Wasman Team, 2010) gives the strengths and the weaknesses and a precise information about the quantity and typology of waste, its collection, segregation and processing. Based on those raw data, we propose a method to measure the overall performance which should give a reference model of good practices in the concerned areas. This method takes into account the importance given to criteria by local experts. We observed that these importances vary significantly from one area to another. This fact motivates our methodology to search for a consensual ranking of practices that is less sensitive to the importance’s variability. The final ranking shows that only three areas demonstrate good performances. The remaining areas could improve their performances by following the (combinations of) working models of better ranked areas. Based on that reference model, a short list of actions is compiled for each area.

Keywords: Municipal Solid Waste Management, multicriteria analysis, electre method, robust ranking, statistics.

1. Introduction

Municipal Solid Waste Management (MSWM) is a challenging problem for the European countries. The high level of complexity inherent in MSW streams (Troschinetz & Mihelcic, 2009) is enhanced by the wide array of economic and environmental structures found in both the developed and developing member countries of the EU. The EU – MED Programme (European Union – Europe in the MEDiterranean), co-finances many projects related to sustainable development. The MED programme is one of the ETCP (European Transnational Cooperation Programmes) in the frame of the ‘Territorial Cooperation’ objective of the EU **cohesion** policy. Among a set of 500 proposals, the MED WASMAN (WASte MANagement) project was ranked by a commission of ETCP at second position. A short description of WASMAN project is provided below (Alfare, 2007):

“The project MED WASMAN intends to promote synergies among MED countries in the field of waste management governance taking into account specific problems of each partner’s area. ... these countries have also similarities of challenges that can be tackled at regional level including: cost recovery and financial mechanism to promote revenue generation; lack of awareness among civil society on MSWM and procedures to encourage better behaviors; capacity of municipalities to manage and learn from other experiences to improve services and the need to promote and reinforce municipal commitment to deliver more effective MSWM services which are an integral part of good local governance”

The eight partner areas (defined as "target areas" in the following) are a sample from Southern European countries: Greece, Italy, Spain, France, Cyprus, and Slovenia (see Table 1). These areas’ MSWM profiles differ significantly when compared both with northern countries and among themselves. Except target area 2, all the other areas are composed of cities and country sides. These areas constitute a little part of Southern Europe and it seems illusory to generalize the results of WASMAN project to all the MED area. The main obstacle to this generalization is the wide array of MSWM policies in each country.

Nevertheless, the data collected (not without difficulty) constitute a precise picture on MSWM policies of the eight areas and approximate pictures of their regions. These data are the starting point of our work. To explain the idea, a MSWM expert or a member of

ETCP that reads these data builds its idea about the ranking of their MSWM policies from the best to the worst. Another one, with another set of priorities, will have probably another ranking. Our intuition is that: despite the wide variety of MSWM policies and the wide variety of expert's priorities, there is a consensual ranking of MSWM policies that represents the "ideal" or reference MSWM for at least the eight target areas under the grid of the chosen criteria.

The ranking is based on the multicriteria aggregation that captures the collective assessment model of practices. Quite different profiles of MSWM practices may be assessed with comparable overall level of performance in the sense of the aggregation model. It means that particularities of areas are not penalized in the multicriteria assessment, because there are several ways to be a good MSW manager in the sense of the aggregation model.

The objective of this paper is to furnish a methodology in order to find such a ranking out from the given data. Such a formal comparison serves several purposes:

- It helps the officers of ETCP in their decision about the areas and actions to co-finance;
- the best-ranked areas can be showcased as models for MSWM practices throughout other similar areas. This step should also facilitate the design of efficient improvements in MSWM practices for the Southern European region.
- it allows easily grasping the level of MSWM performance of each target area;

Our methodology progresses through the following steps. It can be applied whenever the same type of information is available.

Step 1. As said above, the MSWM experts in each area undertook a detailed study of MSWM state-of-the-art in each area. They furnished a detailed SWOT (for Strengths, Weaknesses, Opportunities, Threats) analysis focusing on each of the 11 criteria in the MSWM process assessment (see Table 2). The choice of these criteria has integrated societal, economic and sustainability factors (Nussbaumer, 2009), (Karakosta, Doukas, & Psarras, 2009), (Troschinetz & Mihelcic, 2009). These SWOT analyses are published in (Med Wasman Team, 2010). That document is the additional material of our paper.

Step 2. At the outset, these SWOT analyses were non-formal appraisals. Each partner appointed a group of experts in its MSWM area to a team of judges; these teams (five persons in average) included individuals working in the field of MSWM, experts, municipal public works technicians and other stakeholders. These judges were asked to provide: i) numerical scores corresponding to their quantitative interpretation of the qualitative SWOT results; (ii) numerical scores summarizing the 4 SWOT assessments into an overall level of quality of each MSWM area for each particular criteria; and (iii) a weight that captures the relative importance of each criterion. (see Annex: Score tables of all the judges)

Step 3. Rank the overall quality of MSWM of eight target areas. This step goes through the realization of the following: 1) measuring the level of consistency and unanimity of experts in developing a shared viewpoint towards what constitutes excellence in the set of target areas MSWM practices; 2) proposing a robust ranking method and classifying the overall quality of MSWM practiced within the set of target areas; and 3) giving a list of guidelines per area in order to increase its level in the given ranking.

The paper is organized as follows: Section 2 will explain the material studied and the choice of the method. It is shown there why a Multicriteria Decision Analysis model better fits the objectives of our method and data. Results and discussion are presented in Section 3. Section 4 concludes the paper. In (Annex: Score tables of all the judges) one finds the detailed scores given by all the judges for all the areas.

2. Material and method

In order to assess the quality of MSWM in the target areas, a comprehensive study of actual practices and methods was conducted by local experts from each WASMAN partner following the lines of a common grid of 11 criteria (see Table 2) . This state-of-the-art has been included in (Med Wasman Team, 2010). The target areas and some of their key characteristics are presented below:

Table 1. Target areas.

N°	Target Area	Population	Area [km ²]	Quantity [tons/year]	Waste /Person/ Year [kg]	Recycling Composting %	Energy Valorization %	Landfill %	Other %
TA 1	Umbria (Italy)	894222	8456	552000	632	30.9		68.4	0.7

TA 2	Liguria (Italy)	9174	21	4993	544	20		79	1
TA 3	Gard (France)	280000	1223	167230	324	33.35	58.81	7.75	0.09
TA 4	Zaragoza (Spain)	1300000	47000	779799	411	13.8	15.3	57.7	13.2
TA 5	Alcala la Real (Spain)	24000	261	11332	394	22.49		68.97	8.54
TA 6	Trikala (Greece)	85000	75	27577	367.7	13.48		86.3	0.24
TA 7	Larnaca (Cyprus)	133300	1126	145000 ¹⁾	750	67 ²⁾		33	
TA 8	Inner Karst (Slovenia)	87773	1798	33721	447	26.4		72.6	1

¹⁾ This figure represents the quantity of mixed (not merely solid) urban waste production.

²⁾ As a matter of fact, the landfill percentage is much higher. The sorting/composting plant has not attained its nominal rate due to the non-separated waste streams that have been collected.

In the following discussion, the set P of target areas will be referenced by their number in the above table.

The main idea of this paper is that an overview and comparison across target areas should help each individual area first determine its position relative to the other areas and then define the most relevant scenario in order to introduce the most efficient improvement first. A set of 11 criteria has been established to perform this comprehensive comparison:

Table 2. Selected set of criteria.

Criterion	Description
c_1	Policy Framework
c_2	Tariff system
c_3	Waste collection / transportation
c_4	Waste separation
c_5	Waste disposal
c_6	Energy recovery Recycling / Re-use
c_7	Public awareness / Willingness to pay / Incentives
c_8	Capacity of local and regional authorities to implement the MSWM
c_9	MSWM Plan
c_{10}	Innovative technologies
c_{11}	Innovative approaches

EU policy on waste management sets high targets on the reduction of waste. These are expected to be achieved through the implementation of new waste prevention initiatives, a better use of resources, and a shift to more sustainable consumption and production patterns. The EU's approach to waste management focuses on three main areas of action, namely waste prevention; recycling and reuse; and improvement of final disposal and monitoring. The selected set of criteria fits the EU policy. Criterion c_1

describes the policy framework at the regional level. It tends to measure the eventual gap between the EU/national legislation on MSWM and its regional applications. Criterion c_2 describes the funding / tariff system applied at regional level. This criterion should answer the questions such as : how much costs a “good” MSWM? Who pays it? It has to explain the definition of taxes depending on operational cost of the MSWM system, the kind of waste produced, the need to discourage landfilling, etc. The criterion c_3 , describes the waste streams (organic, paper, packaging, hazardous, ...) and the existence of separate waste collection/transportation. Criteria c_4 measures the performance of waste separation and whether it is realized at the source or at waste separation plants. Criteria c_5 measures the part of landfill among the waste disposal methods. The tendency is the reduction of landfill as these sites remain active for many decades with an unpredictable behavior. Criterion c_6 measures the parts of energy recovery, recycling and reuse in the waste stream. Criterion c_7 tends to estimate the public awareness and its impact on the recycling/reuse rates. Also, it is helpful to know which kind of information campaign can achieve the expected results. Criterion c_8 measures the capacity of local authorities to develop/upgrade the MSWM Plan. It measures the number of stakeholders involved in MSWM. It is known that numerous stakeholders involved with potentially conflicted interests can raise the risk of lack of coordination and difficulties in accessing qualitative MSWM system. Criterion c_9 looks for existence of a MSWM plan, whether it is in line with EU policy, who is in charge of the design and supervision of such plans. Criteria c_{10} and c_{11} estimate the innovative aspects of existing technologies and the capacity to apply new ones.

We'll denote the set of criteria $C = \{c_1, c_2, c_3, c_4, c_5, c_6, c_7, c_8, c_9, c_{10}, c_{11}\}$. For each criterion, a description of the target area contains the following: S – Strengths; W – Weaknesses; O – Opportunities; T – Threats. The complete description of SWOT analyses is in the additional material (see Med Wasman Team, 2010). A description of data collected is given below.

In order to perform the quantitative comparison among target areas and establish best practices, the next step consists of associating a numerical score with the contextual SWOT analysis (see the Table 3 below). Each judge, identified by the number $j \in J = \{1, 2, 3, 4, 5, 6\}$, was asked to provide for each target area $p \in P$ and for each criterion $c \in C$:

- (i) Four scores between 0 and 100, for the purpose of evaluating the S, W, O and T of target area p for the criterion c . The scores for S and O are increasing (with 0 being the worst and 100 the best). The scores for W and T are decreasing (with 0 the best, meaning no weaknesses or threats and 100 the worst).

- (ii) An overall score between 0 and 100 for the MSWM's performance of the target area p for criterion c .
- (iii) A weight between 0 and 100 describing the relative importance of criterion c for judge j .

An example of SWOT data and the scores given by judges is given below. (the complete tables are in Annex: Score tables of all the judges)

Table 3. SWOT of Energy recovery Recycling / Re-use (Criterion 6) in Gard

S	W	O	T
The existence of "green" entities financed by waste producers, whose mission consists of organizing, supervising and accompanying the sorting of certain types of waste in partnership with local authorities: Eco-emballage - OCAD3E. Responsibility for all recyclable waste taken over by local firms. Direct contract between the SITOM entity and the purchaser, generating high income for the SITOM. Building of a strong culture in terms of environmental health protection.	Certain recycling channels incapable of generating intake (wood, rubble). Recyclable wastes generate less in profit than the amount of subsidies granted.	New leads for the reuse of wood waste via wood energy production to be examined in depth.	Persistently poor sorting habits: Littering in front of the waste collection centers. Long-term retention of the "green packaging" subsidy can lead to high prices for selective waste sorting (less pressure on local authorities to lower prices).

Numerical scores corresponding to this SWOT, overall score and the weights given to criteria 6 for target area 3 (Gard) by all judges are:

Table 4. Scores for Criterion 6, Target Area 3 (Gard)

	SWOT Scores	Overall Score	Weights %
Judge 1	80 70 60 65	72	13
Judge 2	90 20 60 25	85	15
Judge 3	90 55 55 80	85	10
Judge 4	75 60 70 75	67.5	18
Judge 5	77 72 57 73	70	10
Judge 6	90 60 60 75	80	10.5

In this process of cross-evaluation, each judge therefore needed for furnish 8 estimations (for all the target areas). The rationale behind this approach was to lend the

greatest legitimacy to these scores by means of a cross-evaluation method. The risk inherent in this approach is that potentially significant variations in scores relative to a pair (p, c) (*i.e.*, assessments of a target area p with regard to criterion c) could be observed from one judge to another. Moreover, major disparities may also be observed concerning the weights attributed by judges to a given criterion c because of quite distinct strategic interpretations in terms of MSW management. These interpretation discrepancies introduce rough disturbances into the design of a shared best practices model and hence must be taken into account in the ranking process of the 8 compared MSWM policies. The data resulting from this cross-evaluation have been organized in 6 scoring tables (see Annex: Score tables of all the judges).

In order to derive overall performance assessments of MSWM policies within the target areas, an appropriate model would be required. Mathematical and decision-making models have been applied to waste management for a long time (Morrissey & Browne, 2004). According to these authors, three classes of models have appeared in this domain:

- CBA – Models based on Cost-Benefit Analysis;
- LCA – Models based on Life Cycle Analysis;
- MCDA – Models based on Multicriteria Decision Analysis.

The CBA class of models proves to be inadequate for our case study, due to the impossibility of measuring or calculating the benefit of all actions on individual WM criteria. We also rejected the LCA models as a result of the great disparity in the life cycles among the eight areas. Our preference obviously is in favor of MCDA Models (Roy, 1991), (Qureshi, Harrison, & Wegener, 1999). One common characteristic of these models is their tendency towards more overall robust decision-making by virtue of taking several conflicting criteria into account. Moreover, the multicriteria approach informs decision-makers about alternative choices from different points of view. Among the main advantages of these methods, let's cite:

- They provide a preferential ordering or ranking of alternatives within a multidimensional environmental assessment;
- They are able to process combined quantitative and qualitative data;
- The preferences of various groups of judges can be accommodated;

On the other hand, when employing these methods:

- Experience needs to be inputted into the decision-making process;
- The allocation of weights to criteria is a subjective step and may depend on regional, political and cultural factors.

Such methods are based on pairwise comparisons. Furthermore, as will be seen in the next section, significant weight variations may be assigned to the various criteria by judges. We have thus proposed a Modified Weighted Average Mean method in order to identify a robust ranking of MSWM quality of target areas in the presence of criterion weight variations.

3. Results and discussion

Based on the given dataset, our methodology has progressed through the following steps:

- (1) measuring the consistency and unanimity of data and expert assessments in order to verify the existence of a shared assessment;
- (2) searching for the ranking method that is less sensitive to weight variations among the 8 target areas, should it be impossible to establish a consensual quantitative model;
- (3) interpreting the results and deriving the actions needed by each area in order to improve its ranking in the classification scheme.

3.1. Consistency and Unanimity

The *consistency* of judges is derived from the way they link the SWOT with the overall scores. A judge j gives its overall marks for the area p and criteria c , we note it by $g(j, p, c)$, by approximately calculating a weighted mean of the SWOT scores:

$$g(j, p, c) = x_S \cdot D_S + x_W \cdot (100 - D_W) + x_O \cdot D_O + x_T \cdot (100 - D_T) \quad (1)$$

Here, D_S , D_W , D_O and D_T are the scores corresponding to Strengths, Weaknesses, Opportunities and Threats and g is the overall score given by judge j to area p for criterion c . As an example, the scores given by judge 3 to area 1 for criterion 1 are: $D_S = 75$, $D_W = 25$, $D_O = 60$, $D_T = 42$ and $g = 75$. The assessment process is subjective and influenced by regional, cultural and other factors. When attributing scores to a target area for the 11 criteria, a judge must remain consistent. A judge $j \in J$ will be assumed to

assess *all* criteria in the same way for *all* partners. In contrast, as we observe further, it is more difficult to expect an objective estimation from a judge concerning the weights allocated to the 11 criteria given that this estimation is intrinsically related to the judge's MSWM policy priorities. A closer look to the weights (see Annex: Score tables of all the judges) shows that the importance of criteria has maximal variation (8%) for criteria 2 and 6 and the minimal variation (3%) for criteria 4 and 8. This big variability will be confirmed below. We assess the consistency of judges by measuring their error in deducing overall scores from the SWOT analysis scores. This task simply needs to perform a linear regression in order to calculate for each judge the coefficients x_S, x_W, x_O, x_T of formula (1). With these coefficients, we derive an estimation $\tilde{g}(j, p, c)$ of the overall scores $g(j, p, c)$. A measure of consistency (more precisely of inconsistency) of judge j is the standard deviation $h(j)$ of the differences $\tilde{g}(j, p, c) - g(j, p, c)$ for all $(p, c) \in P \times C$. The greater $h(j)$, the less consistent the judge. The values $h(j)$ are normalized on the interval $[0, 1]$. Then, the consistency of judge j is given by $H(j) = \exp(-h(j))$.

Table 5. Consistency scores of judges

	Judge 1	Judge 2	Judge 3	Judge 4	Judge 5	Judge 6
Standard deviation	3.26	3.85	4.19	3.94	2.03	4.29
Consistency	0.58	0.45	0.39	0.43	1.00	0.37

These values will be subsequently used to calculate aggregated scores and the final ranking. The required decision-making behavior is as follows: the greater the consistency of judge $j \in J$, the greater his influence on the collective aggregated score. Relying on the results above, it can be assumed that all judges are quite consistent since the standard deviation does not exceed 5% of the score's scale.

Next, we require an indicator of the level of judges' *unanimity*. Two judges will be unanimous if their overall scores look similar. A simple similarity indicator is obtained as follows. For any assigned judge $j \in J$ we denote the matrix G_j of overall scores $g(j, p, c)$, $(p, c) \in P \times C$ and the row W_j of weights $w(j, c)$, $c \in C$ (see Annex: Score tables of all the judges). Two judges j, k are unanimous on *scores* when G_j is similar to G_k . Along the same lines, the judges j and k are unanimous on *weights* when W_j is similar to W_k . In extending this approach further we consider the final ranking that a judge is capable of announcing via the scores and weights provided. Given the normalized scores, we adopt the weighted mean as the aggregating operator. Table 6

below then lists the overall scores F along with the ranking each judge has established for all target areas:

Table 6. Overall scores F and rankings with the judges' weights

Judges \ Target Areas	Weighted Mean Agregation						Weighted Mean Ranking					
	1	2	3	4	5	6	1	2	3	4	5	6
TA1	57.	67.3	72.7	69.4	72.1	71.9	TA 5	TA 4	TA 4	TA 5	TA 8	TA 4
TA 2	62.	69.7	76.8	68.1	71.8	74.5	TA 4	TA 5	TA 5	TA 4	TA 6	TA 5
TA 3	65.	71.2	75.4	72.4	70.7	73.9	TA 7	TA 3	TA 2	TA 7	TA 5	TA 2
TA 4	67.	73.2	82.8	72.5	72.4	79.5	TA 3	TA 7	TA 6	TA 3	TA 7	TA 3
TA 5	68.	72.9	80.3	75.1	72.8	77.5	TA 2	TA 2	TA 3	TA 6	TA 4	TA 8
TA 6	58.	69.5	75.5	71.5	73.9	72.6	TA 8	TA 6	TA 7	TA 1	TA 1	TA 7
TA 7	66.	70.3	74.0	72.5	72.7	73.2	TA 6	TA 8	TA 1	TA 8	TA 2	TA 6
TA 8	62.	68.9	70.6	69.0	75.4	73.7	TA 1	TA 1	TA 8	TA 2	TA 3	TA 1

The unanimity information can be more easily grasped by displaying the histograms of the values:

- $\frac{1}{8 \cdot 11} |G_j(p, c) - G_k(p, c)|$, $(p, c) \in P \times C$ – for all the pairs of judges $j, k \in J$;
- $\frac{1}{11} |W_j(c) - W_k(c)|$, $c \in C$ – for all the pairs of judges $j, k \in J$;

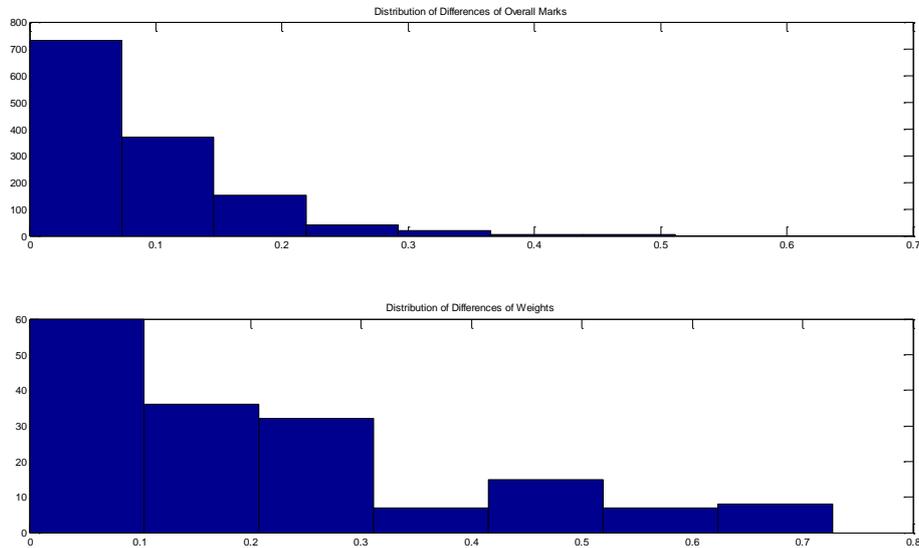


Figure 1. (i) Top histogram: the distribution of $\frac{1}{8 \cdot 11} |G_j(p, c) - G_k(p, c)|$. The populations of the bins are [731, 370, 152, 39, 20, 3, 5]. The mean value of these

numbers equals 0.083 and the standard deviation is 0.0739. This distribution is clearly unimodal, as over 83% of the population lies in the first two bins and the tail of the distribution is thin. In other words, judges are unanimous on overall scores;

ii) Bottom histogram: the distribution of $\frac{1}{11}|\mathbf{W}_j(\mathbf{c}) - \mathbf{W}_k(\mathbf{c})|$. The populations of the bins are [60, 36, 32, 7, 15, 7, 8]. The mean value equals 0.216 and the standard deviation is 0.1849. The first two bins contain only 58% of the total population and the tail of the distribution is thick. Otherwise stated, judges are not unanimous on weights.

The conclusion drawn from these basic statistics is that judges are far more unanimous when assessing the intrinsic qualities of target areas (matrices G_j) than when they are required to define the relative importance of criteria. The importance of a given criterion does not appear to be the same across the various countries. While one country needs to stabilize the "Policy framework", another faces the challenge of managing "Waste Collection". These results strengthen the intuitive notion mentioned above: a judge objectively states the worth of a target area for criterion c regardless of the specific MSWM policy adopted in his country. On the other hand, it is more difficult to expect an objective estimation from a judge concerning the relative importance he assigns to a criterion since his estimation is intrinsically tied to the priorities inherent in his own area's MSWM policy. This conclusion is of great importance for the method developed and results presented in Sections 4.2 and 4.3. It motivates for a ranking method that is less sensitive to the variation of weights.

3.2. Ranking using uncertain weights

The weights $w(j, c)$ that judges assign criteria $c \in C$ can vary over rather wide intervals. Uncertainty is too significant to deterministically establish reference weights that fit "the way of thinking" for the group of judges chosen in the target areas, even though the basic scores provided by judges tend to be quite consensual. The next question raised might then be: is a more qualitative interpretation of experts' assessments available that would lead to a consensus? This consideration will now be examined.

To begin, a reference scoring table can be assembled by considering $G_0 = \frac{\sum_{j \in J} H_j \cdot G_j}{\sum_{j \in J} H_j}$, (Table 7 below) where, the numbers H_j are the judges' consistency values (Table 5). The matrices G_j are the overall ratings given in (Annex: Score tables of all the judges). Each element of matrix G_0 corresponds to the "average" assessment of an MSWM area p with regard to criterion c by the entire group of judges.

Table 7. Reference scoring table G_0 .

	c_1	c_2	c_3	c_4	c_5	c_6	c_7	c_8	c_9	c_{10}	c_{11}
TA 1	66.0	69.1	60.3	70.5	68.8	67.8	63.4	69.9	71.6	70.0	69.1
TA 2	65.0	76.4	70.8	70.9	72.3	66.1	64.9	73.1	73.3	67.3	71.0
TA 3	71.3	72.9	66.3	69.7	74.2	75.2	70.0	66.5	76.7	73.9	68.9
TA 4	69.9	73.9	70.8	71.2	74.2	76.5	76.2	70.0	74.6	75.2	75.3
TA 5	70.5	71.7	72.5	73.5	73.7	74.8	74.2	75.9	75.8	73.6	71.1
TA 6	67.7	69.7	67.0	72.2	74.3	74.9	66.5	69.9	68.5	69.4	63.1
TA 7	66.6	74.2	69.2	74.8	74.3	76.7	63.8	64.1	64.8	71.7	72.3
TA 8	67.8	69.9	65.0	70.6	69.2	71.8	65.9	71.2	67.5	69.6	68.9

Now, given a weights' vector $w = [w_1, w_2, \dots, w_{11}]$ the overall MSW quality of a target area p is calculated as the weighted mean of the scores of row p in the table above:

$$R(p) = \sum_{c=1}^{11} G_0(p, c) \cdot w_c$$

Next, given two target areas p and q , the MSWM of partner p is better than the MSWM of partner q if and only if $R(p) > R(q)$. Of course, this depends on the weight's distribution w . A relevant weights' distribution should then be related to a high value of the probability $prob(R(p) > R(q))$. Furthermore, let permutation σ define a total ordering of the 8 target areas. We want to estimate the probability of this σ -ordering:

$$prob(R(\sigma(1)) \geq R(\sigma(2)) \geq \dots \geq R(\sigma(8)))$$

A large number of total orderings can be found; however, we show that, due to the intrinsic quality of target areas' MSWM (see Table 7), few of them are probable and most of them are simply impossible.

The significant result of these analyses is: even if an objective quantitative model for the MSWM assessment cannot be shared by the group of judges, this section still proves the presence of a consensus regarding the ranking of the target areas. Expert analyses ultimately prevail over policy considerations: this finding argues on behalf of a consensual reference for the target areas from Southern Europe despite individual policy and operational constraints.

With the aggregated scores G_0 there are only 13 (among 40320) possible orderings. A winning order (probability 33%) emerges. 12 remaining orders are found with probabilities extending from 1% to 13%. For all these orders however, the best is target area 4 followed by 5. Then comes the group $\{3, 7\}$, followed by the group $\{2, 6, 8\}$, with 1 holding the end position.

Orders max probable for aggregated scores G_0

Orders								Probability
4	5	3	7	6	8	2	1	0.33
4	5	7	3	6	8	2	1	0.13
4	5	7	3	8	6	2	1	0.12
4	5	7	3	2	8	6	1	0.10
4	5	7	3	2	6	8	1	0.05
4	5	3	7	8	6	2	1	0.05
4	5	7	3	6	2	8	1	0.04
4	5	7	3	8	2	6	1	0.03
4	5	3	7	2	8	6	1	0.03
4	5	3	7	2	6	8	1	0.03
5	4	3	7	6	2	8	1	0.02
4	5	3	7	6	2	8	1	0.02
5	4	7	3	8	6	2	1	0.01

The strong ordering announced has some variations because of the positions of areas inside the groups $\{3, 7\}$ and $\{2, 6, 8\}$. The former group produces $prob(3 > 7) = 0.78$. For the second group we obtain $prob(6 > 2) = 0.69$, $prob(6 > 8) = 0.70$ and $prob(8 > 2) = 0.63$. A visualization of this information follows.

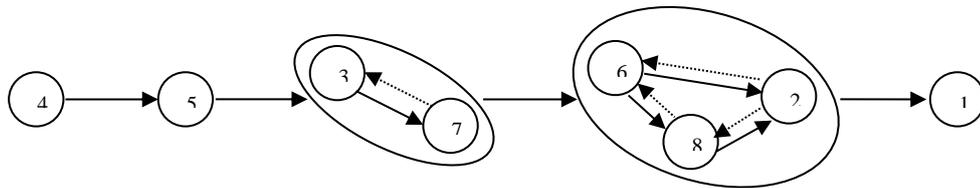


Figure 2. From left to right: best to worst. The ellipse grouping $\{3, 7\}$ is slanted and the shaded arc display the possibility that 7 could be better than 3 for a choice of weights.

3.3. Interpreting the results and improvement guidelines

From this study, it may be concluded that even though no objective deterministic quantitative model for MSWM assessment shared by the entire group of judges actually exists, nevertheless a relatively consensual ranking of MSWM for the target areas can be derived:

- Target areas 4 followed by 5 occupy the top position;
- Target area 3 comes in third followed by target area 7;
- Next come target areas 6, 8 and 2;
- The last position is occupied by target area 1.

It is important to remark that two areas may have similar positions in this overall ranking but not for the same reasons. When target area 3 is at top position for criterion 1, target area 5 is at top position for criterion 3. There are the weights of criteria that permit to obtain their relative position in the overall ranking.

Further collaboration with MSW experts is needed to better explain this ranking. The three top target areas all exhibit the most efficient waste valorization (criterion c_6) with a better position relative to "bio-valorization" (Zaragoza, Alcala la Réal) than incineration (Gard). The position of target area 3 seems paradoxal as it has the highest recycling rate, the highest energy recovery rate and the lowest landfilling rate. To our opinion, deduced from discussions with the members of WASMAN team, this paradox is due to the bad impression that people share about the incineration technologies. The other criteria contributing to the top position of these areas are c_1 (policy framework) and c_2 (tariff system). The areas 3, 4 and 5 are in Spain and France which are in EU since many years. They have put in practice the EU guidelines about MSWM policy and their industrial solutions permit to attain low cost waste treatments. Inner Karst and Larnaka are not completely in line with EU guidelines as Slovenia and Cyprus are new in EU. The consortium of municipalities in Slovenia found the ranking useful for the design of their new waste management plan. On the other end of the spectrum, land filling (Umbria) constitutes the main criterion influencing the poor positioning of this area within the overall classification. Inner Karst (Slovenia) has the same problem as Umbria but with less important waste volumes. There is no more land available in Inner Karst for landfill. Incineration seems a good alternative for these two areas and a working model could be the incinerator of Gard. Larnaka (Cyprus) is at the middle of the spectrum. It is well scored for the criterion 10, Innovative technologies, because it

has installed a new plant (with the EU subventions) for segregation and valorization of waste. But, the actual rate of this plant is about 20% (oral communication during our visit at Larnaka) which is far below the nominal rate 67%. This state of fact is because there is a solely waste stream in Cyprus. The next action of Cyprus should be the organization of separate collection of waste streams as it is actually in target areas 3, 4, and 5. Trikala (Greece) has a good overall valorization rate of waste but the treating centers are far from Trikala and the transportation cost is penalizing. The actual volumes of waste are below the thresholds needed to construct treatment plants in proximity. A transfert station (with or without separation) and transport by train would be an alternative.

4. Conclusion

This research contributes on a methodology for assessing the overall quality of MSWM systems. We show its utility by applying it to a set of eight target areas from Southern Europe on the basis of eleven criteria. This study employed a number of elementary tools from multicriteria analysis and statistics in order to establish the consistency and unanimity of scores given by a panel of experts and provided a robust qualitative ranking of the eight areas. This methodology can be applied whenever similar data are collected.

Further work is needed to better understand the relationship among this ranking and the criteria. We have given already some arguments that explain the position of each target area. Some evident guidelines to improve their MSWM systems emerged from this ranking.

It's a motivating result to verify that quite diverse local MSWM strategies do not prevent WASMAN partners from sharing a consensual ranking of practices and the same ideal reference for MSWM quality. This result can be used to issue pertinent recommendations. Irrelevant MSWM in a given area can be detected through its rank in the list of supervised areas. A set of recommendations relative to the diagnosed area could offer the criteria to be improved first in order to expect a reference area ranking.

Acknowledgments. This paper takes its sources at a 3-year work of the MED WASMAN team. We wish to thank them all for their contribution, viewpoints and passionate discussions.

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5. Annex: Score tables of all the judges

PER SWOT analysis																																												
	C1			C2			C3			C4			C5			C6			C7			C8			C9			C10			C11													
Area	S	W	O	T	S	W	O	T	S	W	O	T	S	W	O	T	S	W	O	T	S	W	O	T	S	W	O	T	S	W	O	T	S	W	O	T	S	W	O	T	S	W	O	T
PER	70	40	60	55	75	55	65	65	65	55	45	70	55	65	50	70	65	55	50	80	45	75	70	55	75	60	50	40	45	60	60	45	55	40	60	35	60	40	80	80	50	55	40	65
GEN	40	60	50	60	85	60	58	65	85	60	65	60	70	70	40	40	80	70	50	60	68	50	45	40	50	45	48	55	60	80	75	85	90	75	55	65	40	70	70	58	85	70	60	48
NIM	80	50	65	53	90	60	66	62	85	48	66	62	89	53	80	65	82	55	60	57	80	70	60	65	67	70	70	66	40	55	65	60	60	88	70	75	85	75	80	60	67	0	60	50
ZAR	55	64	66	55	80	62	70	58	70	72	68	50	70	70	69	60	60	80	50	55	82	60	70	65	87	66	70	60	55	70	50	55	65	70	60	65	78	68	68	60	60	90	70	60
ALC	60	60	55	50	75	75	60	50	85	70	50	40	85	75	65	50	65	70	73	62	80	85	65	55	75	65	70	65	65	72	80	70	72	80	68	60	75	80	70	80	55	60	50	45
TRI	65	60	45	55	65	70	60	62	70	55	80	50	60	75	70	80	60	80	60	82	70	85	73	75	55	62	45	40	65	60	60	55	60	55	50	45	35	70	45	65	50	0	45	40
LAR	65	60	45	55	90	75	60	65	80	70	68	40	82	65	70	70	90	75	80	85	70	80	80	70	55	70	65	50	50	60	55	55	35	55	40	50	65	60	70	65	65	60	70	65
SLO	65	60	45	55	55	75	50	50	55	65	70	65	75	60	60	50	70	85	35	50	85	65	60	55	75	55	70	60	70	60	75	50	70	50	55	50	75	50	65	60	70	50	70	60

PER Overall Rating												
	PF	TS	C	S	D	R	A	C	MP	TI	IA	
PER	56	65	52	60	61	60	57	53	48	58	52	
GEN	51	70	61	63	70	55	43	72	77	57	72	
NIM	64	73	57	72	66	72	60	51	73	78	40	
ZAR	60	70	58	69	65	71	68	60	66	71	72	
ALC	58	69	61	74	67	76	60	70	72	77	54	
TRI	59	66	51	70	70	76	48	61	55	53	30	
LAR	59	77	59	72	83	75	54	55	45	64	64	
SLO	59	61	52	64	67	70	56	64	58	63	62	
Weight	5	15	5	10	7	13	9	7	5	13	11	

NIM SWOT analysis																																												
	C1			C2			C3			C4			C5			C6			C7			C8			C9			C10			C11													
Area	S	W	O	T	S	W	O	T	S	W	O	T	S	W	O	T	S	W	O	T	S	W	O	T	S	W	O	T	S	W	O	T	S	W	O	T	S	W	O	T	S	W	O	T
PER	60	50	60	40	70	60	50	50	65	55	10	60	60	50	45	70	85	65	80	65	50	55	60	55	60	80	40	50	70	50	55	65	60	75	50	40	50	70	60	50	70	80	60	40
GEN	70	60	55	40	85	55	60	50	80	45	40	30	75	65	65	55	80	60	80	60	75	55	75	80	75	65	80	85	65	80	80	85	85	65	80	75	55	75	65	60	80	45	80	45
NIM	85	40	80	30	85	50	75	40	80	40	75	35	75	30	80	40	85	30	65	45	90	20	60	25	85	40	70	40	60	55	60	40	80	40	70	40	80	30	60	50	85	10	50	65
ZAR	70	45	65	55	80	50	70	35	65	40	75	30	60	50	75	40	70	45	65	35	65	35	60	30	80	40	80	30	60	55	60	55	75	45	65	40	70	40	60	35	55	40	60	30
ALC	75	45	65	50	85	50	60	35	65	40	50	45	60	45	55	45	60	40	60	35	75	50	60	30	65	55	55	40	70	40	60	30	75	35	65	35	80	40	70	30	60	50	60	40
TRI	70	45	65	45	65	40	55	30	60	45	70	50	55	50	65	40	70	40	70	40	55	40	60	35	65	35	65	25	65	75	70	65	65	75	85	80	65	45	70	30	60	40	65	30
LAR	75	40	75	35	85	25	65	45	60	70	85	45	85	35	80	55	80	35	50	55	40	60	60	50	55	75	70	30	65	55	70	30	65	35	55	40	70	50	50	40	60	35	60	45
SLO	75	55	75	40	65	50	60	45	65	60	55	35	60	55	65	40	85	40	75	35	55	70	60	45	65	55	60	45	70	40	75	30	75	35	70	35	65	55	75	30	55	55	80	20

NIM Overall Rating												
	PF	TS	C	S	D	R	A	C	MP	TI	IA	
PER	58	70	60	70	75	55	60	68	70	65	60	
GEN	65	65	60	70	70	65	65	70	68	60	62	
NIM	72	70	55	58	78	85	75	77	82	85	85	
ZAR	64	65	66	62	74	75	75	65	70	70	72	
ALC	55	64	69	70	75	72	70	70	75	65	74	
TRI	60	60	56	60	75	65	60	65	68	60	64	
LAR	65	65	50	65	66	60	58	65	68	70	70	
SLO	65	55	60	55	60	55	55	60	60	55	65	
Weight	12	8	10	10	7	15	7	10	6	10	5	

ALC SWOT analysis																																													
	C1			C2			C3			C4			C5			C6			C7			C8			C9			C10			C11														
Area	S	W	O	T	S	W	O	T	S	W	O	T	S	W	O	T	S	W	O	T	S	W	O	T	S	W	O	T	S	W	O	T	S	W	O	T	S	W	O	T	S	W	O	T	
PER	85	50	55	85	85	60	80	65	90	60	0	85	65	85	60	85	80	60	80	55	60	65	75	60	65	90	90	0	85	60	90	60	90	55	90	50	65	85	60	80	85	60	70	70	
GEN	80	55	55	85	95	30	85	40	85	50	65	80	85	60	65	80	85	60	80	65	80	55	90	50	90	60	60	90	80	60	85	55	85	65	85	65	55	85	90	55	85	55	85	60	60
NIM	90	75	90	70	80	65	85	75	65	85	80	65	50	80	85	55	80	65	90	65	90	55	80	65	80	80	90	55	85	70	60	85	90	55	70	85	80	65	85	65	85	0	65	65	
ZAR	90	75	80	65	90	65	75	75	85	70	85	60	85	75	90	65	80	70	85	65	90	70	80	75	85	65	90	65	85	65	75	75	90	60	85	80	90	75	80	70	85	70	75	70	
ALC	80	65	80	70	75	60	85	60	85	70	85	60	80	60	90	70	80	55	65	80	60	80	85	55	90	55	85	60	65	80	80	60	85	60	80	55	85	65	60	80	60	80	60	65	
TRI	85	65	70	80	60	80	75	75	70	80	90	70	65	80	80	75	70	85	85	70	70	80	80	75	85	75	85	75	90	65	85	65	85	70	85	80	85	70	85	55	80	0	85	70	
LAR	80	65	65	85	85	70	85	60	80	85	90	70	85	70	80	65	90	70	65	80	90	60	95	55	60	85	80	60	55	80	70	40	70	70	80	60	75	60	90	60	75	60	80	60	
SLO	65	80	60	80	65	80	75	55	85	65	55	75	80	65	65	80	50	85	55	85	80	60	90	60	80	60	80	60	85	55	85	55	55	80	55	90	85	55	60	80	80	80	80		

ALC Overall Rating												
	PF	TS	C	S	D	R	A	C	MP	TI	IA	
PER	70	75	65	75	65	75	65	80	85	75	75	
GEN	70	90	80	75	80	70	80	80	75	70	75	
NIM	85	80	70	65	80	85	70	70	80	75	75	
ZAR	85	85	85	80	80	85	85	80	85	80	80	
ALC	85	75	85	80	80	75	90	80	80	75	75	
TRI	80	70	75	70	75	75	80	75	75	80	75	
LAR	70	80	80	80	70	85	65	60	70	75	75	
SLO	65	70	70	70	60	85	70	80	65	70	70	
Weight	7	8	10	11	9	10	12	7	8	10	8	

TRI SWOT analysis																																												
	C1			C2			C3			C4			C5			C6			C7			C8			C9			C10			C11													
Area	S	W	O	T	S	W	O	T	S	W	O	T	S	W	O	T	S	W	O	T	S	W	O	T	S	W	O	T	S	W	O	T	S	W	O	T	S	W	O	T	S	W	O	T
PER	75	50	80	60	85	55	70	60	65	55	0	60	80	65	80	70	85	65	80	65	75	60	80	60	0	80	60	65	75	70	85	70	85	60	80	75	75	65	80	75	80	45		
GEN	75	60	65	60	85	55	70	65	80	65	65	60	75	65	65	55	80	60	80	60	75	55	75	80	75	55	65	80	65	80	80	85	85	65	80	75	55	75	65	60	80	45	80	45
NIM	80	50	80	60	85	55	75	60	80	65	75	65	85	60	85	65	85	60	65	55	75	60	70	75	65	80	75	65	50	75	65	70	70	85	80	75	90	65	80	60	85	0	80	65
ZAR	70	55	65	55	80	60	75	65	75	60	75	60	75	60	75	70	70	85	60	75	85	65	80	70	80	70	80	70	60	75	60	75	65	75	65	80	85	70	80	75	70	85	80	65
ALC	75	45	65	60	85	60	70	45	85	70	70	65	85	60	80	60	80	70	75	60	85	70	60	75	65	75	80	70	80	80	70	75	85	70	65	85	70	85	70	70	85	80	70	
TRI	75	45	85	55	85	60	65	60	80	55	80	50	75	85	85	70	70	80	70	90	70	85	80	85	55	70	55	65	65	75	70	65	65	75	85	80	65	75	70	70	0	65	70	
LAR	75	55	75	65	85	65	70	75	70	80	85	45	85	65	80	75	80	65	80	85	70	80	80	70	55	75	70	60	75	65	70	65	65	75	70	80	70	80	70	65	70	75	70	65
SLO	75	55	75	70	65	75	70	65	80	70	70	65	80	65	65	60	85	70	75	70	80	70	70	65	75	55	75	65	70	60	75	50	75	55	60	65	75	50	75	70	75	55	80	70

TRI Overall Rating												
	PF	TS	C	S	D	R	A	C	MP	TI	IA	
PER	62.5	70	60	72.5	75	67.5	62.5	70	77.5	70	72.5	
GEN	67.5	70	72.5	70	70	65	65	72.5	75	65	62.5	
NIM	65	70	72.5	72.5	72.5	67.5	72.5	62.5	77.5	77.5	85	
ZAR	62.5	70	67.5	67.5	77.5	75	75	67.5	70	77.5	77.5	
ALC	60	72.5	77.5	72.5	75	77.5	70	75	80	77.5	77.5	
TRI	60	72.5	67.5	80	75	77.5	62.5	70	70	70	70	
LAR	65	75	75	75	72.5	75	65	70	70	75	72.5	
SLO	65	70	75	72.5	77.5	75	65	65	65	62.5	65	
Weight	5	7	7	8	7	18	7	10	8	13	10	

SLO SWOT analysis																																													
	C1			C2			C3			C4			C5			C6			C7			C8			C9			C10			C11														
Area	S	W	O	T	S	W	O	T	S	W	O	T	S	W	O	T	S	W	O	T	S	W	O	T	S	W	O	T	S	W	O	T	S	W	O	T	S	W	O	T	S	W	O	T	
PER	85	50	75	73	80	63	68	57	62	50	0	62	68	70	82	80	77	67	67	67	72	72	75	72	53	82	60	0	85	67	60	73	80	75	67	80	63	83	75	78	73	82	78	83	
GEN	77	73	58	63	90	68	77	70	70	77	72	73	77	83	67	75	60	78	68	63	82	62	72	68	70	63	68	62	67	75	77	72	53	72	78	60	72	80	65	87	90	65	60	80	
NIM	78	63	63	63	72	75	67	65	73	67	77	60	75	63	70	70	80	82	68	75	77	72	57	73	80	60	80	77	65	75	75	77	73	80	70	70	63	68	70	62	78	0	67	65	
ZAR	68	70	70	67	77	70	72	67	75	70	73	73	80	67	75	63	67	82	75	63	67	78	75	75	72	72	75	78	67	70	72	60	73	83	73	67	70	83	75	83	62	78	68	67	73
ALC	78	68	77	78	87	62	82	58	67	72	70	58	73	62	78	65	53	83	80	77	78	77	73	75	78	73	75	67	75	83	85	68	72	75	68	67	82	65	67	67	83	77	68	68	
TRI	80	70	58	72	77	78	65	63	70	77	75	80	80	75	82	68	63	80	75	72	78	82	73	72	78	75	75	70	70	68	77	73	80	63	80	70	75	77	82	77	65	0	72	80	
LAR	73	67	70	70	67	80	67	68	73	75	75	67	85	67	75	68	75	75	67	68	80	67	82	72	68	75	75	65	67	72	67	70	75	68	70	73	80	70	68	82	83	65	75	82	
SLO	83	85	65	78	75	75	88	78	75	55	63	40	73	75	80	83	45	93	83	75	68	75	60	65	75	75	85	55	83	73	73	78	83	78	73	70	88	93	80	63	83	65	85	73	

SLO Overall Rating												
	PF	TS	C	S	D	R	A	C	MP	TI	IA	
PER	71	67	58	75	70	73	65	71	76	75	79	
GEN	68	76	73	76	67	71	66	73	66	76	74	
NIM	67	70	69	70	76	70	74	73	73	66	70	
ZAR	69	72	73	71	72	75	73	69	73	76	72	
ALC	75	72	67	70	73	76	73	78	71	70	74	
TRI	70	71	76	76	73	76	75	72	73	78	72	
LAR	70	71	73	74	71	75	71	69	72	75	76	
SLO	78	79	58	78	74	67	73	77	76	81	77	
Weight	7	9	4	11	9	10	7	10	10	12	11	

ZAR SWOT analysis																																												
	C1			C2			C3			C4			C5			C6			C7			C8			C9			C10			C11													
Area	S	W	O	T	S	W	O	T	S	W	O	T	S	W	O	T	S	W	O	T	S	W	O	T	S	W	O	T	S	W	O	T	S	W	O	T	S	W	O	T	S	W	O	T
PER	75	25	60	42	80	65	80	65	85	60	0	80	65	80	70	65	75	55	80	60	60	55	80	55	70	80	85	0	80	65	80	65	70	50	85	45	70	60	70	65	80	65	65	70
GEN	80	50	60	70	95	30	85	40	80	60	70	60	70	60	65	85	75	65	75	80	70	60	75	60	80	55	65	70	75	60	85	60	85	50	85	55	50	85	80	75	85	55	85	60
NIM	90	70	85	70	80	65	85	75	75	70	75	65	60	70	80	60	75	60	90	75	90	60	75	70	75	90	60	75	65	70	60	85	65	70	85	75	60	80	75	80	0	65	75	
ZAR	80	75	75	80	90	65	75	80	85	70	90	70	85	75	75	65	75	70	80	75	80	70	85	70	85	65	70	75	70	60	0	0	90	70	80	70	85	70	80	70	80	70	75	60
ALC	75	70	75	75	75	70	75	70	80	65	70	60	75	60	75	75	80	65	75	80	65	75	75	65	85	50	80	65	70	70	70	60	80	70	80	60	80	75	75	75	85	65	75	70
TRI	75	70	70	75	65	85	70	75	75	85	80	70	65	80	75	75	65	85	80	80	70	80	80	75	80	75	70	75	80	65	80	70	80	70	80	70	80	70	80	0	80	75		
LAR	80	65	70	70	80	70	80	65	75	75	85	65	85	70	85	60	85	70	80	75	85	70	80	75	85	70	80	65	65	75	75	65	75	70	80	65	40	65	85	65	75	65	70	75
SLO	70	75	75	75	75	75	80	70	80	65	70	80	80	75	75	70	65	80	70	75	75	70	80	75	80	65	80	65	85	65	80	65	65	80	70	75	65	85	80	65	70	75	70	80

ZAR Overall Rating												
	PF	TS	C	S	D	R	A	CI	MP	IT	IA	
PER	75	70	70	70	70	70	70	80	75	75	70	
GEN	70	85	75	70	80	70	75	70	80	70	75	
NIM	80	75	70	75	75	80	70	70	80	70	70	
ZAR	80	80	75	75	80	80	85	80	85	75	80	
ALC	85	75	80	75	75	70	85	80	80	75	75	
TRI	75	75	70	70	80	75	70	75	70	70	70	
LAR	70	75	70	80	80	85	65	65	65	70	75	
SLO	70	75	80	75	70	75	70	75	75	75	70	
Weight	7	9	10	10	9	10.5	10.5	7.5	7.5	9	10	