Decision-Support in Waste Management: The DeCyDe-4-Sustainability Case

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Abstract

Purpose: Decision-making in a public policy context is a complex issue. One of the greatest shortcomings of many decision support tools is that they are designed in a very sophisticated way, with high complexity, ignoring the fact that not all public policy decision makers have high academic competencies or ample time to spend on decision-making. This suggests that there is room for a decision support system that is quick and easy to use, gives decision makers the factual information they need and is flexible to accommodate a wide range of policy decisions and academic backgrounds. This is particularly important when assessing and improving an area's waste management, where a range of complex and interrelated factors can make decision-making especially cumbersome.

Methods: DeCyDe-4 is an adaptable, flexible and participatory decision-support method that can be implemented to give a "number" to a problem or an issue and to understand the size or the scale of a state/condition, especially in subjective or difficult to quantify cases. DeCyDe-4 is structured in four preparatory, self-contained and interrelated steps and in a final, facilitated stage of participatory decision-making.

Results: DeCyDe-4-Sustainability, a dedicated tool derived from the DeCyDe-4 method, supports decision makers in the prioritization of public spending, including on waste management infrastructure, techniques and methods, to improve local authorities' sustainability.

Conclusions: By removing the bias from decision-making, allowing for constructive participation from all the involved parties, incorporating local data and expertise, and giving numerical results, DeCyDe-4 becomes a valuable tool for waste management decision-making.

Keywords: waste management, decision-support, DeCyDe-4, sustainability

1. Introduction

Decision-making in a public policy context is a complex issue that requires the simultaneous management of a multifaceted problem and of the decision-making process itself, which is often compounded by the conflicting objectives of the various participants [11]. The factors that influence public policy decision making are becoming increasingly numerous and complicated and there is a recognized need to move away from a purely conceptual and theoretical approach to a more pragmatic one based on empirical evidence. More accountability is now required in governmental and societal decision-making [2]. It is therefore not surprising that decision support systems are becoming ever more important in public policy-making.

One of the greatest shortcomings of many decision support tools is that, ignoring the fact that not all public policy decision makers have high academic competencies, they are designed in a very sophisticated way. Consequently, decision makers find them difficult to use and often prefer to rely on their intuition, judgment and sometimes even interests. This is not unreasonable, since decision makers, at any level, do not only depend on hard facts to make a choice but also on other factors such as 'cognitive limitation, behavioural biases, ambiguity and variability of preferences and norms' [7].

Nonetheless, that is not to say that decision-makers would oppose to having a tool that would help them make informed and documented decisions. In fact, research finds that decision-makers, who in general prefer to maintain autonomy and accuracy in their decision-making, would like to receive

information about the available alternatives on which to base their decisions [1]. This information should be adapted to meet the capabilities, interests and also timetables of decision makers [7]. This suggests that there is room for a decision support system that is quick and easy to use, would give the decision makers the factual information they need and would be flexible to accommodate a wide range of policy decisions and academic backgrounds.

These challenges led the authors to develop the 'DeCyDe-4' decision support method, which integrates logical processes and established scientific knowledge and local data, together with local knowledge and experience, in a highly participatory way to give a numerical value to a problem or issue that is considered subjective or difficult to quantify. DeCyDe-4 is a clear and user-friendly method, flexible to accommodate different kinds of decision problems when multiple decision alternatives exist. It offers a framework that supports the decision makers and the stakeholders to understand and justify the main issues that are involved in the process of decision-making and the trade-offs between different decision alternatives. At the same time, it gives them the chance to a real participation, i.e. to incorporate their views, evaluations and perspectives in the process.

This paper presents the DeCyDe-4 method and its implementation through the dedicatedly developed DeCyDe-4-Sustainability tool – a tool that supports decision makers in the prioritization of public spending, including on waste management infrastructure, techniques and method, within the wider framework of sustainability.

2. Method

DeCyDe-4 is a policy oriented decision support method. Its step-wise, cyclical procedure takes the user from the starting point to the expected end point in a logical, step-wise manner. It is a simple, user-friendly and flexible method, able to accommodate different kinds of decision problems when multiple decision alternatives exist. It integrates logical processes, established scientific knowledge and local data, together with local knowledge and experience, in a highly participatory way [3, 4].

In summary, DeCyDe-4 is a spreadsheet-based decision support method, with a strong gamification character [12], which incorporates principles from multi-criteria analysis, public policy approaches, vocational training structures and even basic logic principles from Fuzzy theory (the theory of graded concepts, where everything is a matter of degree).

DeCyDe-4 is structured in four preparatory, self-contained and interrelated steps and in a final stage where the actual decision support work is done. The preparatory steps are self-contained because they can be used *per se*, each step giving specific results. They are interrelated since when put together they lead to the final stage, where the decision is supported, based on facts and data, not on perception and intuition. The following sections outline the steps taken to develop the DeCyDe-4-Sustainability toolbox. The method can be replicated to develop a DeCyDe-4 toolbox appropriate to any decision-making situation.

2.1. Building the database (Step 1)

A main problem in decision making is the lack or insufficient quality of consistent data. DeCyDe-4 addresses this problem through the development of a complete, comprehensive and case-specific database. This step forms the baseline work, as it provides the set of "core" data that are both available and necessary to guarantee the unbiased character of the results of the decision-making process. The core data are organized in a way that supports decision makers to picture the existing situation and understand the problem through numbers.

2.2. Defining indicators and parameters (Step 2)

This step is where the case under examination is structured and modeled.

2.2.1. Part 1: Identifying the salient dimensions and/or perspectives of each case

Each case is defined by a set of indicators and parameters. For example, in the case of DeCyDe-4-Sustainability, sustainability is assessed against four pillars (Fig. 1). Each of these pillars is described by a set of indicators. For example, the indicators of the Environmental Quality pillar include water, waste, air, biodiversity and so on. A set of parameters describes each of these indicators. In the case of Waste, for example, these parameters could include per capita waste generation, recycling rates, amounts of beach litter etc (Fig. 2). It is important to accurately define the case-specific indicators and parameters that are involved in and affect the decision making process.

This is achieved through a participatory process, where the tool developers (i.e. the authors) suggest a rather large set of indicators and parameters, based on research and experience, and decision makers and key actors/stakeholders select the "core" set that is going to be implemented in the decision-making process. The selection can either be done through dedicated structured meetings/workshops or through e-communication.

The involvement of the right decision makers is critical to the accomplishment of meaningful results. Therefore, a stakeholder mapping exercise should be taken in advance to identify those stakeholders/decision-makers that have the ability and mandate to implement the decisions taken.

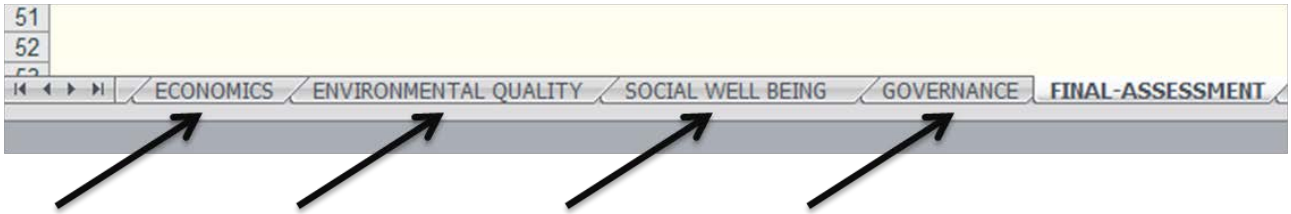

Fig. 1 DeCyDe-4-Sustainability assesses sustainability across four pillars: Economics, Environmental Quality, Social Well-Being and Governance. The tool contains an excel sheet for each of these pillars, with indicators and parameters that users need to score.

2.2.2. Part 2: Scoring through ranges

For each parameter included in the decision-making, the authors define a scoring scale based on ranges (Fig. 2). This step of DeCyDe-4 introduces strategic goals to the system: the ranges are defined based on European Union Directives. When European regulations do not cover the specific parameters, limits provided by International Bodies or Local/National regulations are used. Each range is then assigned a score based on its contribution towards achieving sustainability. The Database (Step 1) is then used to determine the scores for each parameter, based on the current situation. The lowest possible score of 0 is assigned where no data exist for a specific parameter. A score of 1 is assigned to those ranges that demonstrate that significant improvements are required, and a maximum score of 10 is assigned where no further improvements in that parameter are required. This "scoring through ranges" approach converts state-of-<*issue*> indicators, into dynamically evolving indicators. This is because the score attributed immediately gives a reference value and relevance instead of just a snap-shot single figure which stands for nothing but itself.

Scoring through ranges, rather than using precise values, adds flexibility to the method: even data that cannot be specifically identified and have a level of being imprecise or give an approximation can be used, if identified within a range. Thus, all key parameters can be incorporated in the decision process. Lack of a precise value is not a reason of exclusion of an important parameter for DeCyDe-4. This is an innovation that provides the method with high flexibility and integration ability.

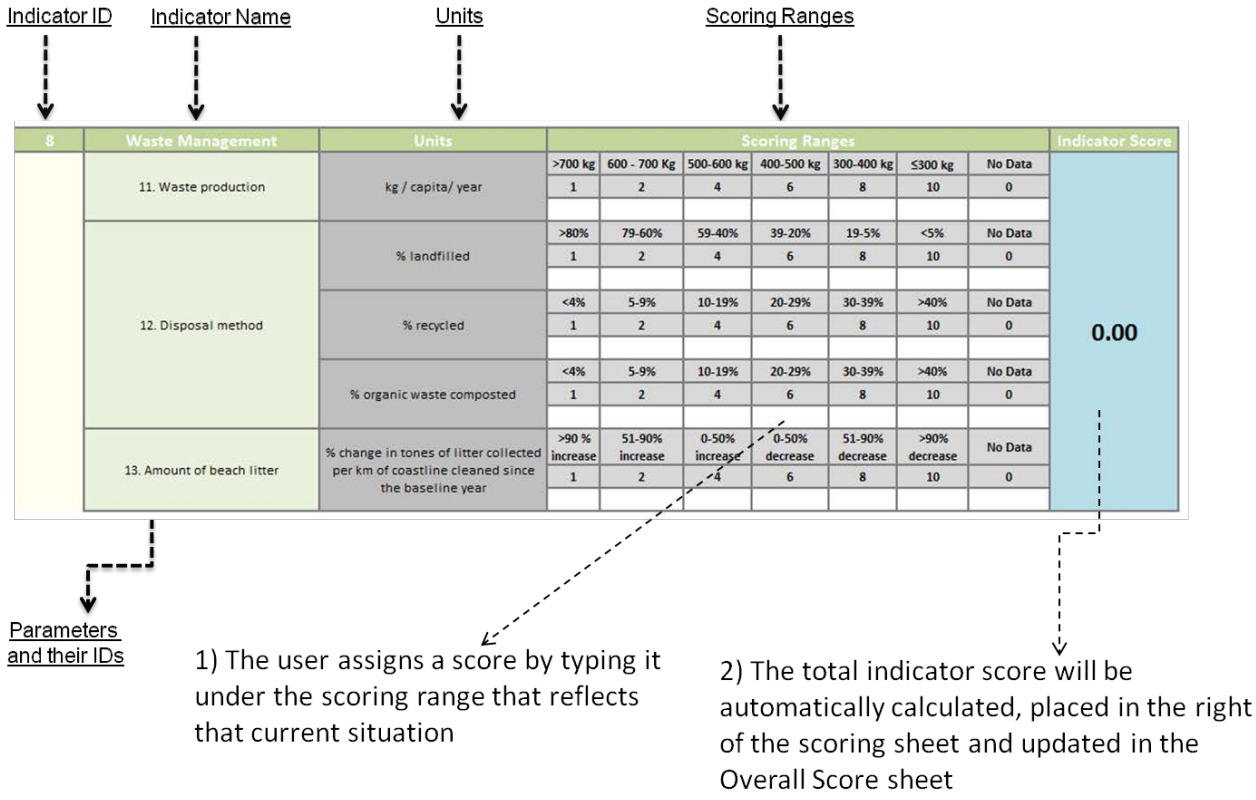

Fig. 2 Waste Management is one of the indicators of the Environmental Quality pillar. DeCyDe-4-Sustainability includes a similar table for each indicator.

2.3. Weighting (Step 3)

When making decisions on complex issues such as waste management and sustainability, it is highly likely that some indicators and/or parameters might be more important to decision makers than others, therefore they should "weigh" more in the decision-making process. The DeCyDe-4 method allows decision makers to weigh each of the indicators and parameter so as to reflect what is most important in their particular area. This is another element of case-specificity.

The indicators/parameters are organized in matrices so that each indicator or parameter is compared and assessed against all other indicators or parameters, based on Saaty's concept of comparing couples [8], using a predetermined scoring scale (Table 1). The number of matrices, i.e. the number of levels that will be incorporated in the decision support method, is defined in step 2. In the case of DeCyDe-4-Sustainability, it was possible to weigh the pillars of sustainability, as one might be considered more important than the others (Fig. 3). In the same way, indicators within each pillar and parameters within each indicator could also be weighted.

The decision makers and stakeholders that participate in step 2 are called upon to undertake this weighting exercise, through well-structure, short and effective workshops. The matrices are presented in a spreadsheet form. An experienced facilitator guides the stakeholders/decision-makers through the weighting process, ensuring that consensus is reached by facilitating conversation among conflicting interests.

Table 1 The DeCyDe-4 weighting scale. If Indicator/Parameter X is extremely less important than Indicator/Parameter Y, then a score of 1/9 is assigned. The scoring continues until all

indicators/parameters are scored against all others. At the end of the process, the geometric mean of the scores for each indicator or parameter is calculated, resulting in a weighted list. When indicators/parameters are inevitably compared against themselves a weight of 1 is assigned. The same applies when two different indicators/parameters that are considered equally important are compared against each other.

1/9	**1/7**	**1/5**	**1/3**	**1**	**3**	**5**	**7**	**9**
←Less important						More important→		

Where:

1/9 and 9	(extremely)
1/7 and 7	(very strongly)
1/5 and 5	(strongly)
1/3 and 3	(moderately)
1	(equally)

SUSTAINABILITY PILLARS	ECONOMICS	ENVIRONMENTAL QUALITY	SOCIAL WELL-BEING	GOVERNANCE	WEIGHTS
ECONOMICS	1	1/7	1/7	1/7	**0.04**
ENVIRONMENTAL QUALITY	7	1	3	3	**0.48**
SOCIAL WELL-BEING	7	1/3	1	3	**0.28**
GOVERNANCE	7	1/3	1	1	**0.21**

Fig. 3 DeCyDe-4- Sustainability matrix for assigning weights to the four sustainability pillars. Scores are assigned horizontally. The purple boxes act as 'mirror lines': when the score of 1/7 is assigned when comparing Economics to Environmental Quality, automatically a score of 7 is assigned to the reverse (i.e. the cell comparing Environmental Quality to Economics). Weights are calculated based on geometric means.

2.4. Facilitated participatory decision-making (Final stage)

When all three steps are completed, the dedicatedly developed DeCyDe-4 toolbox is ready to be operated further: the decision makers can predict how the existing situation will change if, for example, the score of one or more indicators/parameters changes. In this way, they can easily predict how the system will respond should they invest resources to improve a specific indicator or parameter. Additionally, decision makers can also use DeCyDe-4 to forecast how their score will be

affected if they change the weights of specific indicators or parameters.

In the case of DeCyDe-4-Sustainability for example, how will their area's sustainability score change should they invest more in improving their recycling rate? Or how will it change if they consider one sustainability pillar more important than the others?

These forecasting exercises allow decision makers to determine where changes in policy, and in many cases changes in spending, are necessary, basing their decisions on facts and figures rather than on arbitrary judgment. DeCyDe-4 provides them with a "number"/"score", reflected in the Final Assessment sheet (Fig. 4) and based on real data. They have the chance to check the impacts of their decisions, identify the pros and cons of different options, discuss them among the entire group of decision actors and eventually reach an optimized decision.

SELF -ASSESSMENT AND SCORING FOR SUSTAINABILITY RESULTS		
PILLARS	INDICATORS	Indicators Score
ECONOMICS	Economic Opportunity	3.00
	Land Use	10.00
	Tourism	4.00
	Transportation	1.00
		18.00
ENVIRONMENTAL QUALITY	Air Pollution	10.00
	Biodiversity and Natural Resources Management	7.75
	Change at the coast	5.50
	Energy & Climate Change	7.33
	Land use	10.00
	Public Health and safety	10.00
	Waste Management	4.67
	Water resources and Pollution	8.20
		63.45
SOCIAL WELL-BEING	Demography	4.00
	Equity	8.00
	Education and Training	10.00
	Local and cultural identity	0.00
	Public Health and Safety	7.00
		29.00
GOVERNANCE	Policies/ strategies for sustainability	4.86
	Monitoring tools for sustainability	0.83
	Human resources capacity building	1.00
	Implementation of good management practices	1.00
	Stakeholder involvement/ public participation	7.00
		14.69
	TOTAL	125.14
	out of possible	220.00

Fig. 4 DeCyDe-4-Sustainability's Final Assessment sheet presents the sustainability score for the area in question on three levels: overall, pillar level and indicator level.

3. Results: Implementation of DeCyDe-4-Sustainability at Kouklia, Cyprus

The DeCyDe-4 method and the dedicatedly developed DeCyDe-4-Sustainability toolbox as described in Section 2 was implemented through the INTERREG IVC funded project SUSTAIN, in twelve areas around Europe, both at a local and a regional scale [9, 10]. The method was adapted, based on the most important indicators and parameters for each area, as determined by the group of local decision makers and stakeholders, to develop case-specific DeCyDe-4-Sustainability toolboxes. In each case, the toolbox provided the decision makers with a very clear picture of the state of sustainability in their area, often revealing problems and areas of improvement that were previously unknown, or had previously gone unnoticed. This is exemplified in the case of the local

authority of Kouklia, where DeCyDe-4 urged and supported decision makers in taking innovative steps to improve their authority's waste management practices, thus improving the overall sustainability of their community.

3.1. The particularities of Kouklia

Kouklia is a small community of 800 residents, within the wider Paphos district in Cyprus, with some very unique and interesting characteristics:

- It is considered the birthplace of Aphrodite. As such, a large number of tourists visit Kouklia's archaeological site and Petra tou Romiou, Kouklia's coast where according to legend Aphrodite was born. The area is surrounded by archaeological sites and the largest forest park in Cyprus (Ranti's Forest), which extends to the coast. Thus, construction of any type is prohibited. The lack of available accommodation means that the area receives heavy traffic loads as tourists arrive for day-long trips.
- The largest wind turbine park in Cyprus (called 'Oreites') is located within the administrative boundaries of Kouklia.
- Two golf courses have been developed within the administrative boundaries of the community, within the framework of Cyprus's policy for the promotion of golf tourism. Both golf courses include mansions and club restaurants, and one of them also hosts an Intercontinental hotel.
- The Council of Kouklia is comprised of individuals of different educational levels, ranging from basic mandatory education to University degrees.

The above particularities made Kouklia an ideal location for implementing and, to a certain extent, testing the DeCyDe-4 method, and specifically the DeCyDe-4-Sustainability toolbox.

3.2. Implementation of the methodology

Despite the heterogeneity in the level of education, and the experience and skills of the members of the Council of Kouklia, the DeCyDe-4 method was successfully adapted, incorporating the needs and particularities of the area and the decision makers through the development of DeCyDe-4-Sustainability toolbox. Its successful implementation required the organization of an additional workshop, where the authors explained the method, presented the database, provided relevant and area-specific technical and scientific information and discussed the method and tools with the members of the Council. This step was particularly important to reassure decision-makers that the method would provide concrete results to support decision-making, and not attempt to model a system mathematically through a complicated process.

3.3. Improving the sustainability of Kouklia using DeCyDe-4

Waste management is the responsibility of local authorities with community council members taking the ultimate decisions on how to spend public funds to address it. The implementation of DeCyDe-4-Sustainability at Kouklia evidenced the fact that the community had significant improvements to make regarding their waste management. This was an area where their score was particularly low, and as a result negatively affected the community's overall sustainability score. As such the Council:

1. Decided to purchase a shredder to shred agricultural green waste. The shredder was purchased immediately since all Council members were in agreement, as a result of the implementation of DeCyDe-4. The cost of the shredder was 20,000 Euro. The Council aimed to shred about 3,000 tones of agricultural green waste per year, resulting in savings of 8,000 Euro per year from landfill gate fees. Thus, the depreciation period for the shredder was calculated at 30 months.
2. Decided to lay the wood chips resulting from the shredded green waste on the community's unpaved roads as a means of minimizing dust production. This did not only bring additional economic savings to the community from the reduced purchase of inorganic dust suppressants, but also contributed to the further improvement of their DeCyDe-4-Sustainability score.

3. Recognized the need for systematic awareness-raising and training in the community on subjects that are important for a "model" development and growth course, and as such organized home and agricultural composting trainings for its residents. The trainings were provided by experienced scientists on a voluntary basis, had a total duration of 10 hours, and involved residents from Kouklia and the nearby communities. The result was the widespread uptake of composting practices in the community, and related savings from landfill gate fees.

Therefore, through the implementation of DeCyDe-4 at Kouklia, the community was encouraged and supported to implement a set of actions that had the following immediate and direct results:

- Improvement of sustainable infrastructure within the community (purchase of shredder and two home composters).
- Improvement of sustainable practices (use of natural material as dust suppressant on unpaved roads and simultaneous reduction of dust emissions).
- Capacity building for residents and business-people (e.g. through newly acquired comporting skills).
- Networking and improved relations with nearby communities and with the research/scientific community, through the composting workshops.
- Extroversion of Kouklia towards Europe through the presentation of the Kouklia case-study at a European conference.

Through awareness-raising, and participatory and inclusive decision-making, DeCyDe-4 resulted in the immediate implementation of small-scale solutions and applied practices that had a direct effect on the improvement of Kouklia's sustainability.

4. Conclusions

DeCyDe-4 is a robust and flexible decision support method, able to be adapted to specific situations through the development of dedicated toolboxes, the creation of a case-specific database and the incorporation of the perspectives of decision-makers and key actors. This paper presented the DeCyDe-4 method and specifically the case-specific DeCyDe-4-Sustainability toolbox as they were developed and implemented to assess the waste management performance of a small community, within the larger overall sustainability framework. The results show that:

- A robust baseline, in the shape of a comprehensive database is a key requirement for the successful assessment of sustainability through the DeCyDe-4 process.
- Having a trained and experienced facilitator, who supports the decision-making process without imposing her/his views, and who has a good knowledge of the examined case, the date and the local characteristics is very important.
- It is of the utmost importance to involve decision makers and key actors and stakeholders from the very beginning of the process, through their involvement in the selection of indicators and parameters. In this way, they are reassured that the developed toolbox is based on their own views and experience, which are respected by the developers. As such, they are much more likely to be receptive and acceptant of the results and outcomes [5, 6].
- The gamification characteristics of the method are well-perceived by the decision makers since they add 'lightness' and interest to the scoring and weighting process.
- The 'scoring through ranges' method provides decision makers with realistic targets and goals and improves their perceptions on whether these are achievable.
- The process of weighting by comparing couples removes the bias from the weighting process, as decision-makers are not able to 'predict' how the overall weights will be affected by individual scores to compared couples of pillars, indicators or parameters.

- Because decisions are taken through a participatory and inclusive process, requiring the consensus of the decision makers, there is a greater likelihood that they will all commit to the implementation of their decision.
- The Final Assessment worksheet, which presents the overall state of sustainability, clearly identifies 'problematic' areas by their low scores, and promotes agreement on restorative actions.
- The tool makes 'forecasting' exercises particularly easy.

In conclusion, by removing the bias from decision-making, allowing for constructive participation from all the involved parties, incorporating local data and expertise, and giving numerical results, DeCyDe-4 becomes a valuable instrument for waste management decision-making.

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