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FOR ALL IN A FAST CHANGING WORLD****An overview of decision support methodologies
applied in the sanitation sector***A. Ramôa, J. Matos & C. Lüthi, Portugal***REFEREED PAPER 1923**

Recently-developed decision support methodologies (DSM) have been emerging in face of continuing sanitation challenges. As the success of a decision is also dependent on the applied methodology, the present work aimed at analysing: i) their objectives and area of application; ii) the way the decision processes are structured; and iii) the stakeholders' involvement. It was found that the types of selection procedures vary, as well as the technologies under consideration. Used criteria are wide in terms of sustainability dimensions, being either predefined or defined during the decision process. Stakeholders' involvement is clearly a priority in analysed DSM, although differing in range and in the way they are involved. In conclusion, it is believed that learning from experiences of applied DSM will help to better select and adapt them to other contexts.

Introduction

There is a conflict between the provision of decision guidance for appropriate sanitation and the reflection of complex reality (Skat, 2010). Therefore, the sanitation sector is receiving increasing attention when it comes to the development and application of decision support methodologies (DSM) for technology selection. Palaniappan et al. (2008) made an inventory of decision support tools in the WASH sector in developing countries concluding they lack information on economics, financing models, social and equity implications, regional specificity, appropriate user interface, among other aspects. Within the thirteen frameworks for technology assessment reviewed by Skat (2011), only four were specific for sanitation. Two of them were limited to presenting technology options and two others are no longer available. Skat (2011) showed that decision frameworks do not satisfactorily include the system concept and identified transparency issues as well as the risk of exclusion of valid options due to complex scoring procedures or little information on the logic of the evaluation. Other reviews on DSM include MalekPour (2012) who concluded that possible measures to improve technology performance are not systematically incorporated in decision making. In addition, Barnes and Ashbolt (2006) stated that DSM applying sustainability criteria have not been adopted by development agencies.

Previously mentioned reviews have already provided a general overview of sanitation DSM. In the recent past, newly-developed methodologies have emerged. It is therefore important to understand how these new methodologies help to improve decisions in the sector, as well as to identify the aspects that differentiate them. In fact, the success of a decision is also believed to be dependent on knowing which methodology to apply. Consequently, the present work analyses recently-developed methodologies in what concerns: i) their objectives and area of application; ii) the way the decision processes are structured; and iii) the stakeholders' involvement.

Analysis of decision support methodologies**General overview, objectives and area of application**

Recently-developed DSM applied to the sanitation sector were selected from the literature. In order to gather information on real application cases, the methodologies selected for analysis (Table 1) include those which

published, to the authors' knowledge, data on case study application and/or field testing, thus excluding some other interesting DSM like Fenner et al. (2007) who developed a process selection for sanitation systems in refugee camps, Castellano et al. (2011) who established a support and communication tool, or PHSSDA (2007), a manual for sanitation technologies selection to be used in Philippines. Then, analysed DSM were compared in terms of their objectives and area of application, the structure of the decision process and the stakeholders' involvement.

Table 1. Analysed decision support methodologies				
Numbering of methodologies	Main objective	Area of application	Location of case study / field testing	References
(1) Participatory approach	Assessment of sustainable sewage treatment technologies	Urban fringe of Surat city in India	Urban fringe of Surat city in India	Vashi and Shah, 2008
(2) Informatic tool as support in the decision making	Selection of water and sanitation projects	Indigenous communities	Indigenous community of Nazareth, Colombia	González et al., 2009
(3) Technology selection method	Selection of sustainable sanitation technologies	Urban slums	Bwaise III slum in Kampala, Uganda	Katukiza et al., 2010
(4) SANCHIS	Drainage and sanitation system selection	Developing cities	Ho Chi Minh city, Vietnam	Buuren, 2010
(5) Scenario-based multiple-attribute (group) decision approach	Selection of appropriate wastewater treatment technologies	Developing countries	India	Kalbar et al., 2012; Kalbar et al., 2013
(6) Participatory decision making	Decision-making for sanitation improvements	Unplanned urban areas in East Africa	Katanga slum in Kampala, Uganda	Hendriksen et al., 2012
(7) Participatory deliberative planning methodology	Assessment of sanitation infrastructure options	Developing countries	Newly developed peri-urban areas in Can Tho, Vietnam	Retamal et al., 2011; Willetts et al., 2010, 2013
(8) Probabilistic evaluation framework	Technology selection of sanitation solutions	Low-income countries	Nyalenda settlement in Kisumu, Kenya	Malekpour et al., 2013

Six out of the eight analysed DSM are applicable to sanitation systems ((2), (3), (4), (6), (7) and (8)), (4) being the one that most details the system analysis concept. This concept is considered to be important due to the interdependencies found in the segments of the sanitation supply-chain and because, if not considered, there will be the risk of comparing technologies that do not fulfil the same functions. DSM (1) and (5) are specifically applied to wastewater treatment.

DSM (1) was particularly developed for the urban fringe of Surat city in India. Remaining DSM are to be generally applied in developing countries, (2) being specific for an indigenous community, (3) for urban slums and (6) for unplanned urban areas. DSM (4) develops the specificities of new residential areas, existing upgrading areas and high-rise buildings. DSM (5) accounts for different scenarios of decision-making.

Structure of the decision processes

Selection procedures

Decision procedures are structured through a variety of ways and different degrees of complexity. The majority of DSM uses multi-criteria analysis, which is said to rationalise decision making by increasing transparency and acceptability of decisions, to enhance stakeholders' participation and to be easily adaptable to specific local conditions (6). Among the simplest DSM, (1) compares solutions by weighted-scale based

on the calculation of their sustainability index (SI), which results from the multiplication of the importance of indicators and the performance of technologies against them. The calculation of the SI was considered to be systematic, simple and sensitive. In (4), groups of stakeholders were asked to make an analysis of strengths and weaknesses of options, to fill out performance matrix and to weigh criteria. Similarly, in the application of (6), the Proact 2.0, participants were asked to do a SWOT analysis without any pre-given criteria, after which results were presented in a plenary discussion assisted by policy makers and local authorities. The aim of the SWOT methodology was not to come to a consensus but to establish understanding and to provide open discussions. Then, all participants were asked to individually rank the different options in order of preference, and after the individual ranking, the option identified as the “best” was communicated to all participants. In (7), every individual made an assessment of each option against each sustainability criteria and the average of all participant scores was calculated. In (3), a pair-wise comparison by focus groups discussions was performed resulting in scores for indicators which were complemented by the determination of weighted scores by experts. Furthermore, (5) used a scenario-based methodology, in which technologies were ranked for six scenarios representing sets of attribute weights developed to capture the regional and local priorities of urban, suburban and rural areas, thus helping to avoid information loss. The methodology was then followed by TOPSIS, a multi-criteria technique used to rank alternatives.

Finally, in (2), community qualitative attributes were given to elements of pre-defined decision trees, which, in turn, provided as a result the priority order of alternative technologies. Then, the level of consensus was analysed comparing each technology with the overall group decision. Lastly, recognising that reality often deals with a range of possible values, often of poor quality, a probabilistic evaluation was developed in (8). This DSM quantified the probabilities of specific outcomes considering the uncertainties in the evaluation data and applying various quantification methods.

Considered technologies

In general, in order to reduce the complexity of the selection process, DSM include an explicit screening phase which identifies feasible technologies for further analysis, usually considering technical criteria to determine their appropriateness in the study area (e.g. (3), (4), (6) and (8)). DSM (4) is interesting to look at as it includes decision trees as screening aids.

Some DSM consider a reduced number of technological alternatives to be assessed for selection. DSM (1) starts with three technologies believed to be the most realistic alternatives as they are immediately available in the local region, they have been already implemented and data base information is readily available. DSM (5) considers the four most commonly used wastewater treatment technologies in India and in (7), four options are developed based on their proved success at full-scale application and based on local issues. In this last case, a balance was tried between “realistic” and “pragmatic” technologies, and “advanced” or “futuristic” ones. DSM (2) considers two technologies and no explanations are provided. In a context of an increasing number of technological options potentially available, a limited number of technologies might mean that some possible valid innovative solutions are excluded. That is why (4) stresses that facilitators should play an active role in the discussions encouraging to look at solutions that could be judged unfeasible at first sight.

Furthermore, it is to be noted that interesting technological concepts are already present in some DSM. For instance, (7) starts with a range of sanitation alternatives that include centralized, decentralized (at household or cluster scale) and resource recovery options, and (4) includes innovative options in order to create awareness of future possibilities.

Criteria definition, scoring and weighting

The number of used indicators varies from 4 to around 20 indicators. In this respect, (5) stresses that indicators should be judiciously selected in order to avoid excessive time and cost in data collection. Concerning the sustainability dimensions, technical, economic, environmental and social aspects are present in all DSM, although sometimes referring to different indicators, which is understandable due to their contextual relevance. Some DSM focus on practicalities, including local issues as user acceptance or labour availability, while others consider global issues with long-term impacts (e.g. “biodiversity” used in (1) or “global warming” in (5)). Modern aspects are also covered, like the objective of being a “city of the future” (e.g. indicator “positioning the city as innovative” in (7)).

Criteria and indicators were predefined in (2), (3) and (5), while in (1), (4), (6) and (7) they were developed during the decision process itself. In (4), criteria were selected based on a help-sheet list. Also to

note that in (1), scientific validity and credibility of criteria contributed to the acceptance of indicators by all participants.

In terms of scoring, (4) stresses that participants judged options quite differently. DSM (8) tested the sensitivity of the final results to the uncertainty in the input data in order to obtain a deeper insight into the required quality of data and the most influential data on the final quality of evaluations, thus allowing data collection to be redirected. Sensitivity analysis was also performed by (5).

It is also interesting to analyse how weights, i.e., preferences for various criteria, were defined. Weights are particularly important in (5), where they were assigned to different scenarios depicting the most commonly encountered decision-making situations. In (7), an equal weight to each criterion did not provide conclusive evidence for a clear choice in the beginning of the decision process, so participants ended up defining the criteria they wished to give priority, which led to the ranking of options. Furthermore, both (3) and (4) note that specialists and participants groups, respectively, showed different perceptions on weights. Finally, in (8), all the criteria and indicators were assumed to have equal weight, although recognising that varying weights may need to be assigned according to the priorities of decision makers.

Stakeholders' involvement

Recognition of the importance of stakeholders' involvement

All analysed methodologies recognise that stakeholders' involvement is important when taking decisions. The majority of DSM classify themselves as being participatory ((1), (3), (4), (6), (7)) or involve group decision-making (5). Participation is said to achieve stronger democracy and effective processes (1), potentiate the ownership of the projects by the communities (2), engage stakeholders with relevant issues, help results to be locally grounded and accepted (7) and ensure a balance of various inputs (6). However, (6) notes that involvement of end users can add considerable complications as they do not automatically synchronize with experts, also drawing attention to the capacity of end user to (co-)decide in such processes.

Among the most participatory methodologies, in (3), technologies were actually screened by pair-wise ranking through six focus groups discussions with the community. In (6), stakeholders identified preferred solutions among technically and economically feasible ones, connecting knowledge and experiences from scientists, experts and policy makers with those of end users. DSM (5) was implemented by aggregating expert opinions based on an analytical hierarchy process, and then expert judgments were quantified by pair-wise comparison matrices. There is no explicit reference to participation in (8), where intuitive judgements were replaced by probabilistic assessments, noting, however, that the application was demonstrated for a hypothetical situation which is going to be further tested in real case studies.

The transparency and task definition were identified as pre-requisites in order to improve and broaden stakeholders' involvement (1). In (3), the use of pair-wise comparisons, rather than a one-stage ranking, offered an opportunity for beneficiary groups such as women, children, elderly and people with disabilities to influence the choice of technologies in a consensus oriented manner. Technologies were presented to the communities using Information, Education and Communication materials. In (4), presentations about problems and sanitation systems were given to stakeholders as well as an introduction to the methodology and the assignments for participants, which created motivation and promoted a proper preparation. In DSM (7), stakeholders were provided with detailed information about each option, including quantitative data such as costs and qualitative data like social acceptability. Materials handed out were prepared to be understandable at a glance in case little time would have been available (4). From the experience obtained from (4), it is to be noted that the expected duration of participatory workshops might not be enough for a thorough assessment of technologies. Fatigue and the way the participants' views are translated to the group results are also relevant issues, as well as the identification of participants at an early stage and the composition of working groups. Furthermore, potential participants may have to be convinced about the importance of participating. The willingness of all participants to accept the rules is also crucial (4).

Range of stakeholders involved

Stakeholders involved also vary. Four methodologies ((1), (3), (4) and (6)) actually allowed communities or their representatives to be involved in the decision process. In particular, (3) took into account gender, age and representation from the areas under analysis, and (6) considered the diversity and representativeness of participants, presenting data on their background, namely in terms of gender, age, education, marital status, number of children and religion. In (2), the participation of the community itself only served to inform experts and validate chosen technologies.

When it comes to the involvement of experts, the range of stakeholders also differ, which may be justified by context specificities. The stakeholders who participated more were technical experts, policy makers and government departments. Some other stakeholders were not common to all methodologies, namely academia (found in (1), (5) and (6)), non-governmental organisations ((1) and (4)), institutional experts (3), industry experts (5), social scientists ((2) and (3)), finance managers (1), public health specialists (3), and biologists and ecologists (2). In fact, (6) proved to be essential to have diversity in expert groups in order not to become locked in by specific technologies, as too often, individual experts have their own technological preferences based on their specific training, knowledge, institutional affiliation, or on other interests.

Roles played by the stakeholders

Stakeholders have played different roles in distinctive phases of the decision process in analysed DSM. Participation in some cases meant that criteria, indicators and related weights were defined by stakeholders (e.g. (1), (4) and (7)), whereas in other cases, only scores (5) or technological priorities (2) were defined in a participatory way. Arguments were sometimes presented to justify the roles played by the different stakeholders. DSM (6) defended that excluding stakeholders from phases where they have little to contribute makes the process more efficient. For instance, in this DSM, technical viable options were first selected by scientists and technology experts and then end users identified criteria and compared alternatives. In (3), technologies were assessed by community discussions and pre-determined criteria were presented to experts who determined their weights. Collaboratively definition of criteria was said to ensure the criteria held relevance for everyone and also to stimulate the interest of each stakeholder in the process (7).

Conclusions

The present work aimed at comparing recently-developed DSM in the sanitation sector. It was concluded that they mainly focus on the sanitation system as a whole and are mainly applied to urban settings. The used selection procedures, mainly from multi-criteria methodologies to probabilistic evaluations. DSM usually start with a screening phase to help reduce the number of technologies to be assessed. In some cases, a small number of technologies is defined based on existing experiences or available information, which simplifies the decision process but may exclude potential valid innovative solutions. In terms of used criteria, the sustainability concept seems to be already considered. Criteria is either predefined or defined during the process. Scores and given weights were sometimes found to significantly differ, showing the importance of the representativeness of participants. Finally, stakeholders involvement is clearly a priority in all of the analysed methodologies. The range of stakeholders involved (either community or experts) and the exact meaning of their participation is not homogeneous among the analysed DSM, which may be justified by context specificities.

Among the lessons learnt, it can be noted that assumptions, methodologies and results should be defined and presented in a clear and transparent way. In addition, information should be made available to allow informed judgements, stakeholders need to recognise the importance of the decision process, and their involvement should be adjusted to the different decision stages. Nevertheless, some other aspects did not allow for a detailed analysis, probably partly as a result of the restricted length of most research articles and the need to focus on results presentation. For instance, it would be relevant to further analyse the reasons for criteria selection, how was representativeness guaranteed, what were the main difficulties when gathering stakeholders or whether participation actually lead to learning and constructive processes. Therefore, it is considered to be important that applications of DSM are continuously and thoroughly analysed. All in all, although decision making is necessarily contextual and even though the type and quality of information available to decision makers may vary, it is believed that learning from experiences of applied DSM will help to refine their success in technology choice.

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