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Sustainable management of urban soils: Seeking expert consensus through computer mediated decision making

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ABSTRACT

As with air and water, soil systems are an essential finite resource for human existence. Soil characteristics and processes are of high complexity. Moreover, the range of functions and character of soil in an urban setting are considerably more complex, transient and variable. Until recently urban soils did not receive high levels of scientific and political value, importance and appreciation. Thus an understanding of urban soil quality, processes and assessment methodologies for sustainable use lags far behind that of water and air. Recent publication of the soil thematic strategy, raises further the need for policy driven by scientific understanding. Given this, and the context the Aarhus convention, this challenge presents one of even greater urgency. This paper analyses recent case studies that critically assesses online computer mediated decision making, OCMDM, (using an electronic Delphi technique) as a tool to generate urban sustainability metrics and indicators, and for knowledge management for sustainability assessment. The paper describes the methodology of the technique together with its practical application amongst a European wide multidisciplinary expert group engaged in developing a common European methodology for the evaluation of the environmental quality of urban soils for sustainable resource management. The paper concludes with a summary of the identified challenges for OCMDM which would realise its efficient use for sustainable urban management more generally.

Key words: decision support; participation; environmental quality; knowledge capture; heuristic rules.

1 INTRODUCTION

Against the backdrop of sustainable development conventions and legislation, for example Aarhus (UNECE 1998), The Rio Declaration (UNCED 1992) and Executive Order 12898, there is now considerable pressure on local, national and international authorities to place environmental justice at the heart of environmental policy. The reasoning behind the thesis of sustainable development has been articulated through many principles and can be found within the framework/proposals of international law (Graaf de et al. 1996; Kates et al. 2005). A pre-requisite of just environmental policy is the recognition of meaningful involvement of citizens within the decision making process (Kellogg et al. 2003). Thus, environmental justice ensures the right of environmental decisions to be challenged according to the degree of transparency of the decision making process; the degree of public participation and the degree of knowledge equitably distributed to allow informed decision making. Increased efficiencies will arise through avoidance of legal challenges, thus driving environmental management towards more open government and inclusive public participation within environmental policy (Burroughs 1999; Appelstrand 2002; Beierle 2002; Laurian 2003; Soneryd 2004).

Access to information is recognized as a first step to participation within environmental decision making processes (UNECE 1998; UNCED 1992; Executive Order 12898, Kellogg et al. 2003). Principle 10 of the Rio Declaration on environment and development states:

> *“Environmental issues are best handled with participation of all concerned citizens, at the relevant level. At the national level, each individual shall have appropriate access to information concerning the environment that is held by public authorities, including information on hazardous materials and activities in their communities, and the opportunity to participate in decision-making processes. States shall facilitate and encourage public awareness and participation by making information widely available. Effective access to judicial and administrative proceedings, including redress and remedy, shall be provided.”*

This principle is now emerging within national legislation, with over sixty countries now with a freedom of information law.

The internet is recognised as a useful tool for facilitating information for sustainable environmental management (Kellogg et al. 2003). However, available environmental information can be of a highly technical and complex nature. A pertinent example is soils, more specifically urban soils.

Urban soil is a complex environmental issue where current knowledge is limited (De Kimpe et al. 2000; van-Camp et al. 2004). Investigations of rural soils have a long tradition but it is only in the last 2 or 3 decades that research has focussed on soils changed by urban and industrial activities (Hiller 2000). The rapidly expanding urbanisation and industrialization since World War II has consumed large agricultural areas and changes in industrial production have often left these sites disused, and their ecological qualities as well as the composition of their soils are dominated by former land uses. In addition, because urban soils are often developed on composite materials derived from previous uses and exogenous sources, spatial heterogeneity is a typical feature (De Kimp 2000).

Land-use conversion will invariably impact soil properties and processes. Urban soils can consist of many heterogenic layers of material ranging from fine textured material (e.g. loam) to extremely coarse structures, for example gravel and/or bricks (Baumgartl 1998). These layers follow a different scheme in their behaviour towards water uptake and release or in relation to chemical reactions. Spatial heterogeneity thus adds to the complexity of predicting non-linear, long-term changes in soil chemical mobility associated with land-use changes (Hesterberg 1998). Chemicals persisting in the soil may move into plants and the food chain or into surface water and groundwater (Moorman 1996).

There is a higher probability of historic anthropogenic contamination, vertical mixing during development, use of fill from different geologic areas, deposition and/or contributions from the use of pesticides or amendments from other sources in urban soils than in undeveloped areas (Craul 1992). In an urban environment, it is the ambiguity surrounding soil and ground condition, fertility and contamination that problems arise with respect to the design process and the information required for effective appraisal (Barton et al 1995). The process of the assessment of soil properties and function has recently become a major EU policy issue (Europa, 2006).

Soil parameters cannot be considered as isolated entities. They exist within a complex environment, over distinct spatial and temporal scales, and their interaction with other factors within this system has to be considered (Pickett et al. 2001; Pacione 2003; van Kamp et al. 2003; Hossack et al. 2004). All those wishing to participate within environmental decision making processes can not be expected to be expert on all environmental issues. Thus, for enhanced inclusive and informed decision making, diverse information on the status of environmental quality must be translated into a form that decision-makers can understand and use reliably; with confidence. Environmental indicators are ubiquitous but there are many concerns regarding current indicator practice for environmental management (Hull et al. 2003; Ricci et al. 2003). From the policy needs perspective, indicators are inadequate for simple measures of environmental information. From the science (environmental and social) perspective, indicators of complex processes are simplified too greatly. In addition, the constructs and values used to study the environment are not explicit and vary between the disciplines. The terminology is not precise; concealing values, scientific uncertainty and levels of error.

Online Computer Mediated Decision Making (OCMDM) is an integration of online communication technologies with a social science decision support technology known as the Delphi technique. It has potential to generate and deliver knowledge transfer of complex scientific information.

1.1 Background to the Delphi technique

The Delphi technique is characterized by three features that distinguish it from the usual methods of group interaction (Martino 1972; Turoff and Hiltz 1996; Hossack et al. 2004).

(i) Iteration with Controlled Feedback – The group interaction is carried out through responses to questionnaires. The individual involved in the decision making group is informed only of the current status of the collective opinion of the group, and the arguments for and against each point of view. This permits the group to concentrate on its original objectives, without being distracted by self chosen goals such as winning an argument or reaching agreement for the sake of agreement

(ii) Anonymity – the identity of participants are not made known to each other and the interaction of the group members is handled in a completely anonymous fashion.

(iii) All participants views are reflected by statistical group response, median, with the spread of opinion shown by the size of the interquartile range.

The general architecture for OCMDM is a series of timed rounds, thus allowing for asynchronous contributions. The participants are asked to generate information, for example a numerical value or a prediction. In addition, these participants can be prompted to state reasons for their selections. In round one, it can be expected that the results requested would be highly variable (Figure 1).

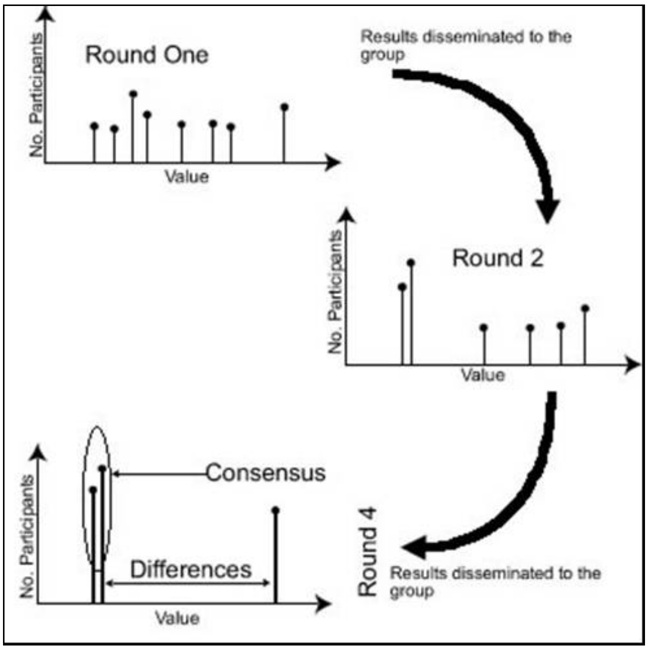

Figure 1: Schematic description of the Delphi Technique highlighting the iterative feedback process.

All results are disseminated to all target participants. The participants are then asked to reconsider their position, round two, now armed with new information from the other participants.

After several rounds, usually four, following the same consultation and feedback method, it is found that the participants are unwilling to change their position (Hajkowicz et al. 2000). In this way, either consensus can be generated or fundamental differences can be highlighted. Input and output from Delphi can be in text or numerical form.

Presented here is a critical assessment of the Delphi technique as the foundation of an online computer mediated decision making (OCMDM) framework. This assessment is based on the technological utility to generate an environmental knowledge base of depth; specifically urban soil. Knowledge depth is defined here as constructs and values, precisely defined, with the complexity of measures transparently available in a manner end users of all levels of expertise can use reliably and with confidence.

The aim of this case study was to produce a knowledge base of guidance and best practice, for analysis and assessment, of urban soil.

1.2 Participants

The group comprised an European Union collaborative network consisting of twenty two target members, from seven institutions, in six different countries throughout the EU: Uppsala (Sweden), Aveiro (Portugal), Sevilla (Spain), Glasgow (UK), Torino (Italy) and Ljubljana (Slovenia). This reflected a wide geographical variation in not only environmental conditions but also cultural and regulatory regimes throughout the EU. The group also reflected discipline diversity with, subsequently, different value sets: five analytical chemists, one environmental geochemist, fifteen soil scientists and one environmental engineer. Between them, there is a cumulative total of over 400 years of expertise. Due to financial and time restrictions, the group could only facilitate face to face general meetings every six months. A sustained cycle of enquiry over a sixteen month period (2003 – 2004) was established to allow in-depth investigation of the OCMDM process and its application.

2. METHOD

2.1 Structure of OCMDM

Each round of OCMDM is essentially an online questionnaire. An assigned independent administrator is responsible to generate unbiased user feedback and questions for all subsequent rounds. Comments are displayed, initially, in the aggregate and in the third person.

The software architecture of the online questionnaire methodology was programmed within an Active Server Page scripting environment and utilised Java applets. To maximise user information, the specification of input (aesthetics, ratings and comments) and output (statistical response and comments) codes were incrementally developed from consequent user information flow. The scripts within each page were programmed as html.

Users were able to see the range of all participant ratings through online box and whisker plots. Normally box plots would only highlight results from the previous questionnaire round. However, any results from any prior round could be used as, for example, a reminder to the group of previous actions and views.

Comments were initially displayed in the aggregate and in the third person. In subsequent rounds, comments were directly quoted with, where necessary, minor editing to:

1. Capture the essence of an opinion while restricting space
2. Correct for Euro-English, where appropriate (Williams 1996)

Results from the input codes were sent via the post method as a form variable to be stored within an xml array. The data was then transferred to an excel spreadsheet. In addition to displaying participant ratings and respective opinions, the spreadsheet calculated:

1. Number of people for and against an issue
2. Ratings for and against an issue as a percentage of the number of participants answering that particular question.
3. Median value of responses

The excel spreadsheet for the round was then printed and analysed. The analysis filtered, aggregated and summarised discussions and ideas. This laid the foundation for the main issues and areas requiring the groups' comments and ratings.

The group was presented with a goal to develop a "soil quality index for urban soil assessment". The group was asked the following questions:

Q1 Did they agree with the wording of the goal?
Q2 List the parameters that are required for a Soil Quality Index (SQI) for urban soils
Q3 Can these parameters given in Q2 be listed in a hierarchical order (i.e. in an order of importance)?
Q4 What else is required for an appropriate SQI for urban soil management?

For questions requiring agreement (Q1 and Q3) a bipolar scaling mechanism, a Likert Scale (Trochim 2002), was utilized to separate the subjective levels of agreement/disagreement between participants. For all other questions, a comment box is supplied for participant responses (Fig 2).

In subsequent rounds, all relevant statements, statistical summaries of agreements, opinions and new statements generated were reiterated back to participants (Fig. 3). Relevant is defined as those statements, statistical summaries of agreements, opinions and new statements that are directly related to the Goal in question and do not overload the workload of the next round. There was always the opportunity to comment on any statement.

Due to the complexity of the subject matter generated and the large amount of information required for assessment, emerging themes were given separate web pages. Incrementally developed was the opportunity for participants to self-assess their expertise.

In all rounds, consensus is defined as the situation where participants generate no comments against a position, accepted by all but one participant. If subsequent rounds followed a consensus decision, the consensus position was presented again with an opportunity for participants to comment.

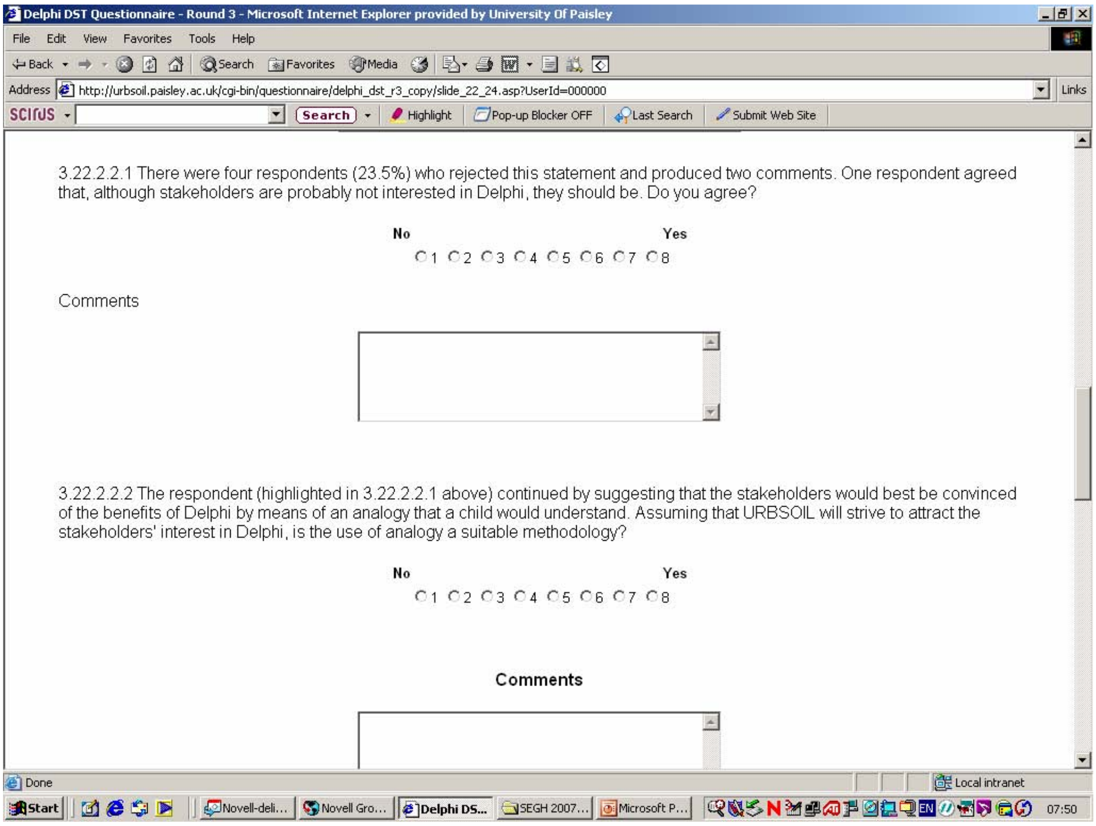

Figure 2. Screen capture of OCMDM display. Note the ability of participants to rate the agreement with the statement and comment box

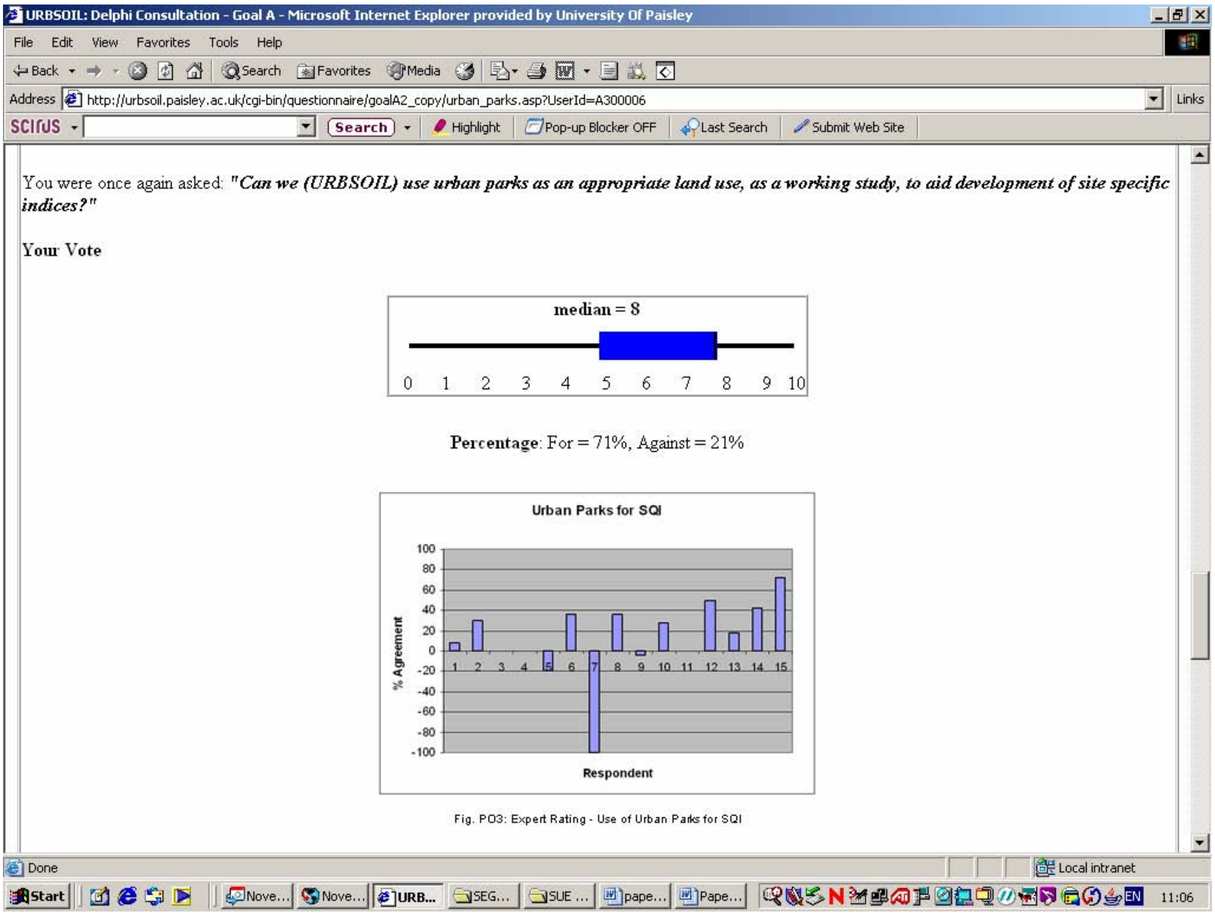

Figure 3: Typical view of box plot and comments returned to the Group. The graph describes expertise rating returned during the preceding round.

2.2 Appraisal of OCMDM

OCMDM was compared to other group communication and decision making processes available to the expert group. These were

- (i) General meetings
- (ii) E-mail
- (iii) Online forum

E-mail and online forums were assessed as participation per week over a two month period. Participation was liberally defined as any message by any member addressing a group within the expert group that included the investigating author and any two URBSOIL institutions.

OCMDM was appraised for its utility for transparent output and inclusive participation.

3. RESULTS AND DISCUSSION

3.1 Participation

Table 1 presents the lowest and highest participation rates for each communication method available to the expert soil group. It shows that general meetings have the highest participation rates overall. However, with only one participant less, it can be said that the online Delphi process is relatively comparable to general meetings in terms of inclusiveness.

The relatively high participation rates can, in part, be explained by continual use of reminders. This is highlighted in Figure 4, which shows a stepwise increase in registered participants and completed questionnaires each time a reminder was circulated to the expert group.

Communication Method	Highest (Value)	Highest (%)	Lowest (Value)	Lowest (%)
General Meetings	18/21	86%	9/21	43%
E-mail	15/21	71%	3/21	14%
Online forum	8/21	38%	1/21	5%
OCMDM	18/21	86%	8/21	38%

Table 1: Group decision making methodologies available to the expert soil group including participation statistics (Participation was liberally defined as any message by any member addressing a group within the network that included the investigating author and any two URBSOIL institutions)

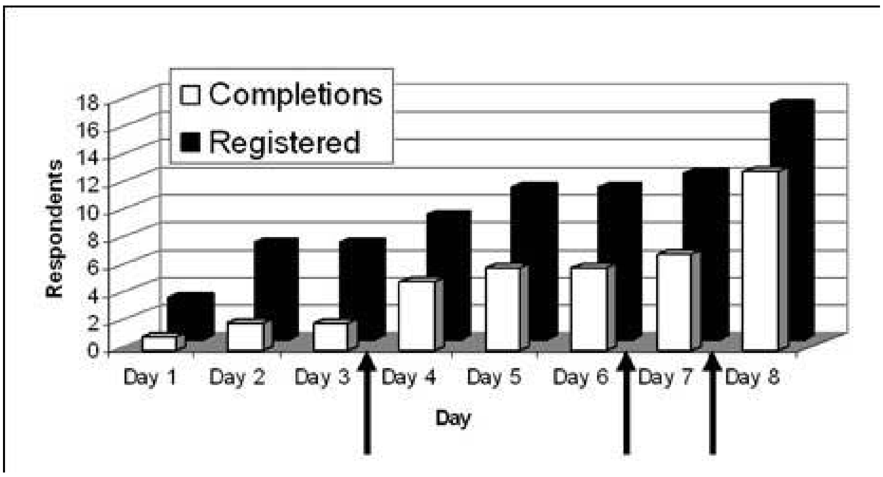

Figure. 4: Timing of participation and response for OCMDM: black arrows indicate when reminders were given to the group

3.2 Process Output

a. Consensus Generation

Figure 5 highlights the maximal recorded shift of opinion throughout the exercise. It relates to the expert group's percentage rating of personal agreement with the proposal: knowledge of urban soil type is required before proceeding with estimation on urban soil quality.

A rating of 100% indicates full agreement with the proposal.

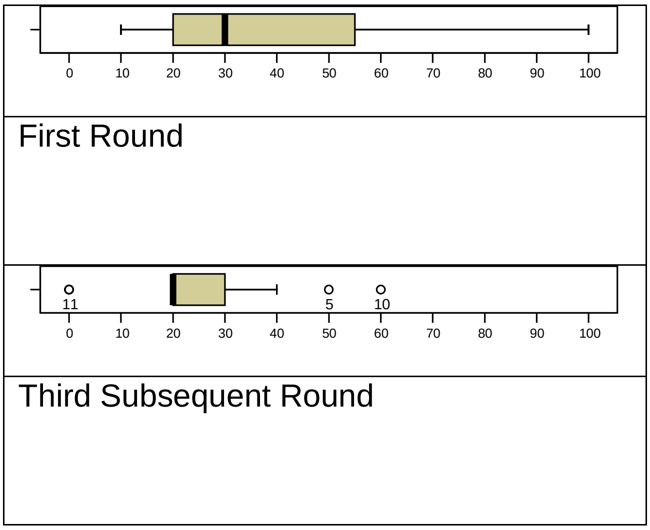

Figure 5: Box Plots highlighting the greatest change in consensus of expert group opinion between one round (top) and a third subsequent round (bottom) of OCMDM.

Figure 5shows almost full disagreement with the proposal within three assessments. However, there is no outright consensus: One person, respondent ten, is still in agreement with the proposal.

As Figure 5 represents the greatest shift in opinion, it highlights that expert opinion was not found to radically alter throughout the exercise. With iterative questioning and with little alteration in opinion, output within this exercise suggests OCMDM to be robust and precise.

b. Decision Trees

Figure 6 highlights OCMDM's utility for development of enhanced decision trees through heuristic (i.e. "rules of thumb") capture of knowledge. Knowledge capture relates to description, analysis and interpretation of urban soil systems. Output can be described as a fuzzy rule based decision tree

Fuzzy rule based decision trees differ from traditional structures because of the degree of depth contained within each node and branch. For each choice presented, there is:

(a) A median value (between zero and ten) highlighting collective rating of the option
(b) Percentage for/against, highlighting the degree of consensus for a particular option.
(c) Arguments for/against an option with an expert rating against each comment to add weight to more informed opinions

Information is concise and written in a non formal manner. In other words, OCMDM has kept it simple. This enhances the ability of non experts to reason as experts through rapid digestion of key issues within a complex subject domain, such as urban soil and sustainable urban soil management.

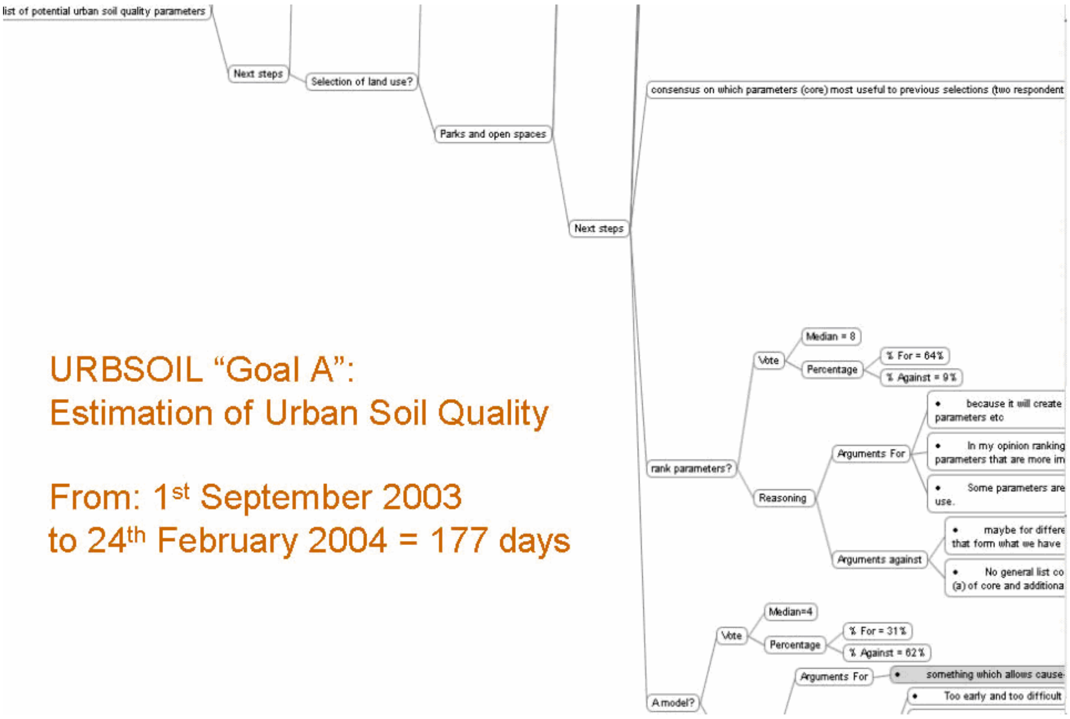

Figure 6: One small section of a discussion ‘branch’ of the process decision trees generated by the OCMDM methodology

Despite these achievements, OCMDM has encountered significant technical inertia. This culminated in the rejection of the tool at a general meeting of the URBSOIL group in June 2004. The reasons are many, some more tangible than others. Presented here are the main barriers identified through group discussion, email and one-one interviews.

Currently the process of OCMDM is too long. Some participants feel the questions asked of them too many and repetitive. Given the workload pressures they are already subjected to, even a small amount of time devoted to this process is too great. Additional comments indicate that the time between successive rounds is so long that they cannot maintain focus on the discussion. Some also suggest that no reward for their efforts provide little incentive for contributing. This contrasts with process of academic paper submission and publication where a structured incentive exists within the academic community.

4. CONCLUSION

This paper has demonstrated Online Computer Mediated Decision-Making, a marriage of the Delphi technique with Internet technologies, to be as inclusive as general meetings, robust and precise. It highlighted the tool's utility in generating fuzzy decision trees, environmental information of depth, where underlying assumptions and disagreements to statements and indicators have been captured. Such fuzzy decision trees enhance the ability of non-experts to reason as experts through rapid digestion of key issues within a complex subject domain, such as sustainable urban soil management. Despite these achievements, the study group cancelled the use of the tool. The length of time to complete a perceived repetitive process, together with a lack of incentive identified as major challenges. The implication is that, as it stands, the tool would have difficulty sustaining support within the wider environmental arena, as it would exacerbate a decision making process already complex and time-consuming. To gain the support potential end-users requires creating more efficient throughput of process and effective, bespoke, means of incentive.

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