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Stakeholder Categorisation in Participatory Integrated Assessment Processes

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ABSTRACT

This paper illustrates how card sorting, a knowledge elicitation method taken from the fields of clinical psychology and knowledge engineering, can be used successfully to elicit stakeholder categorisations from stakeholders in order to inform the design of agent-based models. The paper also describes how such a method can be incorporated into a long-term model-building-as-learning participatory process for the development of sustainable water management solutions.

Using this method, it was found that, of the recommended criteria cited in the literature for use in stakeholder categorisations, *function* and *policy networks* were also used by stakeholders in the Swiss case study. However, criteria that are currently important to modellers, i.e., *scale* and *aggregation*, were apparently not important components of the stakeholders' own mental models of the system. Of the novel criteria that were elicited from the stakeholders, the criteria *working relationships, groups who influence,* and *roles in specific goal implementation* have been used to specify interaction diagrams for the design of agent-based models of stakeholder interaction in the Swiss case study. It is recommended that the *working relationships* criteria is of general use in other stakeholder analysis tasks.

Keywords: integrated natural resource management, integrated assessment, social learning, group model building, water resources management, agent-based modeling.

1. INTRODUCTION

Scientists often divide domain entities into different categories to aid analysis of that domain. The benefits of a good categorisation are twofold; it constrains the investigation, and structures it. Usually scientists develop such categorisations from their perspective as observers of the domain and, as such, these categorisations are embedded in some theoretical perspective on how a system functions. These we term analytical categorisations. Amongst groups of stakeholders, each stakeholder will have their own categorisations, i.e., categorisations that are meaningful to them and that they actually use to interact with, and describe, the stakeholders around them. These we term stakeholder-derived stakeholder categorisations. There is inevitably a difference between analytical stakeholder categorisations and stakeholder-derived ones. Both perspectives are important to capture when trying to analyse stakeholder networks, the former to aid formal analysis and the latter to create a model of the system that reflects the mental models [1] of the stakeholders involved. However, ideally, the process of model development should uncover and eliminate potential discrepancies between the perspective of the analyst and the reality as perceived by individual stakeholders.

This paper derives from work being carried out in a major city in Switzerland, as part of an EU funded research programme called FIRMA (Freshwater Integrated Resource Management with Agents[1]). The goal of this project is to carry out and compare case studies from across Europe that develop solutions to water resource management problems through the use of participatory processes and agent-based modeling techniques (see [2, 3] for more information on agent-based modeling). The modeling is ''agent-based'' since models will be used which explicitly represent the behaviour of the city's stakeholders. The process is ''participatory'' since the stakeholders will actively participate in a process of model and solution development.

As a preliminary stage in developing agent-based models of the city's water management system,[2] stakeholder categorisations were needed. As Bakker et al. [4] writes,

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[1]see http://www.firma.eawag.ch and also http://www.cpm.mmu.ac.uk/firma

[2]Henceforth, termed ''the Swiss case study.''

such categorisations are useful ''heuristics with which to locate stakeholders'' (p. 14). More specifically, categorisations are needed in order to identify the structure of groupings and interactions between stakeholders. For this purpose, there exist a set of recommended categorisations elicited from the literature [4]. However, since Bakker et al. point out that these categorisations are domain specific, it was decided that stakeholder categorisations should be elicited for the Swiss case study, and that the source of these categorisations should be the stakeholders themselves, i.e., stakeholder-derived categories would be sought.

This paper therefore describes the novel application of an old technique, card sorting, for eliciting stakeholder categorisations. To date, this method is not included in the family of methods used in participatory or group model building [5–7]. It has origins in methods used in experimental psychology such as the ''grouping task'' [8] used to elicit the underlying structure in which people store knowledge in memory. It has proven utility as a knowledge elicitation method in the fields of knowledge engineering [9] and requirements engineering [10]. This paper demonstrates how this method can be properly used to elicit stakeholder categorisations from stakeholders. The results of this elicitation exercise are then used to identify which of the recommended criteria can be used as stakeholder-derived categorisations in the Swiss case study and which stakeholder-derived criteria are unique to the case study stakeholders. The stakeholder-derived criteria will be used to inform the design of modelled stakeholder interaction networks.

Section 2 introduces the concepts of stakeholders and stakeholder categorisations and provides an overview of the recommended stakeholder categorisations. In addition it provides an overview of the Swiss case study and the role of card sorting in the context of the participatory process being employed. Section 3 introduces the card sorting methodology in principle and then in practice in this case study. Section 4 describes the results of the elicitation process. Section 5 discusses the results and explains the advantages, disadvantages and adaptations of the card sorting method for this case study and for long term participatory processes in general. Section 6 draws conclusions from the results of the study and proposes future work.

2. STAKEHOLDERS, NETWORKS, CATEGORISATIONS AND THE SWISS CASE STUDY

2.1. Stakeholders and Their Networks

It is important to point out that a stakeholder should not be confused with the general public at large. A stakeholder is only defined in reference to a particular issue. Accordingly, numerous definitions exist. The most appropriate definition for this study derives from [11]: ''A stakeholder is an individual or group influenced by – and with an ability to significantly impact (either directly or indirectly) – the topical area of interest.'' Weaker definitions are also used elsewhere. Stakeholders, for example, may merely be those who perceive themselves to be affected by an event or activity, for example, a government policy change [12].

A key aspect of stakeholder analysis involves identifying potential stakeholders and their interaction networks. Stakeholder interaction networks are the formal and informal connections that link individual stakeholders and stakeholder groups. These structures determine the flow of ideas, plans and goals between stakeholders. Stakeholder networks may be more or less organized. The more advanced the discussion about an issue, the more stakeholders will already be organized in formal and informal groups with established patterns of communication. Generating categorisations of stakeholders is being promoted as a necessary step in analysing stakeholder and institutional networks [4]. Once such networks have been analysed, they can be modelled.

2.2. Recommended Stakeholder Categorisations

Bakker et al. [4] carried out a review of stakeholder categorisations that were used and recommended for water resources management. Every categorisation has two parts: a criterion for dividing the stakeholders, and a list of categories into which they are grouped according to the criterion. Six general criteria and associated categories were elicited (see Table 1).

2.3. The Swiss Case Study

The city at the centre of this case study is one of the largest in Switzerland and operates a supply-oriented water management policy that is increasingly perceived as unsustainable. The dominant policy over the 20th century has been characterized as risk-averse ''worst-case planning'' [13] in which past increasing demand patterns have been expected to continue and supply capacity has been built to meet a level of demand based on the ''upper side'' of possibility. This policy worked well until the 1970s in that it met the legal requirement for water supply security and, while demand increased as expected, it also met the city norm for high water quality. However, problems began when there were two contradictory responses to a particularly dry summer in 1976 in which demand peaked close to the maximum level of supply capacity. The first response was that the water utility increased supply capacity to avoid future problems. The second response was that consumer demand fell in an unprecedented fashion due to increased water saving combined with a general decline in water-using industries. The result was that supply capacity has increased to the point that capacity is now approximately 2.5 times daily demand. Such over-capacity increases the standing time of the water in the supply network and therefore puts at risk the sustainability of the hitherto high standards in water quality that the city has enjoyed. Consequently there has been a call

Table 1. Recommended criteria (adapted from Bakker et al., 1999).

Criterion	Explanation	Categories
Scale	Refers to the resolution of the stakeholder's sphere of influence	Global/national/regional/river basin/local
Tier	Refers to whether the stakeholder has a role in planning or implementing activities in the water management system	Strategic/operational
Function	Refers to whether the stakeholder sets policy, sets regulations, or operates services in the water management system	Policy/regulatory/operational_services
Aggregation	Refers to whether the stakeholder represents an individual or a group of individuals	Individual/collective
Thematic networks	Groupings of stakeholders with respect to a specific task	e.g., water suppliers/water sewage managers
Policy networks	Groupings of "likeminded people that cluster around agents of action . . . to promote certain policies and edge out others"	e.g., anti-smoking lobby/construction industry lobby

for a reduction in supply infrastructure and the development of demand-side policies, rather than supply-side ones.

The development of suitable demand-side policies is hampered by a number of factors. First of all, there is a problem of perception about the water supply management system and what needs to be done to improve it. For example, whilst most stakeholders believe that water saving is a good policy to promote, the water utilities are concerned about the threat to water quality and to their profits, given the need to cover large fixed costs incurred from earlier investments in supply infrastructure. Additionally such conflicts are exacerbated by poor communication between the different stakeholder groups and conflicting institutional norms, e.g., the long-standing norm of risk-averse supply security versus the comparatively newer norm of public utility efficiency. Finally, the city operates a form of direct democracy which means that the residents can vote for or against water utility proposals for change (e.g., price rises). This means that the utility will not be able to improve efficiency or reduce demand without developing strategies to the public's liking.

The water utility and the city as a whole are therefore in the position of having to investigate new ways of managing the system that can resolve a range of conflicting stakeholder goals.

2.3.1. The Actors' Platform

The role of the Swiss case study team is to bring together the city's water management stakeholders within a discussion group, referred to here as an *actors' platform*, as part of a long term participatory process lasting from Autumn 2000 through to Spring 2003. During the participatory process, models are being developed which will lead to:

- the exploration of alternative demand management and efficiency strategies;
- the investigation of likely trends in consumer demand;
- the identification of institutional problems; and
- an increase in knowledge sharing, group learning and communication amongst the stakeholders.

The stakeholders included in the actors' platform include city representatives of the water utility, the wastewater utility, a manufacturer of water using technologies, the architects' association (SIA), the plumbers' association (SSIV), the consumers association, the association for water and gas utilities (SVGW), and the city council.

2.3.2. The Participatory Process

It is important to be aware that the card sorting occurs as a part of a much larger integrated participatory integrated assessment process (see Fig. 1). We are developing a model-building-as-learning participatory process [14] that is tailored for stakeholder participation over a period of years [15]. In our integrative approach, methods from the fields of knowledge engineering, operations research and systems dynamics are used to involve stakeholders in knowledge elicitation, model building, model validation and social learning [16].

Once an initial meeting has be carried with the stakeholders to make an initial problem assessment, there are two

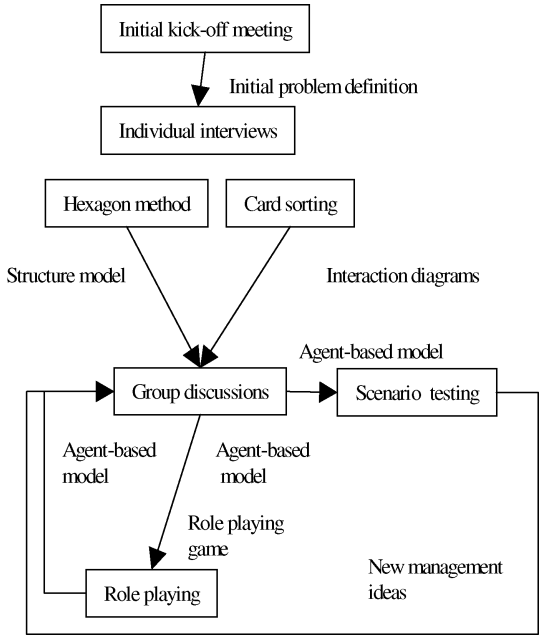

Fig. 1. The Overview of the Process (boxes represent stakeholder activities; arrow labels represent inputs/outputs of these activities).

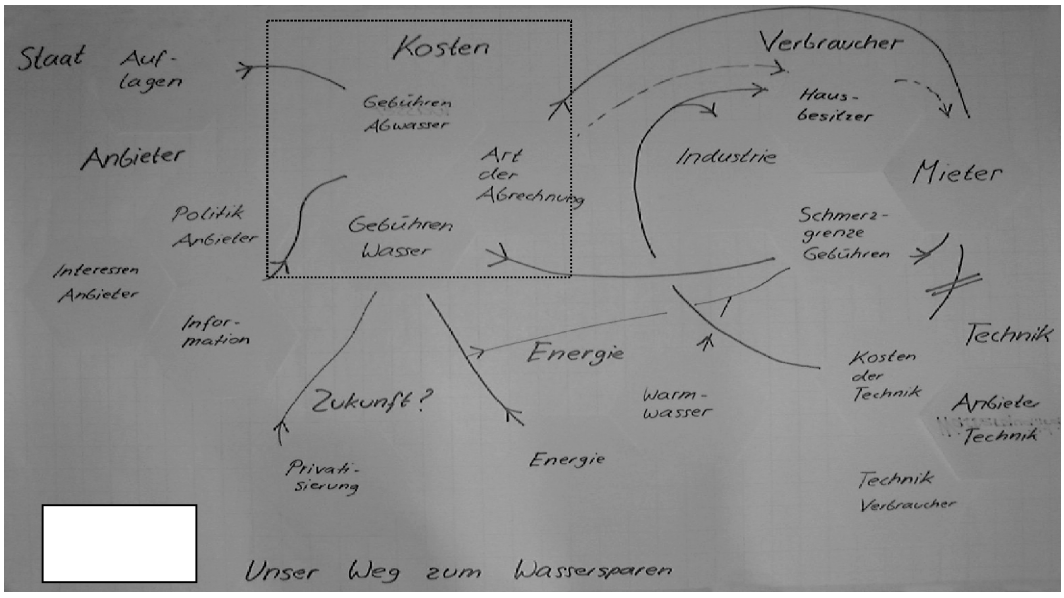

Fig. 2. A completed mental model as elicited from a stakeholder using the hexagon method.

modes of interaction between the researchers and the stakeholders: individual interviews and group discussions.

Individual Interviews. In the first mode, individual interviews are used to elicit stakeholders' mental models [1] of the management system. To do this, two methods are applied. Firstly, a version of the *hexagon method* [17], derived from operations research, is used to elicit system structure and causal relationship knowledge (e.g., knowledge such as ''climate affects water demand''). The hexagon method involves asking the stakeholder to write out on separate hexagonal cards key system concepts that relate to the problem defined in the kick-off meeting (in this case: the impact of water saving and water supply efficiency measures on the sustainability of the management system). The stakeholder is then asked to group the hexagons into semantically contiguous groups and provide these groups with a category label. Figure 2 illustrates a completed mentalmodel elicited from one of the stakeholders. The dotted box overlayed onto the model highlights one such cluster of hexagons (''Gebühren Wasser'' – *water charges*, ''Gebühren Abwasser'' – *waste water charges*, ''Art der Abrechnung'' – *type of water bill*) relating to the group category ''Kosten,'' i.e., key concepts related to *consumers' water costs.*

Once clusters have been formed, using a maximum of 15 hexagons, then the stakeholder is asked to draw links (arrows) between hexagons or clusters which denote the most important relationships (causal or otherwise) between concepts. An example in Figure 2 is the link between ''Privatisierung'' and ''Gebühren Wasser'' which suggests that the stakeholder believes that privatisation of the water utility will have an affect on water charges for the consumer. Finally, the stakeholder provides a descriptive name for the model, in this case ''Unser Weg zum Wassersparen'' – *our way to water saving*. In this way personal perspectives about the concepts and inter-relationships of the system are elicited. The hexagon method can be viewed as being similar to grounded theory techniques [18] used for carrying out qualitative systems analysis, except that rather than the researcher doing the analysis, the subject (stakeholder) is helped to provide their own.

Card sorting, the subject of this paper, is the second method applied within the individual interviews and is used to complement the knowledge from the hexagon method by eliciting stakeholder-derived stakeholder categorizations and interaction networks. The latter provides a stakeholder-oriented mental model, e.g., knowledge that the water utility has a contract with particular architects or that the architects' behaviour is overseen by the Swiss Architects' Association who are responsible for setting institutions and norms.

Group Discussions. In the second mode of interaction, relevant stakeholders are brought together within *the actors' platform*. This is where group learning takes place. A variation of the *nominal group technique* [19] is used to share knowledge amongst the actors, generate consensus on underlying model structure and interaction networks (using the mental models elicited in the individual interviews) and identify important issues and problems. Further learning and scenario testing is carried out in the actors' platform through the development and use of different types of models. Each type of model has a different function and they are presented to stakeholders in the following order:

- *Paper-based structure model* – this is a static model depicting links between system goals, policies, measures

and possible outcomes together with responsible and affected stakeholders. Its function is to represent to the stakeholders a first synthesis of the individual mental models. With this type of model they can begin to explore the diversity of the possible outcomes of policies and validate the structure models.

- *Role-playing agent-based model* – the structure models and the actors' networks are used to develop an agent-based model. This is represented to the stakeholders as a role-playing game. Each of the main stakeholder roles are represented in the game and when the stakeholders play the game, they take on these roles and become embedded within the model. In the game, there is a water utility management role, a waste water utility management role, a water technology manufacture role, a housing association role (responsible for buying and installing water-using household technologies, and therefore water demand) and a politician role. Their activities (e.g., advertising; maintenance of water supply network, etc.; technology production) are controlled by a set of city institutions (i.e., *strategies, norms and rules* [*20*]). The novelty of this game is that players can try to change these institutions and take active part in a possible management scenario. As in [21], the game is used at this stage for model validation and stakeholder acclimatization purposes, i.e., to enhance future ownership and legitimacy of computer models. Stakeholders are also asked to take on roles that they do not normally have in the real world so that they can learn each other's perspectives of the system. The game is additionally used for a further round of knowledge elicitation (e.g., to elicit how institutions are altered and in what circumstances by the stakeholders).
- *Computerised agent-based model* – the findings and adaptations made to the game are then used to implement a computer model of the system. Interaction with the computerised version of the model allows the stakeholders to more comprehensively explore and learn about the implications of many different management scenarios.
- *Internet agent-based model* – having acclimatized the stakeholders to the computer model in the actors' platform, the stakeholders are encouraged to use the Internet as another forum for learning and exploring management scenarios. The role playing game is replicated for multi-player use on the internet. The Internet version's function is to enable the participatory process to function beyond the length of the project.

3. THE CARD SORTING EXPERIMENT

3.1. Overview

Card sorting is a ''contrived'' knowledge elicitation technique [22] used to overcome the so-called ''knowledge elicitation problem'' in that people are very poor at ''conscious verbal reporting'' of compiled knowledge in response to direct elicitation methods such as questionnaires and structured interviews [23]. The method has roots in experimental cognitive psychology and is practiced in the discipline of knowledge engineering. Its strengths are in gathering information about domain classifications, concepts and the way they are structured that are meaningful to the subject whose knowledge is being elicited [24]. Although not directly developed from the psychological theory of personal constructs (Kelly, cited by [25]), as other contrived methods have been, the utility of card sorting as a method appears also to be based on an assumption that classification concepts play a central role in human cognition.

During card sorting the subject is given a set of cards, each of which has a concept written on it. The subject is then asked to sort the cards into meaningful groups. The subject then says what the criterion was for the sorting, e.g., ''sphere of influence'' and identifies the categories used to group particular cards together, e.g., ''national,'' ''local.'' Usually the experimenter does not intervene other than to clarify what the subject means by category and criteria names and to seek explanations as to the composition of groups. The sort process is repeated until the subject is unable to do any more sorts or until a particular time is reached. Card sorting has the advantage of being quick and easy to use both for the respondent and interviewer [24]. Experimental tests has shown that card sorting, in comparison to other techniques such as laddering, structured interviews and protocol analysis, can be highly efficient (in terms of information gain per minute) whilst providing the lowest percentage of garbled and false information [9].

3.2. Method Implemented in This Experiment

In this study, a card sorting method was used which draws heavily from the method described in [10]. The purpose was to elicit stakeholder-derived stakeholder categorisations. Fifteen cards were created on which each had the name of a stakeholder in the city's water supply system. Table 2 presents a list of the cards and the stakeholder names as they were written down.

Seven stakeholders from the Swiss case study volunteered to take part in the card sorting. Each of these were interviewed separately.[3] They were asked to make categorisations of the fifteen stakeholders within the case study using the card sorting methodology. Prior to the start of the experiment, each stakeholder was primed to think about the city's water supply system in terms of how consumers and the water supply industry may react to changes in water tariffs and to the development of water saving technologies. Part of this priming was the construction of stakeholders'

[3] Although one of these seven requested that a colleague outside the actors' platform be present to help him. They thus worked as a pair.

Table 2. Stakeholder names as written on the cards used in the card sort, with accompanying translation and their identification number of card used to refer to them in later tables.

ID	Stakeholder names as written on cards	English translation
a	SSIV *(Schweizerischer Spenglermeister- und Installateurverband)*	The association for Swiss fitters and plumbers
b	SIA *(Schweizerischer Ingenieur- und Architektenverein)*	The association for Swiss engineers and architects
c	Installateur-Unternehmen	Plumber
d	Wasserversorgung	Water supply utility
e	Hersteller von Sanitär- und Wasserspartechnologie	Manufacturer of plumbing and water saving technologies
f	Liegenschaftbesitzer	Landlord
g	SVGW *(Zusammenschluss von Gas- und Wasserversorgungen)*	Association for gas and water utilities
h	Politiker	Politician
i	Konsument	Consumer
j	Ingenieurbüro *(unterstützen die Planung der Wasserversorgung)*	Engineering office (that support the water utility's infrastructure planning)
k	Wasserentsorgung *(verantwortlich für Siedlungsentwässerung und Abwasserreinigung in der Stadt)*	City wastewater treatment utility
l	Architektbüro	Architect office
m	Familienheimgenossenschaft	Housing association
n	Konsumentenverband	Consumer association
o	Gemeinderat der Stadt *(muss Aenderungen des Wassertarifs genehmigen)*	City council (must approve changes in the water tarif)

mental models of the water supply system using the hexagon method [17], the results of which will be reported elsewhere. Each stakeholder was then given instructions to try and divide the fifteen cards up according to as many different criteria as possible within 30 minutes.

At the start of the exercise each stakeholder was given the following instructions: *"I would like you to sort the cards (representing stakeholders) into groups, using one criterion at a time. When you have finished sorting, please tell me what the criterion was for that sort, and what categories you sorted the cards into for this criterion. Once this has been done, I would like you to sort the cards again using a different criterion and keep sorting until you have run out of criteria. Finally, I would like you to make clear any assumptions you are making about the nature of the criteria and categories you are using."*[4]

An example sort was provided to each stakeholder using six cards naming residential areas of Switzerland. The experimenter sorted the cards according to the criteria ''size'' and ''residents' language.'' Each stakeholder was told that cards could be left uncategorised if desired. At the beginning of each sort the experimenter shuffled the cards. At the end of each sort, the experimenter recorded the criterion and categories.

An audio record of the exercise was saved for later transcription so that valuable information about stakeholders' perceptions was not lost. This was helped by asking the stakeholders to describe their thoughts as the card sorting tasks were being carried out.

After the results of the elicitation were collated, two of the criteria that were used by the largest number of stakeholders were presented back to the whole stakeholder group for peer validation.

3.3. Analysis Methodology

Formal methods are rare for analysing card sorting results from multiple subjects. One problem for analysis is the personal nature of classification constructs [25] and thus, the difficulty of objectively identifying equivalent criteria and categories. In the analysis used in this paper, a similar, but not identical, method to the one carried out in [10] was used. Since the words and phrases used by each stakeholder differed, a 'blind' judge A, a member of the academic community, was chosen who had not taken part in the exercises and who would use the written and audio records of the exercises to collate the criteria and categories used into semantically equivalent groups. A second blind judge 'B,' who had knowledge of the recommended categories, was then asked to match the semantically equivalent criteria and categories to the recommended ones.

[4]The original instructions, in German, were: ''Ich gebe Ihnen Karten, auf denen jeweils ein Akteur steht. Stellen Sie die Karten in Gruppen zusammen, indem sie für die Gruppierung ein Kriterium Ihrer Wahl benutzen. Wenn Sie mit Gruppieren fertig sind, sagen Sie mir bitte nach welchem Kriterium Sie die Akteure eingeteilt haben und welche Kategorien die einzelnen Kartengruppen darstellen. Gruppieren Sie die Karten nun nach einem neuen Kriterium und fahren Sie fort, bis Ihnen keine Kriterien mehr einfallen. Nannen Sie mir nun sämtliche Annahmen, die Sie bezüglich der Kriterien und der Kategorien, die Sie benutzt haben, getroffen haben.''

4. RESULTS

Each session with a subject lasted on average approximately 20 minutes. The total number of sorts carried out by the subjects was 23. Each sort produced a criterion. The average number of criteria given by each stakeholder was 3.3; the minimum number was 2 and the maximum 5. The average number of categories given for each criterion was 4.2 (min 2, max 7). Of the 97 categories obtained for the 23 sorts, only 4 were defined as ''not applicable.'' Of the 23 criteria, 10 were deemed by blind judge A to be semantically different and of these, 4 were used by at least two stakeholders. Table 3 shows the list of 10 criteria chosen by judge A and matched to the recommended criteria by judge B.

In Table 3, the column ''Criterion'' indicates the names of the criteria judged by blind judge A to be semantically distinct from the original 23 used in the sorts by the stakeholders. ''Categories'' indicates the categories belonging to the criterion. In the case of criteria used by only one stakeholder, the bold letters in parentheses next to the category represents the IDs of the stakeholder cards (see Table 2) placed in that category. In the case of criteria used by more than one stakeholder, membership of categories were not identical, so stakeholder card IDs have not been included in this part of the table. ''Sorts'' counts the number of sorts out of 23 in which the criterion appeared. ''Subjects'' indicates the number of different subjects that used the criterion. The final column indicates whether or not blind judge B matched the criterion to one of the recommended ones, and if so, which one.

Criteria used by more than one stakeholder included *function*, the activity carried out by the stakeholder; *type*, the nature of the organisation that the stakeholder represents; *working relationship*, the nature of the interaction that a stakeholder has with other stakeholders whilst carrying out its function; *representative groups to political bodies*, the interests that the stakeholders represent when lobbying political bodies.

Criteria used by only one stakeholder included *role in specific goal implementation (water hygiene maintenance)*, the function that the stakeholders have with respect to the task of maintaining water hygiene; *groups who influence*, decisions made in the water supply system that the stakeholder can influence; *members and associations*, the professional organisation that the stakeholder represents or by which the stakeholder is represented; *adding value*, whether or not the stakeholder adds value to the water production process; *communicates with consumers*, whether or not the stakeholder has direct communication with consumers; *cares for environment*, whether or not the stakeholder cares for the environment.

Of the four criteria used by more than one stakeholder, *type* and *working relationship* were novel and thus were not matched by blind judge B to any criteria in the recommended list in Table 1. *Function* was naturally

Table 3. Results of the card sort.

Criterion	Categories	Sorts	Subjects (out of 7)	Matched to . . .
Function	Service (implementation/planning/ water supply/water treatment)/ non-service (government/consumption)	7	4	Function
Working relationships	Professional/contractual/information provision/political/infrastructural	4	3	
Type	Private (water industry associations/ entrepreneurs)/public (water utilities/ politician)	3	3	
Representative groups to political bodies	Consumer bodies/water industry associations/ water industry/building trade	2	2	Policy network
Role in specific goal implementation (water hygiene maintenance)	Norm generation (**l,n,j**)/implementation (**a,e,c**)/ monitoring (**h,g,k,d**)	1	1	Tier
Groups who influence	Consumption (**i,n,e**)/technology (**c,j,m,l**)/ knowledge (**a,b,g**)/water charges (**h,o,k,d**)	1	1	Thematic network
Members and their associations	Architects(**b,j,l**)/water utility(**d,g**)/plumbers (**a,c,e**)/ authorities(**h,o,k**)	1	1	Aggregation/policy network
Adding value to process	Yes(**l,d,k,c,e,j**)/no(the rest)	1	1	
Communicates with consumer	Yes(the rest)/no(**a,g,b,j**)	1	1	
Cares for environment	Yes (**d,k,i,n**)/maybe (**o**)/no(the rest)	1	1	
Total		23		

Note. Note in this case that although four sorts used a criterion judged to be semantically equivalent to ''working relationships'' the choice of categories was not always equivalent in these sorts. The one represented in this table was the most detailed in terms of describing the nature of the working relationship and is thus described in this paper. Other categories used for this criterion included ''primary'' and ''secondary,'' expressing the sense that some actors are involved in more important working relationships than others.

found in the recommended list and *representative groups to political bodies* was thought to represent a policy network.

Of the remaining criteria elicited from the stakeholders, *role in specific goal implementation* was judged to be a tier categorisation. This was because the categories norm generation/implementation, consumption and monitoring fitted the strategic/operational division specified in the *tier* criterion. The criterion *groups who influence* was deemed a thematic network and *members and associations* was interpreted as both a policy network (the professional organisations determine policy for their members) and an aggregation categorisation (an organisation is composed of its members). The remaining criteria used by only one stakeholder were judged novel.

4.1. Group Stakeholder Validation of the Categorisations

In order to test the ability of the card sorting method to elicit accurate categorisations that were accepted by majority of the stakeholders, two of the most frequently elicited ones in the study were presented back to the whole group of stakeholders in the actors' platform. The group was asked to discuss the accuracy of the categories within the criteria and the membership of those categories. As Table 4 illustrates, only a minor change was wanted for the *type* criterion, namely an addition of a new stakeholder.

For the second criterion, *function*, it was identified that the category ''planning'' was ambiguous as to whether it meant planning of the water system in households or the planning done within the water utility. The planning category was thus subdivided. However, more interesting, with respect to understanding the limits of the method itself, was the stakeholders' desire to place stakeholders in two categories within the same criterion (e.g., the SVGW in implementation and household planning). Obviously, some stakeholders will have multiple functions.

5. DISCUSSION

5.1. Results

All but one of the recommended criteria was used by at least one of the stakeholders to describe their stakeholder community. It is however worth considering that important modeling and analysis concepts such as *aggregation* and *scale* were rarely used by the stakeholders, if at all. The use of aggregation by only one stakeholder was a surprise since the stakeholder cards deliberately included pairs of stakeholders at different levels of aggregation (e.g., consumer/consumer forum; architect's office/Swiss association for architects). Again, stakeholder cards included stakeholders at many different scales, from national to sub-city level. However, it was not a criterion that appeared to be included in the stakeholders' mental models of the problem domain. Whilst noting that different categories of stakeholders might have generated criteria that matched the recommended categorisations, these findings confirm the fact that, for the purposes of accurately modeling stakeholder interaction networks, there can be a difference between analytical categorisations and stakeholder-derived ones.

Of the novel stakeholder-derived criteria, *working relationship* appears to be a very useful and generic criterion for describing interactions between stakeholders. The stakeholders not only have functions, working themes and policies to pursue, they also have different modes of interaction with respect to different stakeholders. This categorisation highlights this point. The wastewater treatment utility, for example, described having *contractual responsibilities* with architects,' plumbers,' and engineers' bureaus, *professional obligations* with the SSIV, SVGW, and SIA, *political discussions* with the city council, *information provision* responsibilities with respect to consumers and landlords, and *infrastructural co-decision-making responsibilities* with the water utility. Each of these interactions requires a different pattern of interaction activities. Contractual responsibilities, for example, require communication, negotiation, agreement, implementation and service

Table 4. The criteria shown to the stakeholders in the actors' platform and the changes the stakeholders required.

Criterion	Category	Stakeholders	Changes
Type	Authorities	City council, wastewater utility, water utility	None
	Professional associations	SSIV, SIA, SVGW, consumers' forum	a) New stakeholder (VSA)
	Entrepreneurs	Manufacturer, plumber, engineer, architect	None
Function	Consumption	Housing association, etc.	None
	Service provider	Wastewater utility, water utility, SVGW	None
	Implementation	SSIV, manufacturer, plumber	a) New stakeholder: builder b) Add SVGW
	Planning	Engineer, architect, SIA	Divide planning into two – in house water planning (engineer, architect, SIA, SSIV, SVGW) supply system planning (engineer, architect, water utility)

monitoring activities. Professional obligations require norm setting, norm acceptance/rejection and punishment activities.

5.2. How the Results are Used

As mentioned, one goal of this project is to develop, with the stakeholders, an agent-based model which helps stakeholders to understand the relationship between management strategies and water consumption behaviour in the city. The model itself comprises of a management and negotiation module, a water demand module and a water-supply infrastructure module. The management and negotiation module models the individual decision making of stakeholders in response to system change and how they interact with each other to enforce or to change the system institutions (e.g., how to enforce water supply hygiene). The water demand module models the response of consumers to demand management policies formulated in the management and negotiation module. The water supply infrastructure module likewise responds to supply management policies.

Stakeholder-derived stakeholder categorisations were sought in order to design a model of stakeholder interaction (represented by interaction diagrams) that corresponded to stakeholders' perceptions of reality. These categorisations are particularly used to inform design of the management and negotiation module. Frequency of usage is not, alone, a reason for selecting criteria to inform design: relevance to the modeling task and the added value of the concept are more important. For example, though frequent, the ''type'' criterion does not add much information that cannot be deduced simply from the descriptions of stakeholders. On the other hand, whilst the ''cares for the environment'' criterion is novel, it will not be something that will be operationalised in the model. However, *working relationships, groups who influence, roles in specific goal implementation (water hygiene maintenance),* and *commmunicates with consumers* are all deemed to be useful criteria for the modeling task. These instantiated criteria can then be combined to generate outline interaction diagrams for the stakeholder interactions in the model. Figure 3, for example, illustrates an interaction diagram for the task of maintaining water hygiene, based on the knowledge elicited from the current study.

Figure 3 specifies how, first of all, the SIA sets the norms for water hygiene maintenance for the water utility to follow. When a hygiene action plan is needed, the wastewater utility provides support in the planning. The water utility then contracts the work to the plumbers whose work is then checked for quality. When the plumbers report back on the state of the work, the water utility then communicates the news to both the wastewater utility and the consumers.

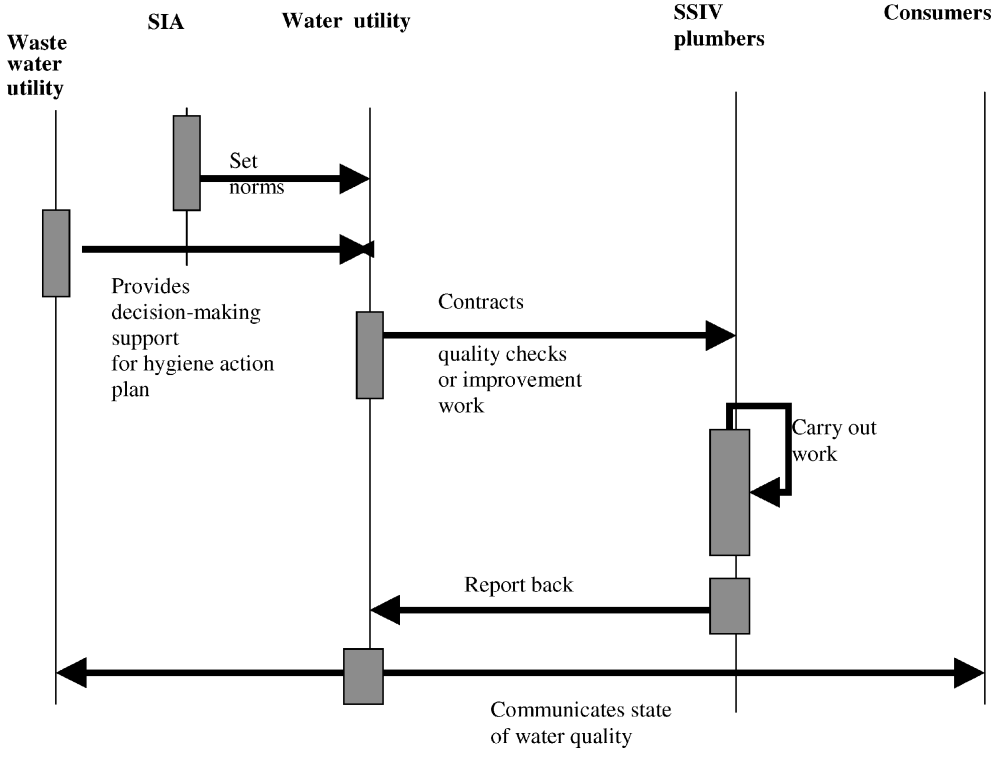

Fig. 3. Interaction diagram for the maintenance of the hygiene of the water supply based upon the criteria *role in specific goal implementation (water hygiene maintenance), communicates with consumer* and *working relationships.* Standard UML notation from Harmon and Watson, 1998.

5.3. Advantages and Disadvantages of the Card Sorting Method Experienced in This Study

The card sorting method was very easy to set up for the interviewer. It was also easy to adjoin it to a mental modelling session using the hexagon method without apparently distressing the stakeholders. The method also appeared easy to comprehend for the stakeholders, if not always easy for them to come up with new criteria. Normally the latter required some facilitation from the interviewer to help the stakeholder generate clear criteria (hence the stipulation that interviewers did not talk during the card sorting was relaxed). An example of this, typically, was when a stakeholder had difficulty dividing cards into clear categories. In this case, it was suggested to them that they split the criterion into two or more specific criteria.

This facilitation role can be played by the presence of a second stakeholder in the interview. Interviewing stakeholders in pairs, as described in [10], appears to have had benefits in this case study too, although only in terms of helping one of our stakeholders (see Section 3.2) overcome his worries and nerves about not being able to provide any information. Whilst working in a pair, the stakeholder and colleague gave each other confidence whilst at the same time asking each other to justify their beliefs. In the end, the pair managed to generate approximately the mean number of criteria for the study.

As the stakeholders' criticisms of the resulting criteria show (see Section 4.1), results are not always perfect with this method. Whilst the absence of particular stakeholders within the final analysis reflects more on preparation rather than the method, the method itself certainly has difficulty eliciting information about stakeholders belonging to more than one category. For example, it was not able to elicit that within one criterion, function, the SVGW could have two functions (implementation and planning). As reported in [24], such subtleties are difficult to catch with this method, without allowing subjects to place a card within more than one category. Whatever the solution to this problem, it confirms the need for post-interview stakeholder validation of categorisations. This was something not carried out by Maiden and Hare [10] and marks a difference between methodologies required for one-off interviewing and for long term stakeholder relationships.

A final problem is the difficulty to objectively find semantically equivalent criteria when stakeholders are from different professional backgrounds and when they do not use the same words and phrases for describing concepts. Clear instructions to judges and the audio-taping of interviews are essential to allow the blind judges to determine the semantics and pragmatics lurking behind the criteria names. Making these instructions explicit also helps others to interpret the results of the card sorting process (for example, see Appendix A for the instructions given to blind judge A). More research is needed to investigate better analysis methods for multiple subject knowledge elicitation using card sorting.

6. OTHER APPROACHES TO STAKEHOLDER CATEGORISATION AND NETWORK ANALYSIS

This paper has demonstrated how card sorting can be used to elicit stakeholders categorisations from stakeholders that can be used to understand stakeholder interaction networks. Other methods have been used to elicit knowledge about categorisations and stakeholder networks, and this section will provide an overview of such methods.

In their summary of stakeholder analysis methods, Babiuch and Farhar [12] do not mention the elicitation of stakeholder networks as a key task to be undertaken. Nevertheless they do recommend the use of particular stakeholder categorisations to help analysts understand and identify stakeholder groups (a prelude to identifying networks). The criteria suggested are ''geopolitical domain of interest'' (a type of ''scale'' criterion – see Section 2.2) and ''function.'' The source of these categorisations apparently derives from their analysis of the domain rather than from the stakeholders and they are, as such, analytical categorisations. Stakeholder categorisations and their network structures are similarly derived in the EUROWATER study [26], the source that provided the bulk of recommended criteria suggested by Bakker et al. [4].

Between the two extremes of eliciting stakeholder interactions through system analysis (as used by the researchers described in the previous paragraph) or from the stakeholders (as proposed in this paper), Tillman et al. [27] demonstrate the utility of a mixed methodology. Here, the analyst generates a description of possible stakeholder interactions (in the form of a rule book) and then presents the interactions for verification by the stakeholders. If any interactions fail verification by the stakeholders, then the rule book is amended according to the stakeholders' consensual opinion and the rule book is re-verified. After several iterations, an agreed set of interactions can be specified in the form of an interaction matrix. Tillman et al.'s method ought only to be used, however, by analysts who are domain experts. This is because it differs from the card sorting method in that in the latter, the stakeholders are unconstrained as to the interactions they can possibly describe, whereas in the Tillman method, the stakeholders are limited to discussing interactions that the analyst has already identified. The onus is thus on the analyst to have a sufficiently broad understanding of the domain.

With respect to identifying stakeholder networks and interactions in general, other methods are cited in the literature. Colfer and Wadley [28] report testing various different methods designed to monitor the type and degree of stakeholder interaction in forestry management in West Kalimantan. The methods they compared were the iterative

continuum method, communication network analysis, structured interviews and what they referred to as card sorting. The iterative continuum method involved the researchers making their own daily subjective assessments of the position of stakeholders along a degree of participation continuum that ranged from *significant* to *insignificant*. At the end of the survey period, researchers were asked to indicate the direction of travel of the different stakeholders along this continuum and the possible causes for the positions and trajectory of stakeholders. In the communication network analysis, researchers provided a questionnaire to stakeholders asking who they talked to about various issues and who they knew. The structured interviews also asked similar questions about interactions directly. The so-called card sorting method was in fact a structured interview method supported by the use of cards to remind stakeholders which stakeholders they should talk about in their answers. Each card representing a stakeholder had simply to be assigned a different rank according to their importance. The interviewees were not given freedom to group cards according to their own categorisations and thus the method is not a card sorting method as defined in this paper.

Colfer and Wadley report that the structured interview and communication network analysis methods failed due to the difficulty in phrasing appropriate and comprehensible questions. The two remaining methods proved useable and beneficial. Interpreted in terms of the knowledge elicitation problem the reason for their comparative success is apparent. They avoided posing direct questions or, when they did so, they provided mental props (e.g., cards).

7. CONCLUSIONS

This paper illustrates how card sorting, a knowledge elicitation method taken from the fields of clinical psychology and knowledge engineering, can be used successfully, with modifications, to elicit stakeholder-derived stakeholder categorisations from stakeholders within a long-term participatory process. The paper also describes how such a method can be incorporated into a long-term model-building-as-learning participatory process for the development of sustainable water management solutions.

Using this method, it was found that, of the recommended criteria for stakeholder categorisations cited by Bakker et al. [4], function and policy networks were the main ones that were also stakeholder-derived in the Swiss case study. Additionally, criteria that are normally of importance to modeling, i.e., scale and aggregation, were apparently not important components of the stakeholders' mental models of the system. Of the novel criteria that were elicited from the stakeholders, the criteria *working relationships, groups who influence,* and *roles in specific goal implementation,* among others, have been used to specify interaction diagrams for agent-based models of stakeholder interaction in the Swiss case study. It is recommended that the *working relationships* criteria is of general use in other stakeholder network analysis tasks.

The process of understanding stakeholder categorisations and interaction networks in the water management system will continue. Future research areas will include further investigations to find out why the criteria of scale were absent in the mental models of the stakeholders and whether it is valid to assume that scale is of no importance to them. Also, the card sorting method will be used to investigate stakeholder interaction networks that go beyond current understanding in the management system, e.g., for tasks that have not been implemented yet, such as stakeholder cooperation under a decentralised water management regimen.

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REFERENCES

1. Doyle, J.K. and Ford, D.N.: Mental Models Concepts for System Dynamics Research. *System Dynamics Review* 14(1) (1998), pp. 3–29.
2. Downing, T.E., Moss, S. and Pahl-Wostl, C.: Understanding Climate Policy Using Participatory Agent-Based Social Simulation. In: S. Moss and P. Davidsson (eds.): *Multi-Agent-Based Simulation*. Springer, New York, 2001.
3. Hare, M.P., Deadman, P. and Lim, K.: Towards a Taxonomy of Agent-Based Simulation Models in Environmental Management. In: F. Ghassemi, M. McAleer, L. Oxley and M. Scoccimarro (eds.): *Integrating Models for Natural Resources Management Across Disciplines, Issues and Scales, MODSIM 2001, 10–13 December.* MSSANZ, Canberra, Australia, 2001, pp. 1115–1122.
4. Bakker, K., Downing, T., Garrido, A., Giansante, C., Iglesias, E., del Moral, L., Pedregal, B. and Riesco, P.: In: K. Bakker (ed.): *Societal and Institutional Responses to Climate Change and Climatic Hazards: Managing Changing Flood and Drought Risk. A Framework for Institutional Analysis*. SIRCH Working Paper. University of Oxford, Oxford, 1999.
5. Checkland, P.: *Systems Thinking, Systems Practice*. Wiley, New York, 1993.
6. Flood, R.L. and Romm, N.R.A.: *Critical Systems Thinking: Current Research and Practice*. Plenum Press, New York, 1996.
7. Vennix, J.A.M.: *Group Model Building: Facilitating Team Learning Using Systems Dynamics*. Wiley, New York, 1996.

8. Voss, J.F., Tyler, S.W. and Bisanz, G.L.: Prose Comprehension and Memory. In: C.R. Puff (ed.): *Handbook of Research Methods in Human Memory and Cognition*. Academic Press, New York, 1982.
9. Burton, A.M., Shadbolt, N.R., Rugg, G. and Hedgecock, A.P.: The Efficacy of Knowledge Elicitation Techniques: A Comparison Across Domains and Levels of Expertise. *Knowledge Acquisition* 2 (1990), pp. 167–178.
10. Maiden, N.A.M. and Hare, M.P.: Problem Domain Categories in Requirements Engineering. *International Journal of Human–Computer Studies* 49 (1998), pp. 281–304.
11. Glicken, J.: Getting Stakeholder Participation 'Right': A Discussion of Participatory Processes and Possible Pitfalls. *Environmental Science & Policy* 3 (2000), pp. 305–310.
12. Babiuch, W.M. and Farhar, B.C.: *Stakeholder Analysis Methodologies Resource Book*. National Renewable Energy Laboratory, Colorado, 1994, pp. 70.
13. Tillman, D.: *Stakeholder Analysis in Water Supply Systems*. ETH, Zürich, 2001, pp. 165.
14. Lane, D.C.: Modelling as Learning: A Consultancy Methodology for Enhancing Learning in Management Teams. *European Journal of Operational Research* 59 (1992), pp. 64–84.
15. Hare, M.P., Gilbert, N., Medugno, D., Asakawa, T., Heeb, J. and Pahl-Wostl, C.: The Development of an Internet Forum for Long-Term Participatory Group Learning About Problems and Solutions to Sustainable Urban Water Supply Management. In: L.M. Hilty and P.G. Gilgen (eds.): *Sustainability in the Information Society*: 15th International Symposium on Informatics for Environmental Protection. Metropolis Verlag, Marburg, 2001, pp. 743–750.
16. Harte, M. and Gough, J.: Sustainability, Uncertainty and Environmental Policy: Lessons from New Zealand's Pastoral High Country. In: J.W. Handmer, T.W. Norton and S.R. Dovers (eds.): Ecology, Uncertainty and Policy: Managing Ecosystems for Sustainability. Prentice Hall, London, 2001.
17. Hodgson, A.M.: Hexagons for Systems Thinking. *European Journal of Operational Research* 59 (1992), pp. 220–230.
18. Strauss, A. and Corbin, J.: *Basics of Qualitative Research: Grounded Theory Procedures and Techniques*. Sage Publications, London, 1990.
19. Delbecq, A.L., van de Ven, A.H. and Gustafson, D.: *Group Techniques for Program Planning: A Guide to Nominal Group and Delphi Processes*. Management Applications Series. Foresman & Co, Brighton, Scott, 1975.
20. Crawford, S.E.S. and Ostrom, E.: A Grammar of Institutions. *American Political Science Review* 89(3) (1995), pp. 582–600.
21. Barreteau, O., Bousquet, F. and Attonaty, J.-M.: Role-Playing Games for Opening the Black Box of Multi-Agent Systems: Method and Lessons of its Application to Senegal River Valley Irrigated Systems. *Journal of Artificial Societies and Social Simulation* 4(2) (2001), [online]. URL: http://www.soc.surrey.ac.uk/JASSS/4/2/5.html
22. McGeorge, P. and Rugg, G.: The Uses of 'Contrived' Knowledge Elicitation Techniques. *Expert Systems* 9(3) (1992), pp. 149–154.
23. Evans, J.S.B.T.: The Knowledge Elicitation Problem: A Psychological Perspective. *Behaviour and Information Technology* 7(2) (1988), pp. 111–130.
24. Gammack, J.G.: Different Techniques and Different Aspects on Declarative Knowledge. In: A.L. Kidd (ed.): *Knowledge Acquisition for Expert Systems: A Practical Handbook*. Plenum Press, New York, 1987.
25. Shaw, M.L.G. and Gaines, B.R.: An Interactive Knowledge Elicitation Technique Using Personal Construct Technology. In: A.L. Kidd (ed.): *Knowledge Acquisition for Expert Systems: A Practical Handbook*. Plenum Press, New York, 1987.
26. Harmon, P. and Watson, M.: *Understanding UMC*. Morgan Kaufmann San Francisco, 1998.
27. Correia, F.N. and Kraemer, R.A. (eds.): *EUROWATER: Institutionen der Wasserwirtschaft in Europa*. Vol. 1. Springer, Heidelberg, 1997.
28. Tillman, D., Larsen, T.A., Pahl-Wostl, C. and Gujer, W.: Interaction Analysis of Stakeholders in Water Supply Systems. *Water Science Technology* 43 (2000), pp. 319–326.
29. Colfer, C.J.P. and Wadley, R.L.: *Assessing "Participation" in Forest Management: Workable Methods and Unworkable Assumptions*. Center for International Forestry Research (CIFOR), Jakarta, Indonesia, 1996, pp. 31.

APPENDIX A

Instructions for judge A.

"*Please try and find semantically matching criteria and choose names for them. Within these new criteria select the simplest, most expressive set of common categories.*"

For two criteria to match, they have to meet all the following stipulations:

1) *the criteria names must have the same basic meaning, e.g., "function" = "function groups" = "activities." Where available, the protocols should be checked to make sure the criterion name written on the sheet is the correct one.*
2) *the categories used must be able to be mapped in some way (though not necessarily exhaustively) both in terms of meaning and similar actors grouped.*
3) *if there exists a criterion that is a category within another criterion, then the former is marked as subordinate to the latter.*

An example:

Criterion	Cat1	Cat2	Cat3	Cat4
Black hair	Yes (Jon, Bob)	No (Mark, Tom, Peter, Cindy)		
Baldness	Yes (Jon, Bob)	No (Mark, Tom, Peter, Cindy)		
Amount of hair	Lots (Mark, Cindy)	Not much (Tom)	None (Jon, Bob)	Don't know (Peter)
Lots	Shoulder-length (Mark)	Waist-length (Cindy)	Not applicable (the rest)	

According to the instructions above, "baldness" and "amount of hair" would be semantically equivalent since:

1) *the criteria names have the same sort of meaning and*
2) *the categories "lots" and "not much" can be combined to create most of the "baldness" category "no," so that roughly the same categorisations are achieved (ignoring the "don't know" category in "amount of hair").*

Note that "black hair" and "baldness" would not be semantically equivalent, even though they have the same categories and the same members in each category, since the criteria names do not share the same meaning. Note that "lots" would be marked as subordinate to the new combined criterion "baldness/hair amount" since it can be used to describe the hair of those who have lots of hair (whose combined members are more or less the same).

The final interpreted set of criteria would be:

Criterion	Cat1	Cat2	Cat3	Cat4
Black hair	Yes	No		
Baldness/amount of hair	Lots	Not much	None	
Lots (subord. to baldness)	Shoulder-length (Mark)	Waist-length (Cindy)		

Note that the more expressive categories of amount of hair have been chosen for the new criterion and "not applicable" has been left. "Please make a note of all such decisions and assumptions made whilst creating new criteria."