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Experiment on decision-making approaches for complex water management issues

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Abstract: Water management problems are embedded in a natural and social system that is characterized by complexity. Knowledge uncertainty and the existence of divergent actors' perceptions contribute to this complexity. Consequently, dealing with water management issues is not just a problem of knowledge uncertainty; it is a problem of ambiguity too. In this paper, we investigate how a decision-making process, for a complex water management issue, influences the creation of a knowledge base, the development of actors' perceptions and the formulation of a problem-solution combination. There are many different approaches to decision-making processes. We distinguish two 'extremes': the analytical decision-making approach and the participatory decision-making approach. In the analytical approach, decision-making is based on rationality and objectivity. This process is non-interactive, i.e. it assumes one steering actor. Participatory decision-making is an interactive process. During this process several actors contribute to problem structuring. In literature, many examples of empirical case studies on decision-making processes for water management can be found. Nonetheless, as every decision-making process is unique, it is difficult to compare results from different case studies. Therefore, the aim of the study presented in this paper is to make such a comparison using two decision-making processes, which focus on the same problem situation. This comparison sheds a light on the effectiveness of participatory processes, while most literature simply assumes such effectiveness.

The methodology that is used for the comparative study is quasi-experimentation. The experiment was carried out within the framework of a multidisciplinary design project at the University of Twente, The Netherlands. This design project focused on the extension of Schiphol Airport on an island in the North Sea. Schiphol Airport is the biggest airport in the Netherlands and it has a leading position within Europe and the world. Whereas many studies on participatory processes focus only on the local level, this comparative study focuses on a high-level decision-making process as the extension of the airport is of national importance. In the experiment, the project teams – consisting of students – were divided into two types of groups. Each group followed a different approach: the analytical or the participatory decision-making approach. At the start of the project both groups received a different corporate identity explaining their role as a professional (analytical or participatory) consultancy. Furthermore, three parallel workshops took place; separate for each group. Also, the level of stakeholder participation differed for both approaches. In the analytical approach there was no direct contact with stakeholders during the project, they were only informed afterwards. For the participatory approach, however, some stakeholder representatives were consulted at the beginning of the project.

In the analysis of the decision-making processes we found that four of the six project teams did indeed follow two different approaches; two teams for each approach. From our experiment, we can conclude that the analytical approach leads to a knowledge base which mainly exists of expert knowledge, whereas the participatory approach leads to a combination of expert and practical knowledge sources. Furthermore, the results of the experiment support the conclusion that – for complex water management issues – an analytical decision-making process does not lead to an agreed upon problem-solution combination. Also, we can conclude that a participatory process does lead to a joint problem-solution combination, which results from cognitive and strategic learning. Furthermore, our findings form an argument for practitioners in water management to choose a learning approach in problem structuring. Structuring and solving water management problems benefits from learning processes.

Keywords: *experiment, analytical, participatory, decision-making, knowledge base, learning*

1. INTRODUCTION

Natural resources management in general, and water resources management in particular, are currently undergoing a major paradigm shift (e.g.: Pahl-Wostl 2007b). Until recently, management was often the exclusive task of technical experts working under the auspices of the state. Their activities were based on the assumption that water and natural resources can be predicted and controlled, for example by dikes or other infrastructural works. However, at the moment, participatory management and actor involvement are becoming increasingly important (e.g.: Bouwen and Taillieu 2004; Pahl-Wostl 2007a). In several countries, governments are experimenting with participatory processes on all kinds of policy domains and levels of government (e.g.: Edelenbos and Klijn 2005). The development of participatory approaches is related to the recognition that a government alone does not determine societal developments; in fact they are shaped by many actors. Actually, we live in a network society in which resources are fragmented and where public and private actors are mutually dependent (Teisman 2000). A network society is not governed at one level, but at multi-levels, by multi-actors, with multi-instruments and multi-resources (Bressers et al. 2004).

Many authors claim that an analytical decision-making approach, in which the problem is assumed to be exclusively of a technical nature is inadequate for complex issues (Arentsen et al. 2000; Koppenjan and Klijn 2004). The analytical decision-making approach focuses on single-actor complexity and reducing substantive uncertainty. Thereby this approach risks producing superfluous knowledge and is not likely to result in a joint problem-solution combination. The experiment presented in this paper focuses on a comparison between two decision-making processes, i.e. a participatory and an analytical process. From literature and two previous case studies on Mainport Rotterdam (Hommes et al. 2009) and the Delta-region (Hommes et al. 2008), we found that a decision-making approach influences the knowledge base, actors' perceptions and the substantive outcomes. However, as every decision-making process is unique, it is difficult to compare results from different case studies. Therefore, the aim of this paper is to present such a comparison using two decision-making processes, which focus on the same problem situation, in an experimental setting.

2. CONCEPTUAL MODEL FOR PROBLEM STRUCTURING

We define problem structuring as one or multiple rounds of interaction in which actors actively participate in the formulation of a problem and its solutions. Problem structuring should not be understood as a linear process through which an unstructured problem becomes structured. Problem structuring rather aims to identify, confront and (if possible) integrate divergent views with respect to a given problem situation (Hisschemöller and Hoppe 2001). Problem structuring thus requires a participative or interactive decision-making process, including multi-level interactions. Figure 1 shows how the input, process and outcome of problem structuring are related. The input of problem structuring is a complex, unstructured problem. We conceptualize the process of problem structuring along two tracks: the development of actors' perceptions and the creation of a knowledge base. Furthermore, we focus on the connection between these tracks in relation to the process of problem structuring. The outcome of the process of problem structuring, i.e. a problem-solution combination, will also be investigated.

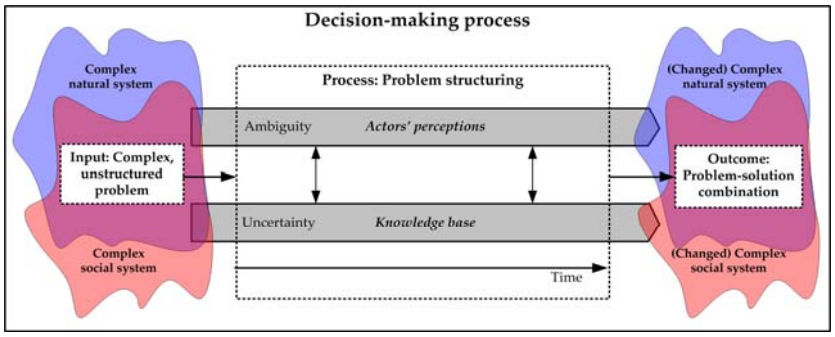

Figure 1 – Conceptual model on the input, process and outcome of problem structuring.

2.1. Development of actors' perceptions

Actors' perceptions are based on frames (of reference). These frames function as filters through which information or a problematic situation is interpreted (Rein and Schön 1993; Sabatier 1988). Actors' perceptions develop and change as a consequence of learning processes. After Koppenjan and Klijn (2004), we distinguish two types of learning processes of individuals in a network context: cognitive and strategic learning. Cognitive learning relates to the content of a process. We interpret it as actors' increased knowledge and insight about the nature, causes and effects of the problem, possible problem-solution combinations, and their consequences. Besides cognitive learning, actors can learn about the involvement of other parties and mutual dependencies. This learning about social aspects is called strategic learning.

2.2. Creation of a knowledge base

A knowledge base is defined as a collection of knowledge sources (i.e. research reports, models, data, practical experiences, etc.) that have been made explicit and are related to a specific problem situation. Actors from both the scientific (or expert) arena and the practical (lay or non-scientific) arena should contribute their knowledge, to the knowledge base, during the process of problem structuring (Figure 2). Scientists or experts add knowledge based on scientific or applied research, whereas practitioners add knowledge from experiences. When these two knowledge sources are integrated, e.g. by the process managers, a context-specific knowledge base is created, which can be used to deal with a specific problem.

To deal with ambiguity actors should not only contribute their knowledge, they should also be stimulated to reflect upon the knowledge base. This enhances that actors learn about the nature, causes and effects of the problem, i.e. cognitive learning. Furthermore, as actors interact with each other, they become aware of their mutual interdependencies and of other actors' perception. Then strategic learning takes place. The strategic and cognitive dimensions of actors are closely related. Therefore, adjustment of cognitions, i.e. cognitive learning, is only possible if actors are confronted with other cognitions. In Figure 2, the production of a knowledge base and the related learning processes in a problem structuring process are shown.

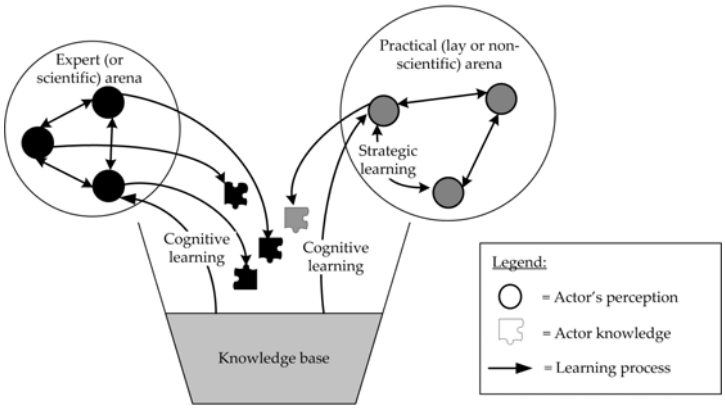

Figure 2 – Conceptual model on the creation of a knowledge base and related learning processes

2.3. Problem-solution combination

A problem-solution combination, or the joint formulation of the problem and its solutions, is the substantive outcome of a process of problem structuring. It is the result in which various knowledge sources and diverging actors' perceptions are brought together. A problem-solution combination (or a problem formulation) goes beyond defining the discrepancy between a given state and a desired state. It includes the following three elements; description of present and future situation including causal structure; definition of criteria and objectives; and definition of direction(s) for solutions (Dery 1984).

3. EXPERIMENT ON DECISION-MAKING APPROACHES

3.1. Methodology

The methodology that is used for this comparative study is quasi-experimentation (Cook and Campbell 1979). In this experiment, the treatment was formed by the decision-making process that the students followed. The outcome measures are: knowledge base; actors' perceptions and problem-solution combination. The units of assignment are formed by the groups of students, i.e. the project teams. The comparison is made between the two decision-making processes. In the multidisciplinary design project of this experiment, a total amount of 29 students participated. All participants had the same education, i.e. Civil Engineering, and were approximately in the third year of the Bachelor program. The students were divided into six project teams by the experiment leader[1]. All project teams received an identical assignment. During the multidisciplinary design project three parallel workshops were conducted; separate for the analytical and the participatory decision-making process.

The project teams had the role of a professional consultancy that executes a project for a client. The teams were required to work according to a corporate identity. The experiment leader divided the project teams into two types, both consisting of three project teams. The A(nalytical)-teams[2] worked in line with the corporate identity of analytical decision-making. The P(articipatory)-teams were required to work accordance with the

[1] The first author was the experiment leader.
[2] Further on we will refer to specific project teams. A1 to A3 followed the analytical approach and P1 to P3 followed the participatory approach.

corporate identity of participatory decision-making. The following observations were done during the experiment and are used in the analysis: workshop observations; logbooks; process reports; products; questionnaires; and interviews.

3.2. Process description

The multidisciplinary design project focussed on Schiphol Airport, which is the biggest airport in the Netherlands. Schiphol Airport is located in the Province of Noord-Holland, southwest of the city of Amsterdam. Schiphol Airport is of strategic importance to the economy of the Netherlands. The Schiphol-team of the Province of Noord-Holland is the client of the students' assignment. The aim of this assignment is to: "…*design a, feasible and accepted, long-term (2040-2060) growth strategy for the extension of Schiphol Airport on an island in the North Sea*…" This shows that this comparative study focuses on a high-level decision-making process, whereas many studies on participatory processes focus on the local level.

At the start of the first workshops, the students received their corporate identity, a one page text. For the participatory teams, the second step was to identify actors for the extension of Schiphol. Furthermore, five interviews with stakeholder representatives were planned for the participatory teams. At the end of the first week the project teams handed in their action plans. These plans consist of: problem formulation, goal formulation, allocation of tasks among the project team members and planning of different activities. In the second workshop, the project teams worked on a SWOT (Strengths, Weaknesses, Opportunities and Threats)-analysis. A SWOT-analysis distinguishes between the internal and the external environment. In this case, the internal environment consisted of the Province of Noord-Holland. The external environment consists of actors and the physical environment in which the extension of Schiphol Airport takes place. During the first weeks, the participatory project teams conducted interviews with five stakeholders. At the start of the second workshop these project teams analyzed the results of these interviews. During the project, all students of both groups followed several courses on water and morphology, infrastructure and financial feasibility.

The second product, to be delivered by the project teams, consisted of the SWOT-analysis and three alternative strategies for the airport. One strategy for each scenario: best-, worst- and mid-case. It was observed that the participatory teams (P1 to P3) propose to involve other actors, apart from the province, into the 'internal organization'. They explain that from the SWOT-analysis, it can be concluded that the biggest threat is formed by the province's dependence – in authority and knowledge of airports – on the Schiphol Group. They state that this threat cannot be eliminated by strengths of the province. Therefore, the Province of Noord-Holland should cooperate with the Schiphol Group, according to all P-teams. During the final workshop, the project teams worked on their growth strategy. The experiment leader explained that the growth strategy should consist of a rough design of the airport island, taking into account the different scenarios. This rough design should include a process design (which actors to involve and when) and a technical design. At the end of the project, the teams handed in their final reports on the growth strategy for Schiphol Airport on an island in the North Sea. During a final plenary session, each project team gave a brief presentation of their growth strategy. At these presentations all other project teams, teachers and stakeholder representatives were present.

4. ANALYSIS

4.1. Decision-making processes

In this experiment, two decision-making approaches were 'imposed' on the different project teams. The experiment leader provided them with a corporate identity, exercises during workshops and interviews with stakeholders (for participatory teams). However, it still depends on the project team itself how and to what degree they followed these directions. Therefore, we analyzed to what extend the different project teams really worked analytically/participatory. In Table 1, we ranked the project teams from most analytically (project team A3) to most participatory (project team P2).

The project teams were first ranked based on their 'scores' on the first two categories, actor analysis and actor involvement (first four columns in Table 1). These categories were part of the experimental setup. These 'direct' measurements are used to check if the instructions given in the workshops were followed by the project teams. Also the project team characteristics and products were used to analyze the decision-making process that was followed by the project teams. These two categories are used as 'indirect' measurements to check the ranking based on actor analysis and actor involvement and/or to further rank the project teams.

	Actor analysis		*Stakeholder involvement*		*Project team characteristics*			*Products*	
	Identification	P/I-grid	# stake-holders	Level of participation	Satisfaction with approach	Similarity	Group level	SWOT perspective	Process design
A3	no	no	4	informing	++	0	7,7	Province	no
A2	no	no	4	informing	0	0	6,4	Province	no
A1	yes	no	4	informing	+	+	6,1	Province	no
P3	no*	no	8	consulting	0	-	6,1	Province + SG	no
P1	yes	yes	8	consulting	+	-	7	Province + SG	yes
P2	yes	yes	8	consulting	+	-	7,5	Province + SG	yes

Identification:	yes = actors were identified; no = no actors were identified; *only included in WSI & III, not in products
P/I-grid:	yes = a power-interest grid was formulated; no = no power-interest grid included
# stakeholders:	Number of stakeholder representatives involved during the process
Level of participation:	Stakeholder involvement, determined by 'ladder of participation'
Satisfaction with approach:	-- = very unsatisfied; 0 = it doesn't matter; ++ = very satisfied
Similarity:	-- = completely different to previous used approaches; ++ = exactly the same
Group level:	Determined by grade for final product. Scale from 1 (= fail) to 10 (= excellent); 5,5 = pass
SWOT perspective:	Actors involved in the internal environment of the SWOT analysis; SG = Schiphol Group
Process design:	yes = a process design was included in the final product; no = no process design was included

Table 1 – Analysis of decision-making processes, project teams ordered from: most analytical (top) to most participatory (bottom) oriented.

The project team characteristics are subdivided into: satisfaction with approach; similarity; and group level. We argue that the higher the satisfaction, the more similar the approach and the higher the group level, the more willing a project team was to follow the decision-making approach and the higher the scores for approach conformity. Last, the products (last two columns in Table 1) were used to analyze and rank the decision-making processes of the project teams. In the second product by the project teams a difference in the involvement of actors in the internal organization of the SWOT-analysis was found. The A-teams did not involve other actors than the Province of Noord-Holland in their organization, whereas the P-teams proposed to involve other actors, i.e. Schiphol Group. For the involvement of the Schiphol Group the P-teams referred to the interview with this actor[3].

From these observations we conclude that the P-teams focused on a cooperative strategy, which fits the participatory approach, whereas the A-teams focused on central steering actor strategy, which matches the analytical approach. It was observed that two project teams (A1 and P3) did not entirely follow the approach that was given to them. Although, it would be interesting to investigate the reasons of this neglecting, this is not the scope of our comparison. Therefore, the results of these teams were omitted from the further analysis.

4.2. Knowledge base & Actors' perceptions

At the start of the project, the two groups received two different information packages. The A-teams received an information package with technical information on Schiphol Airport. The P-teams also received an information package about each stakeholder representative they had to interview. During the process several other knowledge sources were added. Furthermore, there were two models available: a morphological model and a financial model. Moreover, the P-teams received practical knowledge from the stakeholder interviews. We observe several differences between the knowledge bases of the A-teams and the P-teams. Firstly, the participatory teams did not use all documents from the information package on Schiphol Airport. Instead, it was observed that they used the stakeholder interviews, i.e. practical knowledge sources on this topic. It can be concluded that the knowledge bases of the analytical teams existed of expert knowledge sources, whereas for the participatory teams combined expert and practical knowledge sources.

The actors' perceptions could not develop during the experiment. There was too little interaction, between the project teams and the stakeholder representatives, and it is a fictional project. Also, the different stakeholders did not interact with each other, only with the project teams (students).

4.3. Problem-solution combination

The outcomes of the experiment were the final products of the project teams, which consisted of a growth strategy for Schiphol Airport on an island in the North Sea. The final products included a technical design of the airport island, i.e. location, size, shape, rough outline, landside infrastructure. In the technical designs of

[3] Interview Schiphol Group, Department Airport Development, 11 February 2008

all participatory teams it is observed that a solid seawall is recommended for the island, to prevent nuisance from birds on the island. The analytical teams did not focus on nuisance of birds. The P-teams focused on this issue as it was named in several stakeholder interviews[4]. Thus, they include stakeholders' perceptions in their technical design and use arguments from practical knowledge sources.

We analyzed the island size in the technical designs proposed by the project teams. For the A-teams the size of the island is between 25 and 63 km^2. The islands by the P-teams are between 50 and 82 km^2. Thus, the islands by the participatory teams are bigger, which led to larger landside infrastructure higher construction costs compared to the A-teams' designs. This difference is caused by the fact that all participatory teams advised to move Schiphol Airport entirely to the island in the North Sea. This choice was motivated by the perception of two important stakeholders, i.e. Province Noord-Holland and Schiphol Group. Project team P1 explains that there are two important conditions for the Schiphol Group to participate in the project: *"…the airport has to be competent; and all activities have to be moved to the island…"* On the contrary, the analytical teams all advised to preserve Schiphol Airport on the current, inland location and create a step-by-step extension of runways on the island. The analytical teams give financial and technical reasons for this choice. However, they did not take into account the problem perceptions of the province and the Schiphol Group. This caused that there is no agreement on the designs the A-teams proposed, as one of the actors explained *"…if the island is this little, there is no use for Schiphol to move…"*[5]

We conclude that the designs by the P-teams are (more likely to be) an example of joint problem-solution combination, whereas the designs by A-teams are not agreed upon by the actors involved. We claim that this difference is caused by the fact that the participatory teams learned about the mutual dependency between relevant actors (Province Noord-Holland and Schiphol Group), i.e. strategic learning took place, while the analytical teams did not learn this.

5. DISCUSSION AND CONCLUSIONS

In this paper, we presented an experiment between two decision-making processes. This experiment was executed within a multidisciplinary design project for Civil Engineering Bachelor students of the University of Twente, The Netherlands. The aim of this experiment is to determine how a decision-making approach influences the creation of a knowledge base, the development of actors' perceptions and the substantive outcomes. Thereby, we investigate the effectiveness of different decision-making approaches.

There are several factors that might influence the external validity of our experiment. One of these factors is the composition of the participants in the experiment; all participants are Civil Engineering Bachelor students in their third or fourth year. This is not a composition that one would find in practice. Nevertheless, these students are trained to become practitioners in the domain that is the focus of the research. Also students are quite 'mouldable', whereas practitioners are experienced and have their own approaches, which would probably make them less flexible in following our proposed approaches. Thus, the composition of the participants does influence the external validity of our experiment. However, an experimental setup with other participants, e.g. practitioners, will probably cause at least as big impacts on the validity. Another factor that influences the external validity is the limited interaction with actors, in the participatory decision-making approach. In the experiment, the interaction is limited to an interview at the beginning of the project and a presentation of the growth strategy at the end of the project. Therefore, it is not possible for the actors to continuously interact with each other and to co-produce in the technical design.

Furthermore, in practice, the process design that is formulated by the participatory teams would have been 'executed' to create the technical design. In our experiment, the participatory project teams had to come up with the technical design without interaction with actors, which does not match the participatory decision-making approach. Thus, the limited interaction does influence the external validity of the experiment. Moreover, most participatory processes engage with multiple stakeholders that already have a shared history. This path-dependency of stakeholder relationships is neglected in our experiment. The experiment is also influenced by the limited resources (time, people, money etc.) available. In practice such resources are also limited. Therefore, we argue that this does not influence the external validity of the observations significantly. Finally, while experiments in an artificial situation have obvious limitations, we claim that experiments can be a welcome addition to the ubiquitous case study methodology, which also has its drawbacks.

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[4] Interview Schiphol Group, Department Airport Development, 11 February 2008; Interview Province of Noord-Holland, Schiphol team, 11 February 2008; Interview North Sea Foundation, 13 February 2008

[5] Interview Schiphol Group, Department Airport Development, 22 April 2008, by S. Hommes.

In the analysis of the experiment, we found that four of the six project teams did indeed follow two different approaches, i.e. participatory and analytical. From our experiment, it can be concluded that the analytical approach leads to a knowledge base which mainly exists of expert knowledge, whereas the participatory approach leads to a combination of expert and practical knowledge sources. Furthermore, it was found that actors' perceptions were divergent in the experiment. However, they did not develop during the process as there was too little interaction for this to happen. It was found that the substantive outcomes by the analytical project teams, which consisted of the growth strategies, were not agreed upon by the relevant actors. The substantive outcomes of the participatory approach are an example of a joint problem-solution combination, as they represented the relevant actors' perceptions. We conclude that this resulted from strategic learning between the participatory project teams and the actors involved.

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