A DECISION SUPPORT SYSTEM
BASED ON MENTAL REPRESENTATIONS

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ABSTRACT

The purpose of this paper is to further explore some of the questions
raised at a Task Force Meeting held at IIASA in June 1980 and entitled:
Decision Support Systems: Issues and Challenges. The discussion
attempts to focus attention on the need for a better understanding of
management behavior in the context of decision support systems (DSS).
The paper introduces the concept of mental representations, that is, sub-
jective representations managers have of their management activity and
environment. It deplores the little attention devoted so far by DSS
research to the importance of these representations in the decision-
making process. A proposal is put forth that would enable managers to
formalize their mental representations in order to use them in the course
of their management activity. The paper concludes that unless managers
can (and think that they can with a reasonable amount of effort) imprint
onto their DSS the complexity and subjectivity of their own thinking,
there is a serious doubt as to whether DSS will ever have wide application
in management.

CONTENTS

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INTRODUCTION

What kind of support would managers like to have; what kind of assis-
tance do they really need; and how can decision support systems (DSS)
help them? Until these questions have been properly addressed, how can
we talk about DSS design and development, let alone implementation and
evaluation? These questions are now topical in DSS research and are
characteristic of a field that is attempting to transcend the technology to
which it owes its existence.

Decision support system is somewhat of a misnomer as it implies
post-decision support rather than the intended pre-decision support. A
more accurate name might have been: Decision making support systems.
Moreover, the term is still not well understood and no agreed upon defini-

tion as yet exists. I define DSS very generally to include all systems that support the decision-making process in such a way as to improve managerial effectiveness. By "*system*" I mean a complex whole comprising a professional worker or workers (e.g. managers, researchers, professionals, staff analysts, and clerical workers whose primary responsability is the handling of information in some form), a set of tools (usually, but not necessarily, computerized), and, when different from the user, a system designer or developer. "*Support*" here means to make possible or to expand human capabilities for such activities as accessing facts, retrieving information, making computations, comparisons, projections, models, simulations, decision trees, etc. "*Decision making*" implies the intellectual activities that might comprise a decision such as intelligence gathering, screening, classification and structuring of data, model construction, simulations, formulation and testing of alternatives, choice of approach and implementation strategies . The distinguishing feature of DSS is its objective to improve managerial effectiveness.

At one of the earlier conferences on DSS in 1977 [3] concern for the manager had already surfaced, as evidenced by Carlson and Scott Morton's editorial comments:

> The development of DSS has been stimulated more by increasing sophistication in technology than by better understanding of decision makers or decision making.

At a more recent conference held at IIASA in 1980 [7] DSS researchers agreed on the necessity to de-emphasize the technological problems and to pay more attention to the behavioral and organizational design issues. Dempster, in his closing remarks, echoed the feelings of the participants when he said:

the misguided technological thrust in management and information science during the last two or three decades has been caused in part by our poor understanding of organizational behavior, of the management task environment, and of human learning.

Gorry and Scott Morton [9] articulate the problem as follows:

Although the evolution of information systems activities in most organizations has led to the accumulation of a variety of technical skills, the impact of computers on the way in which top managers make decisions has been minimal. One major reason for this is that the support of these decision makers is not principally a technical problem. If it were it would have been solved. Certainly there are technical problems associated with work in these problem areas, but the technology and the technological skills in most large organizations are more than sufficient. *The missing ingredient, apart from the basic awareness of the problem, is the skill to elicit from management its view of the organization and its environment, and to formalize models of this view.*

This paper discusses how to provide the *missing ingredient* in the context of DSS. The concept of *mental representations*, that is, subjective representations managers have of their management activity and its environment, is introduced. The importance of these representations in the decision making process is discussed and a methodology to elicit them from the managers is proposed. Finally, the paper describes how the systematic use of these representations by means of a DSS could assist managers in their decision-making tasks. In summary, the paper presents a framework for the development of a DSS to elicit and formalize the view managers have of their organization and its environment.

 Italics are the author's.

MENTAL REPRESENTATIONS

The decisions that we make in the course of our daily lives are based, to a large extent, on representations we have constructed of our own universe. Piaget [14] points out that all species inherit the basic tendency to systematize or organize their processes in coherent systems, namely, the tendency to form mental models. The quality of even the most mundane decisions depends, among other things, on the quality of these mental models. But because we tend to use them instinctively, most of us would be hard pressed to describe the various mental representations we use in making such decisions (I prefer talking of representations rather than models, the latter having too definitive a connotation). I argue that the same holds true for managers. Mintzberg [13] aptly describes these representations as follows:

> A model is an abstraction of reality, a set of causal relationships by which the effects of given conditions can be predicted. *One gets the impression,* in listening to managers as they make decisions, that they carry an array of such models in their heads... In effect,the manager absorbs the information that continually bombards him and forges it into a series of mental models of the internal workings of his organization, the behavior of subordinates, the trends in the organization's environment, the habits of associates, and so on. When choices must be made, these models can be used to test alternatives...The effectiveness of the manager's decisions is largely dependent on the quality of his models.

When questioned or asked to justify decisions, managers tend to rationalize their choices; however, the representations they in fact use to make decisions are not the models one finds in a management science textbook. Their mental representations include their beliefs, be they

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* Italics are the author's.

intuitive, unquantifiable, or political; their values, be they ethical, moral, or religious; their idiosyncrasies and peculiarities; their ambitions and hidden agendas; in other words, all the so-called *unscientific* factors. It is not surprising that students of management have not yet dared to venture into this marshland, preferring the solid ground of rationality. Managers for their part have not been forthcoming in making explicit their decision-making processes. Perhaps they do not want to do so because, on the one hand they may not know exactly how they reach decisions, and on the other, they may fear revealing confidential details, in particular details concerning the "unscientific" factors of their mental representations. Thus, mental representations have not been made explicit and suitable approaches to this task are still lacking. I contend that mental representations, even with their *unscientific* factors, are important in the decision-making process and therefore pertinent to the effectiveness of the managers. If we are serious about aiding managers to improve their effectiveness, we must venture into the morass.

The intellectual processes which lead to a management decision must necessarily operate within the context of the mental representations. It is by no means clear how mental representations help managers decide--and hence how improvements to the representations would enable managers to make better decisions. However, the representations which managers use instinctively when they make decisions, are at the root of their managerial effectiveness. In order to be truly useful to the managers, DSS must take them into account.

Unfortunately, the development of DSS has so far paid far too little attention to the importance of managerial representations in the decision-making process. As a result, the present DSS systems are either too simple to take the representations into account (in which case it may be argued that we do not really have a DSS), or the costs to managers in time and effort necessary to articulate and incorporate the representations into such systems are prohibitive (or at least appear to be so).

If we accept that managers carry in their heads mental representations of their management activity and environment, and if we believe that these representions are at the root of their managerial effectiveness, then the objective of DSS to improve managerial effectiveness becomes clearer: it is, among other things, to enable managers to access, improve and make better use of these mental representations.

ELICITATION PROCESS: A TECHNIQUE

There are several ways of eliciting the views managers have of their organizations. The two most obvious are to ask for the subjective perceptions of the managers involved or observe unobtrusively the actions of the managers in actual decision-making situations. In this paper, I opt for the former.

A possible approach for eliciting mental representations by asking for the subjective perceptions of managers was developed by Eden [6]. Eden believes that some managers can benefit from, and are keen to spend the time, exploring their own thinking. He and his colleagues have developed a technique that would enable managers to do so. The process can be viewed as a kind of psychoanalysis for managers, an attempt to make explicit the fundamental psychological structures underlying their behavior. Eden's approach is relatively straightforward and not particularly time consuming which greatly enhances its appropriateness as a tool for eliciting the mental representations of managers.

Eden and his group proceed in the following manner. The first step is to collect data from the managers on a specific activity. In this respect Eden does not restrict the approach to any one method. He does, however, provide some guidelines: the purpose of the exercise must be clear at the outset; the technique chosen to collect data should capture the complexity of thinking, its peculiarities and idiosyncrasies, its particularities as well as its generalities, and it should stay within the reality of the managers; and the data collected must be such that it can be presented comprehensibly. The coding method they employ (see Appendix 1) was developed from the basic ideas Holsti and Wrightson used to code

documents and texts describing the political activity of foreign policy leaders.

Secondly, using the collected data, they develop cognitive maps (for an example see Appendix 2) to capture the interplay of the concepts which managers have about their worlds. Constructing corresponding interaction matrices provides a formal representation of the maps. Data entry and map construction and analysis is done with the aid of the computer.

Thirdly, a software package, COPE (Cognitive Policy Evaluation), is also used in presenting results to the managers. It provides two levels of analysis. The first can handle questions such as: If I can describe an event in the following way, what theories (or paths linking concepts: A gives rise to B, C can be explained by D, etc.) do I bring to bear to explain the occurrence of the event? and, What theories do I use that enable me to predict future consequences of an event occurring? The second level of analysis answers questions such as: Can the event, described as follows, be explained through a sequence of theories by the occurrence of another event? and, Does the occurrence of an event have consequences for a particular concept?

Eden's approach could be used in the context of a DSS system to enable managers to articulate the mental representations they have of their management activity and environment. I envisage the following kind of DSS. Managers first input their thoughts about their management activity and environment in a formal way. The program interacts with the manager in a stylized English-like dialogue (questions and answers). Replying to a series of structured questions enables managers to describe

the concepts they have of their management activity and its environment and to define the theories linking them. Based on those replies, the program elicits the managers' mental representations and constructs visual maps of them. Managers can then review and when necessary revise those maps. Finally, when faced with a decision or confronted with an issue, managers use a "COPE type" program to assess the consequences of actions, to explore possible courses of action in order to obtain a desired result, or simply use the system as a "check list" or "sounding board".

Two other instances where similar approaches have been used in the context of decision making are worth mentioning here. The first is a "situation-based" system, as opposed to a "knowledged-based" system, called GODDESS (A Goal-Directed Decision Structured System) developed at UCLA by Pearl, Leal, and Saleh [15]. The system assists managers in structuring and searching their *own* knowledge (e.g. state relations among aspects, effects, conditions, and goals in addition to actions and states which are the basic components of the traditional decision tree approach) in a decision-making situation. The second is a method of computer assisted learning developed at the London Graduate School of Business Studies by Boxer [2]. The method enables managers to explore the value of their experience in relation to a particular problem context; to consider how their own experience relates to that of other managers; and finally to create design criteria for strategic options capable of commanding a consensus between managers. Whilst both approaches implicitly make use of mental representations, neither seem to offer managers the capability of exploring their own thinking in a more general way nor

of storing and subsequently accessing (in the course of problem solving or

of reflecting on managerial issues) the resulting formal representations.

ELICITATION PROCESS: THE MILIEU

The introspective qualities required for the elicitation process are uncharacteristic of today's managers [13]. Even if managers did possess the means to express their mental representations, would they have the time, inclination and aptitudes necessary to do so without any assistance? Managers may need to be convinced not only of the benefits which accrue to them and their organization from such an exercise but also of the need for the effort required by them. It may very well be, therefore, that busy managers will require the assistance of an analyst to articulate their mental representations.

Given the differences among cognitive styles,[*] the possibility certainly exists that the analyst's style will be at odds with that of the manager. Mathes [12] perhaps summarized it best when he said: "Managerial people analyze problems on the basis of differences or changes in situations. Scientific people look for similarities or common elements." According to Mason and Mitroff [11], designers of management systems have tended to project their dominant psychological type onto that of their clients. This must not happen in the case of the proposed DSS because the cognitive style of the manager needs to be at the centre

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[*] Excerpt from Benbasat's article [1]: There are a number of theoretical models on the nature of cognitive styles. Schroeder characterizes individuals as abstract versus concrete, where abstract types are able to handle and integrate more information cues than concrete types. Huysman differentiates between analytics, who use a planned model-based quantitative approach and heuristics, who use intuition and search for analogies and feedback in decision making. Keen categorizes decision makers as systematics versus intuitives on the problem solving dimension and as preceptives, that is, focussing on patterns and deviations from norms, versus receptives that is, direct examination of all data, on the data-gathering dimension. Driver and Mock distinguish between maximal and minimal data users on one dimension, and between individuals who would support one conclusion versus the ones who would put various interpretations on data and thus support various solutions with the same data, on a second dimension. Finally, Witkin defines individuals as field independents who have the ability to delineate and structure a given whole, or as field dependents who show a global point of view and for whom the organization of a field as a whole dictates the way its parts are experienced.

of the elicitation process. Support should therefore be in the form of coaching, which implies that the managers develop the representations themselves but that they do so with the aid, support, and encouragement of the analysts.

The need for privacy when articulating mental representations and the confidential nature of of these representations is a delicate problem. We certainly cannot expect managers to divulge their innermost thoughts about their organization without some assurance as to the privacy and confidentiality of the process. This means that the computer processing must either be in the form of a mini- or micro-computer which is physically located in the manager's office or a terminal (also in the manager's office) equipped with an encryption device and hardware key [5].

How we reconcile the need for the intervention of an analyst with the question of privacy and confidentiality is a very difficult question for which no general prescription is possible. Acceptable solutions will only emerge as a result of understanding on the part of the analyst and trust on the part of the manager.

USING FORMAL REPRESENTATIONS

Managerial effectiveness depends not only on the quality of "corporate" decisions--managers make very few of those individually--but also on "day to day" decisions like: What kind of report should I submit to my superior? How can I best present this new idea to my colleagues? How can I motivate John re the Three Star project? What will be Mary's reaction to my new resource allocation scheme? When thinking about such decisions managers bring to mind the mental representations that are most pertinent to the situation. Within the context of these representations, they then seek and review information of relevance. This is where DSS can be useful. DSS can improve managerial effectiveness by enabling managers to extend their mental representations to incorporate all information pertinent to them and yet avoid or at least diminish the systematic biases managers have when processing large amounts of information. In fact, mental representations can provide a most natural and most convenient structure for managers to store information effectively. As Chase and Simon [4] have explained, the development of expertise can in part, involve the storage of meaningful *patterns* of information.

If we are to support the managerial decision-making process we must rely on the strengths of both the managers and the computer aids. We must have the two working as a team. Unfortunately, managers tend to have a holistic, broad, and somewhat nebulous vision of their activity, organization and environment, whereas computer systems tend to picture the world as exact discrete facts which are later built into a more complete description. As Lee [10] points out: "The real challenge of DSS research is to find a useful working relationship between these extremes

of cognitive style." Indeed, a relationship where the computer system complements the cognitive weaknesses of the manager.

With the aid of the computer, managers could easily:

- search out from a given concept to any level of related concepts;

- follow a path of adjoining links between concepts;

- review all associated concepts using a keyword search function;

- review the various networks of contacts (political, organizational, technical, or other) associated with any given concept or group of concepts.

Of course the formal representations and the information they contain would have to be stored in such a way as to allow such manipulations. Given such a powerful aide-memoire, managers would be better able to:

- assess and store new information by relating it quickly and accurately to the appropriate concepts;

- assess the ramifications of various courses of action by examining the links between concepts in the representations;

- perform "what if" or contingency analyses for the same reason;

- explore new ideas or associations between concepts.

Managers are able to perform the above operations without the aid of the computer and do so all the time. However, the computer can *extend*

the mental representations, that is, increase the information captured by each representation well beyond the limits of human cognitive capacity. Therein lies the strength of the machine, its "mechanical" capacity to store large quantities of data without any loss in either the quality of the data or the ability to manipulate it. The real gain, however, is in over-coming the systematic biases (e.g. the tendancy to give undue weight to recent information) managers have when processing large amounts of information, as would be the case for their mental representations.

Humans attempt to minimize "cognitive strain" when required to handle uncertainty. Judgmental heuristics [16] by which uncertainty is reduced can be of the following kind:

- *representativeness*, whereby the probability of an event is judged by how representative--i.e. similar in characteristics--the event is to the process from which it is supposed to have been generated; for example, given a description of a student in high school and asked to identify his area of graduate specialization, people will tend to ignore the general distribution of graduate students among special-izations and rely solely on the five year old profile;

- *availability*, whereby the probability of an event is judged by the ease with which similar instances come to mind; for example, homicide, cancer, tornodoes are overestimated as causes of death whereas asthma, emphysema, diabetes are underestimated;

- *anchoring and adjusting*, whereby one estimates a quantity by starting from a suggested value and making adjustments from it; for examlpe, we are all aware of how difficult it is to overcome first impressions.

Relying on these heuristics results in people making biased decisions or failing to make adequate use of the information they have (as illustrated in the examples given). However, with the use of the kind of DSS described here, managers would use the information available more effectively, thereby reducing the need for misleading heuristics.

The views expressed in this section are in sympathy with those of Gorry [8] who demonstrated that even simple descriptive models can help managers find the right problems to solve. Gorry's interest in such simple models, which he calls managerial models, stems from his belief that they are central to managerial decision making; that they expand the limited capacity of managers to use information effectively; and that to the extent that these models can be discovered and ways found to improve them, there is hope of directly increasing managerial effectiveness.

CONCLUSION

DSS constitute a new field of information science aimed at bringing computer technology closer to managers. It is very much a child of recent advances in computer technology (e.g. mini- and micro-computers, time sharing, etc.). So far DSS have remained a captive of this new technology and their developments have been characterized by a general lack of insight into managerial behavior. As experience has shown, disregard for the concerns of managers can slow down the development and implementation of a new system and ultimately result in its underutilization—if not eventual total failure.

Managers appear most comfortable with those management tools that they can personalize or manipulate to reflect their own thinking. In the case of DSS, the systems developed so far are either too simple or too rigid to allow managers to do so. The ways and means by which the views of managers can be formalized, the *missing ingredient* according to Gorry and Scott Morton [9], has been the subject of this paper. I have introduced the concept of mental representations and have proposed a technique recently used by Eden [6] to construct cognitive maps to elicit them. I have also discussed the functions and possible uses of a DSS based on mental representations.

Unless managers can (and think that they can with a reasonable amount of effort) imprint onto their DSS the complexity and subjectivity of their own thinking, there is a serious doubt as to whether DSS will ever have wide application in management.

In this paper I have introduced, in the context of a DSS, a scheme whereby mental representations managers have of their activity and environment could improve their decision-making ability. The next step is to examine decision-making cases, both in the public and private sector, in order to identify if and how the proposed approach would improve the final decisions. It is clear, however, that only through the actual application of the method can concrete evidence emerge to support the merit of the proposed approach.

APPENDIX 1: DESCRIPTION OF THE CODING TECHNIQUE USED BY EDEN*

Let c be a group of words descibing the object of coding consideration; it may be qualitative or quantitative, a subjective concept or an easly operationalized object. Let a and b be a group of words describing the opposite poles (if such exist) of the state of the concept c. Either pole may be void, or it may be that both poles are left void, in which case the concept c is subjet to a monotonic increase or decrease in potential states. Thus in the concept "increased delinquency", a = increased, b is void, and c = delinquency. Then two concepts may be related by an arrow with a +ve or -ve sign. For clarity, and subsequently for computer recognition, the poles are separated by slashes, thus:

/bad/good/housing ———→⁺ /increased delinquency//

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*Taken from Eden's book entitled "Thinking in Organizations" [6].

Note that if one pole is void it is convenient to combine a and c so that a double slash appears which more obviously suggests the occurrence of a void pole.

An assertion is coded using three slashes--thus suggesting, implicitly, two void poles without the further implication of a monotonic relationship. Thus the previous example is coded:

$$///\text{bad planning in the 1950s} \longrightarrow^+ /\text{bad}/\text{good}/\text{housing}$$

A MORE FORMAL STATEMENT

Monotonic- Monotonic

$c_1 \longrightarrow^{+(-)} c_2$ gives:

"an increase in c_1 can lead to an increase (decrease) in c_2, or

"an decrease in c_1 can lead to a decrease (increase) in c_2", or

"an increase (decrease) in c_2 can be explained by an increase in c_1", or

"a decrease (increase) in c_2 can be explained by a decrease in c_1".

Monotonic-Bipolar

$$/ a_1 / b_1 / c_1 / \longrightarrow^{+(-)} c_2 \quad \text{gives:}$$

"$a_1 c_1$ can lead to an increase (decrease) in c_2", or

"$b_1 c_1$ can lead to a decrease (increase) in c_2", or

"an increase (decrease) in c_2 can be explained by $a_1 c_1$", or

"a decrease (increase) in c_2 can be explained by $b_1 c_1$".

The reverse of this relationship behaves similarly.

Bipolar-Bipolar

$$/ a_1 / b_1 / c_1 / \longrightarrow^{+(-)} / a_2 / b_2 / c_2 / \quad \text{gives:}$$

"$a_1 c_1$ can lead to $a_2 c_2 (b_2 c_2)$", or

"$b_1 c_1$ can lead to $b_2 c_2 (a_2 c_2)$", or

"$a_2 c_2$ can be explained by $a_1 c_1 (b_1 c_1)$", or

"$b_2 c_2$ can be explained by $b_1 c_1 (a_1 c_1)$".

$$/ a_1 c_1 / / \longrightarrow^{+(-)} / a_2 / b_2 / c_2 / \quad \text{gives:}$$

"$a_1 c_1$ can lead to $a_2 c_2 (b_2 c_2)$", or

"$a_2 c_2 (b_2 c_2)$ can be explained by $a_1 c_1$".

Assertions

$/ / / c_1 \longrightarrow^+ c_2$ gives:

"c_1 can lead to an increase in c_2", or

"a decrease in c_2 may be because c_1", or

"an increase in c_2 may be because c_1".

$/ / / c_1 \longrightarrow^+ / a_2 / b_2 / c_2$ gives:

"$a_2 c_2$ may be because c_1", or

"$b_2 c_2$ may be because c_1".

$/ / / c_1 \longrightarrow^+ / / / c_2$ gives:

"c_2 may be because c_1".

An assertion may be explained by a previous concept but the previous concept may not have the consequence of an assertion.

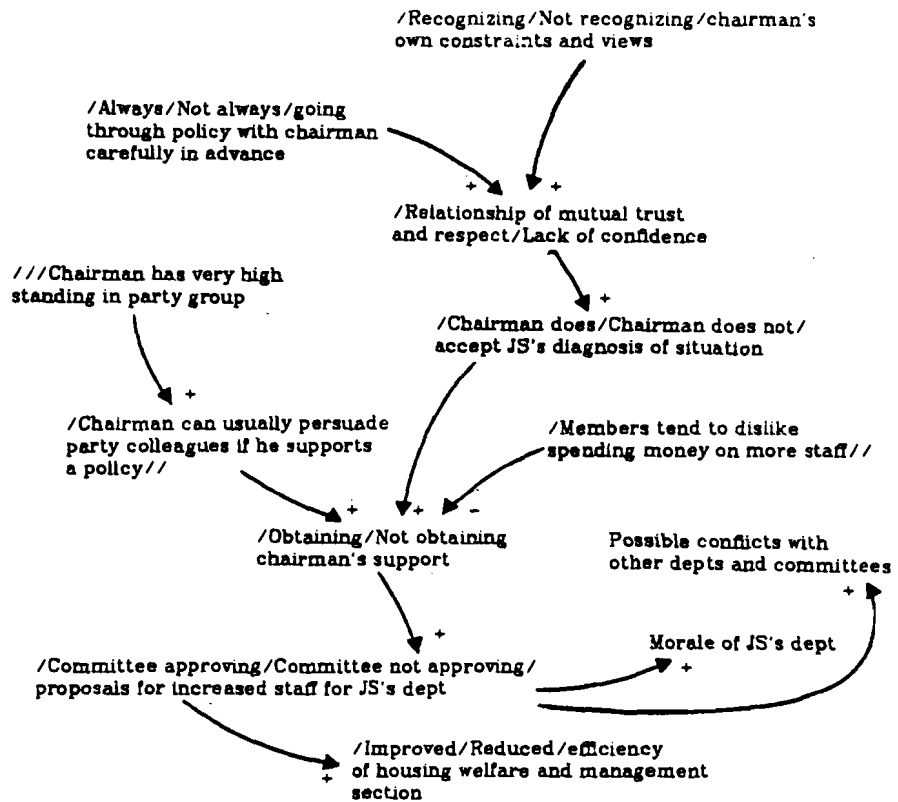
VOID POLES

Void poles are important for several reasons:

(i) they indicate possible intervention strategies that have never previously been considered (thus their being void).

(ii) a void pole can lead to a suggested loop (that is a path formed by the edges) not being a loop in the cognitive sense, thus the figure below is not a negative feedback loop because of the existence of void poles.

$$^+/a_1c_1//$$

$$c_2^+$$

$$/a_3c_3//^-$$
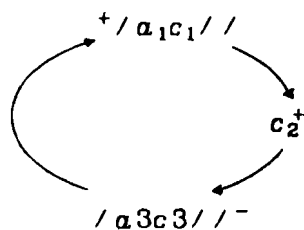
A Void Loop

(iii) a void pole can have been properly coded as such but not represent a good cognitive map. This occurs when the client has only *expressed* one pole but psychologically treats it as bipolar. A situation of this sort is usually corrected during feedback.

APPENDIX 2: EXAMPLE OF A COGNITIVE MAP*

/Recognizing/Not recognizing/chairman's own constraints and views

/Always/Not always/going through policy with chairman carefully in advance

/Relationship of mutual trust and respect/Lack of confidence

///Chairman has very high standing in party group

/Chairman does/Chairman does not/ accept JS's diagnosis of situation

/Chairman can usually persuade party colleagues if he supports a policy//

/Members tend to dislike spending money on more staff//

/Obtaining/Not obtaining chairman's support

Possible conflicts with other depts and committees

Morale of JS's dept

/Committee approving/Committee not approving/ proposals for increased staff for JS's dept

/Improved/Reduced/efficiency of housing welfare and management section

Some of Mr. Saunders' beliefs about the importance of the Chairman of Committee, relating here to the question of staffing.

*Taken from Eden's book entitled "Thinking in Organizations" [6].

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