THE IMPACT OF STRUCTURAL MODELING ON THE CREATION OF NEW PERSPECTIVES IN PROBLEM SOLVING SITUATIONS

Ioannes B. Kapelouzos

Council of State

Athens, Greece

and

Institute for Advanced Study in the Integrative Sciences

George Mason University

Fairfax, Virginia, U.S.A.

Paper prepared for presentation at the

European Congress on System Science

Lausanne (Suisse)

October 3-6, 1989

THE IMPACT OF STRUCTURAL MODELING ON THE CREATION OF NEW PERSPECTIVES IN PROBLEM SOLVING SITUATIONS

Ioannes B. Kapelouzos

Council of State

Athens, Greece

and

Institute for Advanced Study in the Integrative Sciences

George Mason University

Fairfax, Virginia, U.S.A.

Abstract

A system of process management known as Interactive Management (IM) is a major component of an emerging science of generic design. It facilitates the management of complexity through the participative building of structural models by groups. Data from applications of IM are presented which support the hypothesis that the process of structural modeling enables group members to appreciate and conceptualize new perspectives on the problematic situation. A case is also presented that illuminates this hypothesis.

Introduction

This paper refers to a system of management known as Interactive Management (IM) that has been designed to enable members of interdisciplinary and interfunctional groups to deal

with complex problems. The system provides a holistic approach to group work and it promotes the emergence of a collaborative environment and cooperative climate in which participants can work. There exists an extensive literature dealing either with the system itself or with various aspects of its supportive philosophy and epistemology [3,6,7,8]; a number of cases concerning applications of IM have also been reported. After its systematic application for eight years, initially at the University of Virginia and for the past five years at George Mason University, Va, U.S.A. , the system became a major component of a science of generic design that is the subject of a forthcoming book [11].

In what follows, data from applications of IM are presented which support the hypothesis that the process of structural modeling helps expert and stakeholder teams to reach new perspectives on the problem situation or issue under investigation. A case is also presented that illuminates this hypothesis.

Background

Data from applications of IM were published in a recent paper by Warfield [9]. These data shed light (a) on the diversity of belief that exists among group members as to the relative importance of factors pertaining to a complex situation or issue and (b) upon the form of the organized logic that expresses relationships involved in attempting to resolve such issues.

Specifically the data were derived from two most commonly used methodologies in IM, namely the Nominal Group Technique (NGT) and the Interpretive Structural Modeling (ISM) .

Data from applications of the NGT supported the hypothesis that regardless of the issue and across a wide variety of groups, there is always substantial difference in belief concerning relative saliency of factors involved in the issue. The data revealed that on average the value of diversity was closer to perfect disagreement than to perfect consensus. This finding was considered very significant in terms of complex problem solving and complex system design because it made clear that in order to diminish the diversity that prevails at the beginning and reach a reasonable degree of consensus on a complex issue or design situation, significant changes in perspective will be required from members of the group.

Data from applications of the ISM process on the other hand, revealed that the structures developed contained logic cycles with numbers of elements that equal or exceeded the effective limits of short-term memory as it is reflected in the "span of immediate recall" and that the longest span of inference involved in comprehending the logic patterns exceeded that limit. These data were supportive of the sensed need for development of visual logic representations in order to enable the unaided mind to learn and amend relationships that are critical to a complex situation, to use analytic procedures of comprehending the structures, and to provide documentation for communication.

The significance of the above findings must be assessed in full recognition of their relevance to two foundational assumptions and three laws of generic design science. One of the assumptions states that every human being possesses an "unshakable cognitive burden" which is the state in which he or she necessarily approaches a problem situation. The other states that the human brain has a "bounded rationality" i.e. a limited capacity to process information.

Three of the laws of design are known as laws of (1) requisite variety, (2) requisite saliency, and (3) requisite parsimony. The first law requires that design and problem solving activity for complex situations be carried out participatively by groups of individuals with diverse viewpoints in an effort to ensure the requisite variety inherent to the design situation. The second law requires open, focused dialogue and justified decisions in order to ensure the achievement of the kind of understanding that is needed to put the design factors in accordance with judgments of relative significance. The third law places a requirement to monitor the rate of presenting and processing information by the human mind in order to avoid cognitive overload during the design process.

In an effort to manage the difficulties stemming from the combined impact of complexity and human-bounded rationality and to monitor group activity during the participative design process, a methodology called Interpretive Structural Modeling (ISM) was invented by Warfield [5]. The ISM is founded on

behavioral theory and the mathematical theory of relations. It enables participants to carry out actions and take decisions in order to define complex systems. Among the critical ingredients required for implementing ISM are: (1) a skilled facilitator who is knowledgeable of the process and who helps groups work together, (2) computer equipment with ISM software that minimizes the time required to draw logical inferences from participant responses, and (3) the participant group whose members have substantive content knowledge on the issue to be studied as well as capacity to read and engage in focused dialogue.

There are five phases usually applied in dealing with the substantive content. In the first phase a context, i.e. an issue or problem to be investigated, is identified. Next there is identified a set of elements along with a contextual relationship. In the third phase the participants view the statements posed by the computer, discuss them, and vote on them. When the entire element set has been explored the computer makes available the information needed to construct a map of the relationships uncovered during the previous phase. In the final phase the map is assessed and interpreted by the participants.

The ISM method is used in IM in combination with the NGT method [4]. The latter has been proved to be very useful for the generation, clarification and assignment of relative importance to ideas that are subsequently organized into a model of interrelated elements with the ISM. The combined use of these methods became a powerful tool to yield substantial improvements

in group effectiveness to complex problem solving.

The assignment of relative significance among factors pertaining to a problem situation or issue comes from the alternative perceptions and valuations of the group members. During the implementation of NGT process, group judgments concerning the saliency of factors relevant to the issue are not permitted. Specifically the process is divided into four steps. In step one, each participant silently generates ideas. The ideas thus generated are in the subsequent step recorded in a round robin on flip charts that are displayed in such a manner that every participant has visual access to all information. In step three of the process, every idea is clarified in order for the group members to understand its intent or meaning. No value judgments are allowed during this clarification step. In step four, each participant votes silently by selecting from the universe of generated and clarified ideas five that he or she considers to be relatively most important in relation to the issue being discussed. It is only with the use of the ISM method, whereby group members try to explore interrelationships among ideas selected with the NGT, that value judgments come to the surface as a result of the dialogue, explicit argumentation, and assessment of opinions. In this way it is expected that faulty reasoning will be uncovered and good ideas will come out of a state of confusion.

In light of these considerations it is interesting to compare the outcome of the NGT process with that of the ISM

process, in order to get some insight as to the contribution of the latter towards improvement in participants' perception of the situation. The assignment of relative saliency to factors involved provides good grounds for such a comparison. As the preceding discussion shows, the ISM products correspond to the collective perspectives of participants while the results of the NGT process represent the sum of their single perspectives.

Data from IM Sessions

The voting that takes place in the fourth step of the NGT method is partitioned in two succinct stages. In the first stage each participant selects five ideas that he or she considers to be of highest saliency. In the second stage each participant ranks the five ideas he or she selected in the previous stage according to perceived relative saliency from one (high) to five (low). For purposes of data analysis, the scores were reversed. One can easily conceive a structure that reflects the voting results as to factor saliency. The level of the structure in which an idea is placed is contingent upon the sum of scores the idea has received. Ideas with equal values are considered to be placed in the same level. Subsequently each idea received a score in accordance to the level of the ISM structure in which it is located. Both the NGT and ISM scores for each idea were converted into decimal numbers and subjected to a correlation analysis. In addition a multiple regression analysis was performed using the ISM data for the dependent variable. Tables 1 and 2 show the results of the compared values from 23 applications of IM.

TABLE 1

Correlation of NGT-ISM Data From IM Sessions

CASE *	N	CORRE-LATION	R SQUAR.	SIGNIF-ICANCE	CASE	N	CORRE-LATION	R SQUAR.	SIGNIF-ICANCE
3	21	.06775	.00459	.7704	19	17	.05652	.00319	.8294
5	17	-.37841	.14320	.1342	20	18	-.49717	.24718	.0358
6	21	-.06900	.00476	.7663	22	19	.09952	.00990	.6852
7	26	.17467	.03051	.3934	23	21	.10863	.01180	.6393
8	25	-.31726	.10066	.1223	24	33	.39881	.15905	.0215
9	27	-.37621	.14153	.0531	25	20	-.40487	.16392	.0766
10	28	.33400	.11156	.0824	26	21	.07121	.00507	.7590
11	19	-.03490	.00122	.8872	27	28	.05665	.00321	.7746
12	32	-.13510	.01825	.4610	29	24	-.61270	.37540	.0015
13	16	-.10679	.01140	.6939	30	20	.05806	.00337	.8079
15	12	.48431	.23456	.1106	31	22	.16379	.02683	.4664
17	25	-.37950	.14402	.0613					

* The case number is a key for access to the relevant file. A total of 31 cases were considered for analysis out of which 23 were selected according to criteria explained later in the paper.

TABLE 2

Multiple Regression Analysis of NGT-ISM Data

Multiple R	.0519
R. Squared	.0027
Adjusted R. Squared	.0007
Standard Error	.2849

Analysis of Variance

	DF	Sum of Squares	Mean Square
Regression	1	.11201	.11201
Residual	510	41.39998	.08118

F = 1.37982 Signif F = .2407

Table 1 indicates for each case (a) the number of ideas structured by the participants, (b) the correlation between NGT and ISM scores, (c) the R. Square value, and (d) the corresponding level of significance. Examination of the data in Table 1 shows that in all but three cases (20,24,29) the correlation between NGT results and ISM results is not significant ($p > .05$). Note that of the three cases above, two exhibit a negative correlation.

Table 2 indicates the multiple regression analysis for the combined results from all cases. As the analysis of variance from this table shows, the F value for regression is not significant ($p > .05$).

Two findings come out of the analysis of these data: (1)

that the product of the ISM method does not resemble in any significant way the product of the NGT method with respect to factor saliency, and (2) that the ISM product can not be predicted by the initial perceptions of participants. One should not expect that such a comparison could reveal the particular kind of changes in participant's perception of the situation or the way such changes undergo. However,one can conclude from the above data that the final product of the ISM method is largely an outcome of the modeling process, not an outcome of the initial viewpoints of participants as to the saliency of factors relevant to the issue.

Certain limitations must be taken into consideration. The cases of Table 1 were selected on the basis of the type of relationship used for the construction of the model. While the ranking of factors in the NGT process reflects always a relationship of importance, the relationships used for the construction of the Interpretive Structural Model vary. In order to diminish the possibilities for mismatch of the compared relationships, the sample used contains cases in which the ISM were constructed under such relationships as "aggravates", "increases the severity of", "contributes to the resolution of", "supports the achievement of", and "should be addressed before". Underlying is the assumption that when the group members are asked to select among a number of problem statements those they consider as relatively most important, a normal connotation is that they select them in terms of their relatively higher impact to the severity of the problem; and when the group members are

asked to select among a number of objectives or issues those they consider to be as relatively most important, a normal connotation is that they select them in terms of their higher contribution to the achievement of the pursued target or the resolution of the issue.

A Case Study

Having shown that the process of structural modeling has an impact upon the creation of new perspectives on the issue or situation under study let us illuminate the matter by use of an example taken from a relatively recent application of IM.

On June 29, 1987 Indian leaders and U.S. government representatives met together at the Russell Senate Office Building in Washington D.C. to define the barriers to effective participation of tribal governments in the U. S. federal system. The IM method was used for this purpose. Starting with the NGT process, the group of participants generated and clarified 64 critical barriers. A subset of these barriers was subsequently structured with the ISM method in a sequence for future work. During the ISM process, the participants were presented with pairs of statements and judged after thorough discussion whether or not a particular barrier should be addressed before or at the same time as the other barrier in the pair. Figure 1 shows a structure of the barriers contained in Figure 2 reflecting the NGT voting results (constructed as described previously in this paper). Figure 2 shows the product of the ISM process.

Figure 1

Structure of Barriers to Effective Participation of the Tribal Governments in the U.S. Federal System (NGT Process)

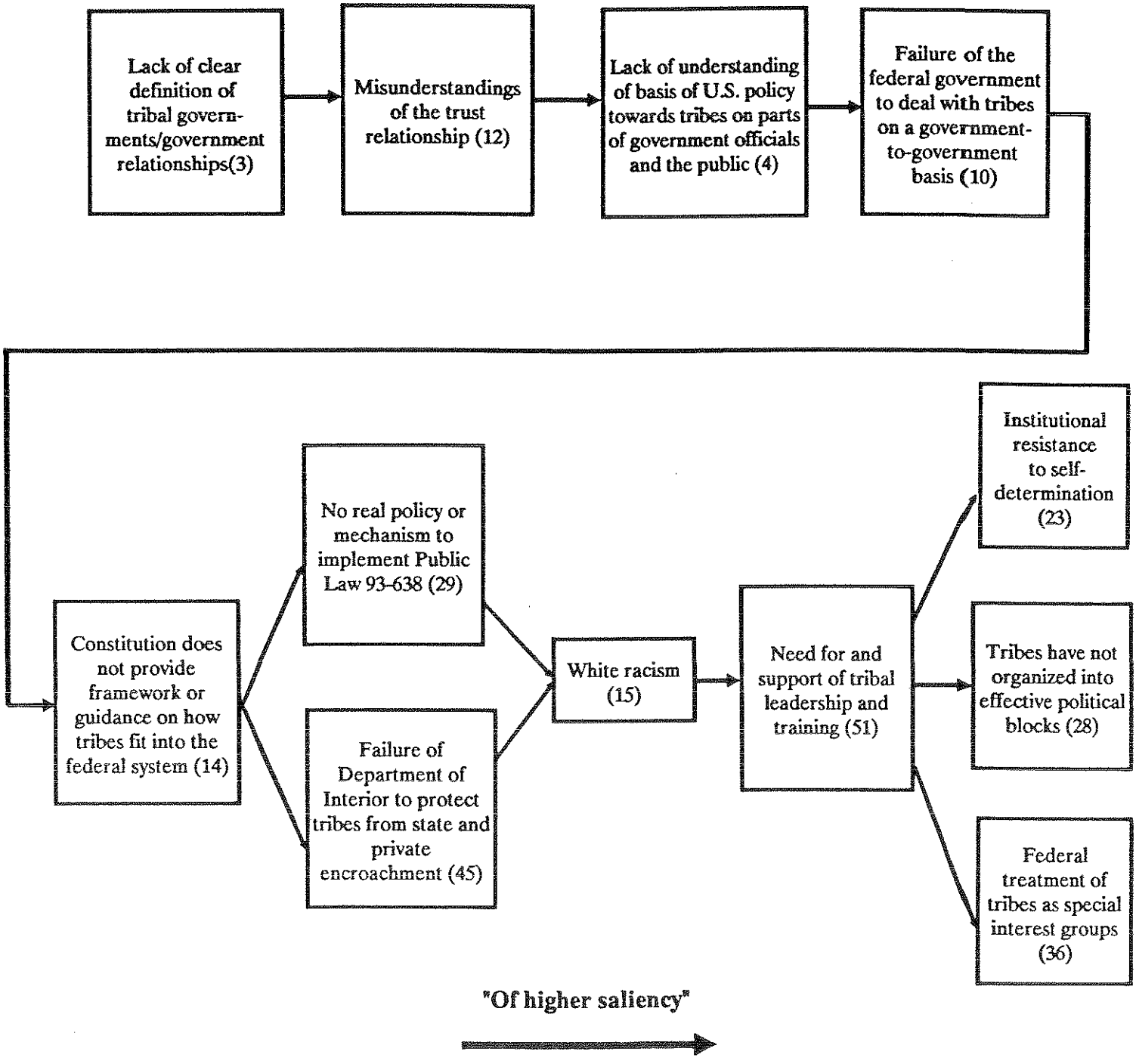
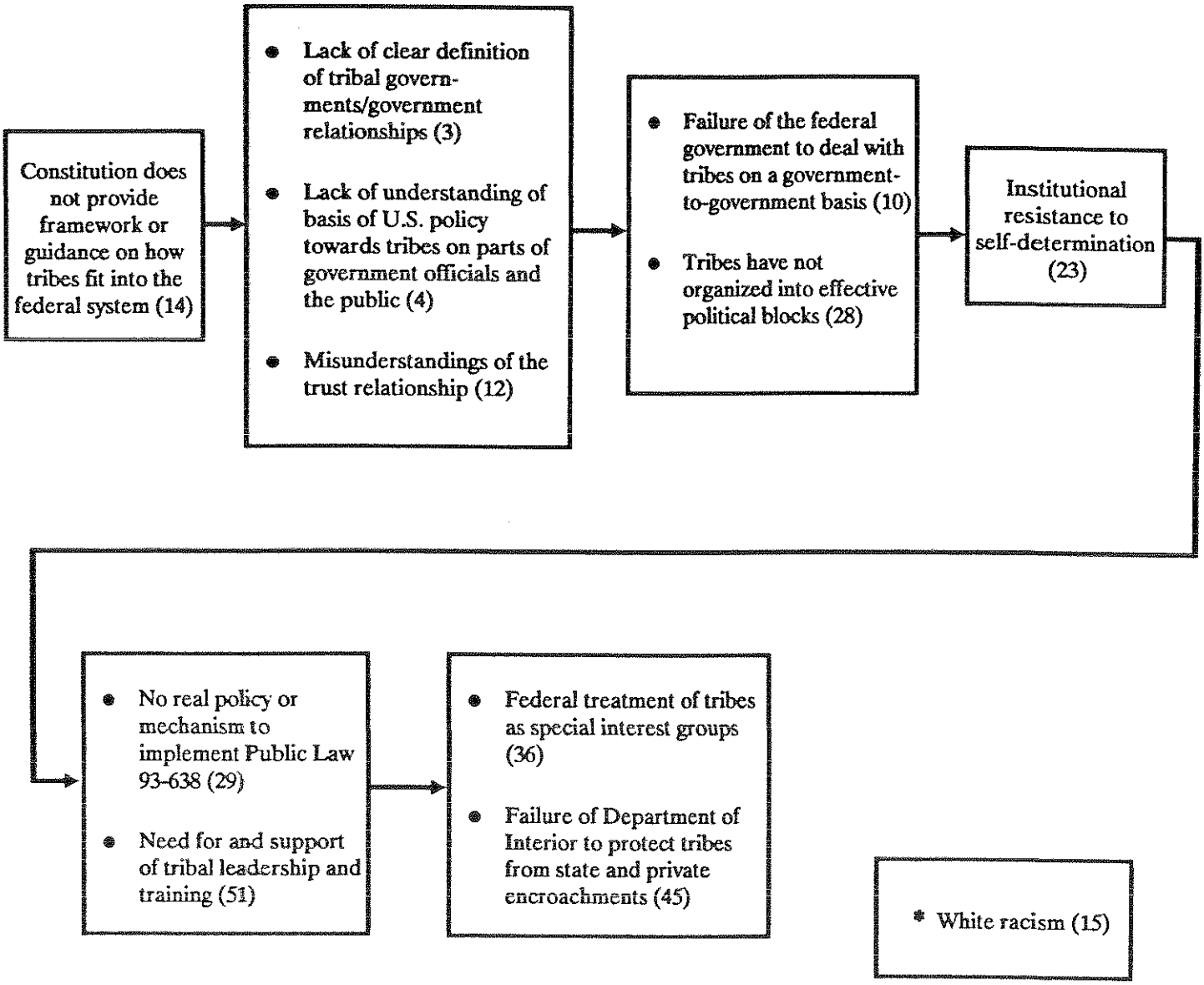


Figure 2

Structure of Barriers to Effective Participation of Tribal Governments in the U.S. Federal System (ISM Process)



A comparison of the two structures reveal differences in relative saliency of factors pertaining to the issue. In Figure 1 for instance, barrier # 3 "Lack of clear definition of tribal government / government relations" is considered to be of highest importance while barriers # 14 "Constitution does not provide framework or guidance on how tribes fit into the federal system" and # 15 "white racism" occupy respectively the middle and a low position in the structure. In Figure 2 on the other hand, the most important barrier to be addressed before any other barrier in the structure is barrier # 4 "Constitution does not provide framework or guidance on how tribes fit into the federal system". The same Figure reflects also a proposed and agreed upon amendment to move barrier # 15 "white racism" out of the structure, for this item appeared to affect everything in the structure.

It seems clear that the process enabled the participants to consider a barrier that raises the issue to the constitutional level of the political system as the most salient one. (NOTE: The above case is case No. 15 of Table 1).

The same case lends itself also as an example of a different kind of impact of IM in changes of perspectives of those exposed in its experience. There are inherent conflicts of interests in the history of Indian government / U.S. government affairs. Many of the elements in the structures reflect this conflict. IM offered an alternative way to resolve the issues based on mutual

efforts of the interested parties to understand each other's positions and to develop a common vision of the situation. The experience of IM itself resulted in new perspectives towards ways to conflict resolution. A follow-up forum on February 21, 1989, was dedicated to the generation of alternative solutions and a third meeting is scheduled to occur for the creation of a strategic action plan in order to achieve full political participation of tribal governments in the U.S. federal system.

Epilogue

In maintaining that the conceptualization of new perspectives on the problem situation, as revealed by the interpretation of the data in Tables 1 and 2, is due to the ISM method, the following matter needs to be clarified: In each of the 23 cases , both the group of participants and the issue under study were different. What these cases share in common is the method employed. Since the compared data show a discontinuity in most cases of participants' initial perception (represented by NGT data)with their final perception of the problem situation (represented by ISM data), it is highly improbable for these findings to be attributed to other factors.

The primary benefit from IM lies in that it promotes learning by the participant group. ISM provides the major vehicle towards this learning. There is no way to estimate by use of statistical evidence the quality of learning that occurs during the process. Yet, the span of inference in the structures

produced with the application of IM indicates that the groups reach wide perspectives on the problem situation. Furthermore the data offered in this paper support the assumption that these perspectives are largely due to the ISM process. One can not go further in appreciating the results of this study. Additional research on the field may reveal certain patterns of changes in participants' perceptions during the implementation of this process.

Acknowledgments

Dr. B. J. Broome, Dr. A. N. Christakis, and Dr. J. N. Warfield read a draft of this paper and commented on it. Ms. M. Connelly produced the figures. The author gratefully recognizes Dr. Broome's assistance in the completion of this work.

References

1. BROOME, B. J. & CHRISTAKIS, A. N. (1988). A Culturally Sensitive Approach to Tribal Governance Issue Management. International Journal of Intercultural Relations, Vol. 12, (pp. 107-123).

2. CROMER, I. & CHRISTAKIS, A. N. (1987). Moving Toward The Effective Participation of Tribal Governments in the U.S. Federal System. Report, Center for Interactive Management, George Mason University, Fairfax, VA.

3. CHRISTAKIS, A. N. (1986). The Cosmology of Design. Paper presented at the Annual Meeting of the American Society for Cybernetics. Virginia Beach, Virginia, Feb. 19-23.

4. DELBECQ, A. L. (et al.) (1975). Group Techniques for Program Planning; a guide to nominal group and delphi processes. Scott,Foresman and Co.

5. WARFIELD, J. N. (1982). Interpretive Structural Modeling (ISM).In Shirley A. Olsen (Ed.), Group Planning and Problem-Solving Methods in Engineering Management (pp. 155-201). John Wiley.

6. WARFIELD, J. N. (1984). Principles of Interactive Management. Proceedings of the International Conference on Cybernetics and Society. IEEE, New York, NY.

7. WARFIELD, J. N. (1985). On the Choice of Frames for Systems Study. Proceedings for General Systems Research. Louisville, Kentucky.

8. WARFIELD, J. N.(1988). Implicit Aspects of Much Systems Thinking. Systems Research, Vol. 5, No 4, pp. 333-342.

9. WARFIELD, J. N. (1989). Underconceptualization. Paper, presented at the meeting: "Support, Society and Culture: Mutual Uses of Cybernetics and Science". University of Amsterdam, March 27-31.

10. WARFIELD, J. N. & AYIKU, M.N.B. (1989). Sociotechnical Modeling for Developing Nations. Paper, prepared for Presentation.

11. WARFIELD, J. N. (1989).A Science of Generic Design. Forthcoming.