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ABSTRACT

Description of the characteristics and mechanics of the Delphi technique of identifying the likelihood of occurrence of specified future events precedes suggested uses for the technique in research, planning, and teaching. The procedure involves obtaining individual predictions, aggregating results, presenting results to the individuals, and having individuals evaluate predictions. A RAND Corporation study to predict major developments in population growth, probability and prevention of war, future weapon systems, automation, space progress and scientific breakthrough illustrates the mechanics of the technique. The potential of the procedure for resource forecasting, application of the technique to establish city planning goals, and a discussion of a modified version of the procedure as used in teaching a graduate course in research methodology indicate the possible value of the Delphi technique in incorporating variables in research and in attempting to identify priorities at various spatial scales of planning. (Author/SHM)

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THE DELPHI TECHNIQUE IN RESEARCH AND TEACHING

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A problem encountered by investigators in a variety of disciplines is that of forecasting future events. Questions concerning the linearity or non-linearity and time horizons of variables must be considered, since operationalization requires assumptions about the behaviour of phenomena over time. Another difficulty, however, is often that of identifying relevant variables, determining a procedure to facilitate their measurement, and incorporating them into a forecasting model. For example, when studying land use patterns, specific location decisions or consumer behaviour, the impact of transportation or marketing innovations could be significant. Or, in analyzing the pattern of resource development, the role of variables ranging from new extractive processes to national self-consciousness should be considered. These illustrations have a characteristic common to many geographical studies. The measurement and incorporation of the identified variables necessitates consideration of the probability of events occuring in the future. It is the aspect of determining how to incorporate variables such as technological innovations or social values which prompted this paper. With this consideration, the paper examines the utility which a technique developed for futuristic forecasting might have for geographical inquiry. The characteristics and mechanics of the Delphi technique are briefly described, and then several instances in which it might be of use are discussed. It is hoped that the potential and demonstrated utility of the technique will result in its consideration and eventual application by a wider range of investigators.

THE DELPHI TECHNIQUE

The Delphi technique, generally attributed to Helmer,[1] has been described as a "...succession of iterative brainstorming rounds..."[2] Briefly, the purpose of the technique is to identify the likelihood of occurance of specified events in the future. The manner in which this is accomplished is by soliciting the viewpoints of a number of experts as to whether an event will occur and if it will occur as to when its occurance might be expected. The viewpoints of individuals are obtained through letter or questionnaire in an attempt to minimize the direct impact of the other participating experts upon an individual's judgement.

The iterative characteristic is attributable to the fact that after the viewpoints of individual experts are obtained they are aggregated with the viewpoints of other experts. After aggregation, each expert, still in isolation from the other participants, is presented with the aggregated results and asked if he would alter any of the predictions. In addition, he might be asked to state reasons for any viewpoint or prediction with which he disagreed. This procedure of obtaining individual predictions, aggregating results, presenting them to the individuals, and having individuals evaluate the predictions may be conducted for as many rounds as is considered feasible.

From this brief description, it will appear that the Delphi technique belongs to the family of "think-tank" procedures which involve the assembling of an array of experts for a given problem. The distinction from other procedures, such as group "brainstorming", is that with the Delphi technique individuals are ideally kept separate. In this manner, while the individuals are influenced by the aggregated results at the end of each round, an attempt

is made to decrease the influence of group psychological effects.

A number of questions obviously require attention in the use of the technique. First, the selection of experts or judges may introduce bias in the predictions. When considering solutions to environmental problems, for example, an engineering-dominated group might be expected to stress development of technologically-based procedures while a group of social scientist-dominated experts might reach a different prediction set. This problem is vividly illustrated in flood plain management where engineers have emphasized structural solutions (dams, levies, dikes) while social scientists have urged nonstructural approaches (zoning, taxes, insurance). Clearly, for a given problem an attempt should be made to assure an appropriate mix of backgrounds among the experts.

A second point deserving study is the comparability of predictions made by individual experts. When aggregating individual responses, it is essential that the collator be able to compare statements from two people in order that they may be allocated to appropriate categories. Using environmental problems as an example again, one expert might predict a solution from the "development of automated waste collectors" while another might predict the "development of irrigation systems collecting and utilizing domestic sewage". These two predictions represent different levels of generality, and while the latter could be taken as a specific illustration of the former it is not difficult to imagine responses which would be awkward to compare and evaluate.

With this very brief introduction to the technique, an example of its application by the RAND Corporation may more clearly illustrate the mechanics of the procedure. It seems appropriate to use a RAND study since, if Helmer may be said to have developed the technique, it appears as if RAND's use of the Delphi technique led to its popularization. The technique was used by RAND when the corporation was asked to predict the major developments which might be expected in six areas: population growth, probability and prevention of war, future weapon systems, automation, space progress, and scientific breakthroughs.[3]

As reported by Jantsch,[4] RAND proceeded in the following manner. Eighty-two experts from North America and Europe were enlisted and divided into six groups, one group for each subject area. In regard to scientific breakthroughs, during the first round the participants were asked by letter to name breakthroughs urgently needed and realizable within the next fifty years. This question resulted in forty-nine items being identified. In the second round, the experts were asked to estimate when each of the items identified in the first round would be realized. Consensus was reached on ten of these items. For the third round, the participants were given the ten items for which substantial agreement existed, and were asked if those disagreeing with the estimated timing would elaborate upon their reasons. As well, seventeen items for which no agreement had been reached were presented with the request for experts to explain why such a range of viewpoint existed on their timing. In a fourth round, a similar procedure was followed as in the preceding round. The final outcome was general consensus on the timing of thirty-one of the original forty-nine breakthroughs which initially had been identified. Having now considered the characteristics of the technique, the rest of the paper examines its application to problems of geographic interest.

POTENTIAL FOR RESOURCE FORECASTING

It seems that the Delphi technique offers potential for investigations of natural resource supply and demand patterns in nations. An integral part of such investigations would be a consideration of the importance of changes in variables in the future. In an attempt to identify those variables which need to be considered in forecasting water requirements, Sewell and Bower have provided a list which is relevant to general resource forecasting situations.[5] The variables - population, nature of the economy, technology, social tastes, policy decisions, nature of the physical system - are similar in that to varying degrees it is difficult to estimate the magnitude and timing of changes associated with them. For example, technological innovation could result in new products by substituting one raw commodity for another. The competition between aluminum and wood in house-building , plastic and glass for containers, and petroleum and coal for fuel come to mind. New processes which utilized greater or smaller amounts of water or energy to produce the finished product could also effectsupply schedules. On the other hand, demand schedules could be influenced by social tastes, witness the demand for green lawns and coloured paper towels with their associated effect upon water supply requirements. Nevertheless, identifying these variables is only one step forward. Having recognized their importance, it then becomes necessary to determine how they might be incorporated into forecasts.

A more detailed discussion of technology illustrates the nature of the problem. As Sewell and Bower note

> Forecasts of future water demands, particularly where industrial demands are significant, need to take into account possible technological changes. This is not an easy task. First, it is difficult to forecast what technological changes are likely to occur, particularly when the time horizon extends beyond five to ten years. Second, it does not follow that, because improved technology is developed, it will begin immediately. Typically, technological changes find their way into practice only slowly, even in a technologically-oriented society such as North America.[6]

Several problems are thus clearly identified in regard to technology: the need to identify breakthroughs, the need to estimate the timing of their development, the need to estimate the timing of their implementation. These aspects are of common concern to forecasts relating to a range of resource management issues.

A number of alternative approaches are available to accommodate such variables as technology. One approach is exemplified by the work of Landsberg and colleagues in estimating the adequacy of natural resources in the United States to the year 2000.[7] In that study, "reasonably possible estimates in technology" were taken into account whenever their form could be envisaged and the likely consequences estimated by the investigators. On the basis of estimated gains in technology, and the influence of other variables, a series of projections were developed to represent low, medium and high patterns of resource availability.

A somewhat different approach which assumes no changes in technology may be adopted. To some extent this approach was followed by the National Energy Board when forecasting supply and demand of Canadian energy from 1966

to 1990.[8] In this study demand was estimated for market sectors, while supply was estimated for petroleum, natural gas, coal and electricity. A number of assumptions were made as to political, economic, technological and social variables over the forecast period. Under technological considerations, it was assumed that there would be no new energy form, no new means of energy transportation, increased use of electricity and natural gas, and increased pressure for the reduction of air and water pollution. In contrast with the previous study, it can be seen that little effort was made to estimate or incorporate the impact of changing technology by the National Energy Board. This may well be a significant weakness, especially since the extent to which changing technology can interact with other variables to make energy projections go astray has been documented.[9] In summary, therefore, it would appear as if it is inadequate to hold technology constant. On the other hand, neither does it appear ideal to include only technological changes when their form can be estimated by the investigators involved.

It appears as if the Delphi technique, as applied by the RAND Corporation to estimate scientific breakthroughs, offers considerable scope for incorporating some of the variables identified by Sewell and Bower. In particular, the technique seems relevant for estimating the development, timing and occurance of technological gains, as well as changes in the economy, social tastes and policy decisions. If a pool of experts from government, private enterprise and universities, representing a range of disciplinary backgrounds, could be assembled, it might be feasible to attempt application of the Delphi technique in resource forecasts. In a pilot study, the experts could be divided into a number of panels to concentrate upon the variables noted above. If the pilot study proved workable, the technique might then be applied to individual resource commodities or combinations of commodities at different spatial scales over varying time periods. In short, the application of the Delphi technique seems to provide a chance to refine and improve forecasting methodologies for which present assumptions often seem inadequate. Whether done at a county or a national scale, however, the task would be complex and demanding. It is with this in mind that the following examples are presented to illustrate that the technique may be applied in situations offering more immediate dividends.

APPLICATION IN PLANNING

The Delphi technique was applied by Brian Turnbull, as Planning Director for the City of Waterloo, to determine priorities for area planning goals. The City of Waterloo was given a list of twelve planning goals by the Waterloo Area Planning Board for consideration. Turnbull felt it was important that city aldermen and planning board members discuss the goals in some detail since all were desirable and all were phrased in fairly general terms.

In October 1969, the city aldermen and planning board members were asked to evaluate each goal, and assign a number from one to ten to it, with ten being the highest possible rating. At a subsequent meeting, the participants were presented with the aggregate scores, and discussion ensued. Following the meeting, participants were asked to re-score the goals to see if any changes had occured as a result of members having encountered other viewpoints. In fact, between the two rounds there was no change in the ranking of goals. The final priorities for the twelve goals, and their respective scores, were as follows: first, to minimize air and water pollution (102); second, development

consistent with social and housing needs (82); third, to minimize cost of essential public services (77): fourth, to preserve the unique attributes of the area landscape (72), fourth to minimize commuting distance and time (72); sixth, to minimize the urban use of productive agricultural land (67); seventh, to develop with respect to requirements of major economic activities (65); eighth, to facilitate and maintain a pattern of local communities (61); ninth, to consider economic and technical change and their social implications in development (60); tenth, to maximize opportunities for using specialized services and facilities (56); eleventh, development consistent with technological innovation (46); and twelfth, to minimize cost of moving goods within the region (43).

The aldermen and planning board members, taken as separate groups, ranked the twelve goals in a similar manner. A notable difference was "to minimize cost of essential public services" (aldermen, second; planning board members, fifth). Interesting similarities were: "to minimize air and water pollution" (first for both groups), "to preserve the unique attributes of the area landscape" (third for planning board members; fourth for aldermen), and "to minimize cost of moving goods within the region" (eleventh by aldermen; twelfth by planning board members). Of additional interest is the fact that when Turnbull went through the same procedure with senior geography undergraduates at Waterloo Lutheran University the ranking of goals proved to be the same.

When considering the benefits of the Delphi technique in the modified version described above, Turnbull noted several advantages. It forced the participants to evaluate a set of goals, all of which were socially desirable but couched in terms susceptible to misinterpretation. During the discussion between the two rounds, participants found that different rankings by individuals often arose because of different interpretations of the same goal. Having ranked the goals and discussed each individually, participants frequently were able to resolve differences arising from differing interpretations and to put the goals into terms in which they could be clearly understood by laymen. Thus, in a practical planning situation, the Delphi technique provided a method for a city to systematically evaluate and establish priorities for a set of goals. The satisfaction with the procedure is reflected by the group's recommendation that the technique be utilized by area planning boards or councils faced with similar evaluation exercises and Turnbull's intention to use it in planning studies with which he is currently involved in Oxford County.

APPLICATION IN TEACHING

A somewhat different modified version of the Delphi technique has been used by the writer in graduate seminars. At the University of Waterloo, all first year graduate students take a course in research methodology, part of which involves faculty presenting seminars on selected topics. In the autumn of 1970 a seminar was to focus upon the "Uses and Abuses of Quantification". In preparation for the seminar, each student was asked to indicate what were to him the three most significant abuses of quantification in geographical research. The twenty participating students each submitted a list of abuses, which was then aggregated with the other submissions to identify possible patterns. In the seminar itself, the aggregated responses were presented to the students under three categories: philosophical, conceptual and operational. The abuses noted by the students falling under each of these headings then served as departure points for discussion. At the conclusion of the seminar, the students submitted a new list of the three most significant abuses, which in effect constituted a second round in the Delphi procedure.

TABLE 1

ABUSES IN QUANTIFICATION

Issue	Percentages of Responses Round 1	Round 2
Philosophical		
1. Quantification for its own sake, confusing ends with means	11	15
2. Quantification equated with theory, treated as a panacea for lack of theory	5	6
3. Confusing definition of quantification: mathematics? statistics? logic? all?	4	3
4. Emphasis on math to neglect of geography	4	3
5. Quantification of the trivial, the obvious relationship	2	-
6. Manipulation of data to confirm pre-conceived ideas	2	-
Conceptual		
1. Used instead of theory to organize and select research problem	2	-
2. Quantifying when too many variables are involved	2	-
Operational		
1. Failure to meet test assumptions	20	28
2. Incorrect interpretation of results	15	16
3. Faulty or inadequate data	11	8
4. Using inappropriate techniques	8	5
5. Faulty sampling procedures	6	3
6. Drawing inferences from descriptive techniques	4	-
7. Underuse: not considering power, power efficiency, not combining techniques	2	8
8. Overuse: using techniques which duplicate one another	2	5

The purpose of asking for a second submission was to allow each student to see if his own viewpoints had changed, and to allow the writer to determine if any shifts in aggregate pattern had occurred. Twelve students responded in the second round, and the results of responses to both rounds are presented in Table 1.

The approach described above deviated from the Delphi technique in that individuals were not kept separate from one another, but rather discussed the aggregate results as a group. In this way, the procedure followed was similar to that adopted by Turnbull. On the other hand, each participant had the opportunity to evaluate his own priorities before and after the discussion. What were the benefits of such an approach? First, basing discussion on students' submissions kept the seminar relevant to each individual whether or not he was sophisticated in his knowledge of quantitative methods. Since each participant had enumerated significant abuses prior to the discussion, he was placed in a position where he had to defend his observations or be willing to discuss their modification. Second the categorization of responses into three classes raised the question as to

different scales or levels of generalization which might arise when identifying abuses. In this manner, communication was facilitated in that discussants could address themselves to issues at the same level of generality. A valuable side effect was the questioning of the relevance or need for such a classification of abuses. Some wondered whether it was more realistic to consider the problem as one of a continuum, ranging from philosophical or ethical issues at one extreme to operational abuses at the other.

What are some of the patterns noted between the two rounds? In the second round there was a slight shift away from philosophical questions to those of an operational nature. Some students argued that it was necessary to differentiate between basic abuses and symptoms of abuses. It was suggested that there were not problems as long as researchers were familiar with assumptions, mechanics and implications of analytical techniques. Problems only arose if the researcher were not familiar with a technique and then unknowingly violated some of its requirements, or if assumptions were deliberately ignored. In either situation, it was felt that these were abuses which could be resolved. From this line of argument, discussion then shifted to such questions as the underuse of techniques. In other words, some argued that it was an abuse to use statistical techniques without adequate attention to concepts such as power and power efficiency. Students felt that these concepts were too often ignored, and that their consideration would lead to a more fruitful application of techniques. Discussion also covered such topics as modifiable areal units, drawing inferences about individuals from aggregate analysis, using combinations of analytical techniques, meeting normality and homoscedasticity assumptions, and using parametric or nonparametric techniques.

By concentrating upon operational problems, the students were able to explore a wide range of issues that had considerable relevance to their own research endeavours. While after two rounds and discussion it was clear that group consensus had not been achieved, the individuals had sharpened their ideas concerning possible abuses, had recognized a hierarchy of problems, and perhaps had had some of their own questions answered. A comment received during the second round of the Delphi procedure perhaps best summarizes the effect of the session. One student commented that

> I believe (contrary to what I may have said earlier!) that discussion is valid only in terms of "operational" effects. Why discuss the use or non-use of quantitative methods? Obviously they are a necessary tool. Those of us who are not fully conversant with these tools and may feel that there is a "quantification for its own sake", are defeating our own purpose by dwelling excessively on this. Criticisms should be confined to how and when techniques are used, thus reducing the artificial level that is attached to this at the moment overworked topic of quantification.

The examples presented in this paper will hopefully suggest other applications of the Delphi technique, in its ideal or a modified version, for teaching. The procedure might be applied in a manner similar to that used in the Waterloo planning illustration. The students themselves, through several rounds, could identify problems or issues in their own community which could be investigated by field investigation. Depending upon the outcome, the students might focus upon attributes of a specific issue, such as environmental degradation, or upon a range of issues, such as the environment, education, poverty and health. In a different context, the procedure could be adapted to stimulate seminar or class discussion, as was done at the University of Waterloo. In either of these types of applications, the technique seems to

generate student interest and involvement in addition to assimilation of knowledge.

CONCLUSIONS

This paper has attempted to indicate the value, both demonstrated and potential, of the Delphi technique for purposes of research, planning and teaching. While not a panacea for problems encountered in research involved with forecasting, the technique seems to offer one method of incorporating variables which are handled inadequately at the moment. At a different level, the technique offers interesting applications in teaching, regardless of topic or subject matter, or in attempting to identify priorities at various spatial scales of planning. In brief, it would appear as if more attention might be given to this technique, and other similar ones such as the Scenario, as valuable aids for teaching and research.

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