A FORMAL METHOD FOR THE CONSTRUCTION OF CROSS IMPACT MATRICES

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As resource scientists explore a wider and wider range of techniques to test the consequences of human activity, one technique frequently used is cross impact analysis. This involves the construction of a matrix listing all of the important variables in the system under consideration as both rows and columns. You then designate that one axis, for instance the rows, represents the "impacts upon" list, and the other axis represents the "impacts of" list. Proceeding down the rows and columns you repeatedly ask the question "how does this variable affect the other?" This question can be answered in a variety of ways; either by yes or no, or positively, negatively, or not at all, or some indication of the magnitude of the effect may be expressed depending upon the use to which the cross impact matrix will be put. We frequently use these matrices as the first step to building simulation models of ecological system. The matrix is used to isolate the relationships between variables which will have to be defined in the model. Sometimes the matrix is an end in itself; it is used as the data base for a qualitative simulation or assessment procedure which can be used to predict trends or impacts of manipulation of the variables.

(Kane, 1972; Gallopin, 1974). In these cases any errors in formulating the cross impact matrix will have effects upon the final conclusion. The rest of this paper will be devoted to these types of situations.

We have found from actual experimentation that formulating cross impact matrices is extremely qualitative and the same person will rarely produce the same matrix on two separate occasions. Although this is not surprising when considering systems which are poorly understood, it nevertheless seems to happen just as frequently when dealing with systems the formulator knows well. In a recent experiment one researcher who had built several simulation models of a 10-variable system, produced two very different cross impact matrices on the same day. I believe that this is a product of the mental procedure used to formulate the cross impact matrix, and I will propose a mental procedure which should eliminate this problem. The usual mental method used when asking how does A affect B, is to ask what effect will there be on B if A is increased slightly (or decreased slightly) -- basically a mental partial differentiation. The problem stems primarily from situations in which A affects B which affects C. If you ask what effect will a slight increase in A have on C, you must decide if you will say yes because B will go up which causes C to go up, or if you will say no because the action is mediated by B. There is general agreement that you should take the second choice, "no," but experience has shown that people do not act in this fashion while formulating their matrices.

I propose that we should redesign our mental method for asking the questions by formulating our knowledge as a simulation of the system and then looking at the equations formulated and simply copying onto the cross impact matrix the relationships used in the model. Cross impact analysis is generally used for situations in which there is insufficient knowledge to formulate a working simulation model. The functional relationships are not known, only the general directions and intensities of these relationships. This is not a barrier to the formulation of the structure of the simulation. You are simply admitting that you can't guess the parameter values very well. I believe that you can almost always actually formulate the equations to the extent required to pull out the needed information for a cross impact matrix. Some people may use this method when they formulate their matrix -- but from actual experience I think such cases are rare indeed. From a plus-minus matrix you can state the simulation functions. The fact that these differ between sessions for the same individual suggests that either the system is poorly understood or the proper method was not used.

May (1973) has discussed the use of plus-minus matrices in food web modelling and assumes that the formulation follows the Lotka-Volterra community matrix. This eliminates any ambiguities because the question to be asked when filling in a location in the matrix is very explicit. In this case it is, "if X eats Y, then the effect of X on Y is minus; if Y eats X, then it is plus; and if they compete for limited resources, the effect of X on Y is minus." ne is rarely fortunately enough in environmental systems to have such a simple structure. We hope that the basic structural elements of the system will emerge by formulating the system as a simulation model.

There are two additional advantages of the procedure. The process of trying to formulate the system as a simulation model is quite useful in defining new state variables which reduce the complexity of the formulation, and it provides the basic starting format for actually building a simulation if the information required about the system is available. The study of cross impact analysis is in its infancy and one could argue that it is most useful in situations where the information about the system is so limited that it is impossible even to formulate the basic structure of the simulation. If this is true, I believe that the value of the analysis would lie solely in the discussion generated while constructing the matrix and not in the final matrix produced.

I have carefully avoided discussing the techniques and merits of cross impact analysis in general. It is certainly questionable whether even the most sophisticated algorithms for prediction from cross impact matrices are useful at all. If these matrices are ever to be of use, I believe we must produce some formal methods for generating them.

References

Gallopin, G., 1974. Reference unknown at present.

Kane, J., 1971. Reference unknown at present.

May, R.M., 1973. Stability and complexity in model ecosystems. Princeton Univ. Press. 235pp.