SPECIFICATION OF PLAN-MAKING PROCEDURES FOR A GIVEN PLANNING SITUATION

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Earlier papers by the authors identified requirements and characteristics of an operational metropolitan plan-making process. This paper proposes a method for designing plan-making procedures for use in such a process. The first part of the paper specifies a simple iterative process involving planners and decision-makers and examines possible approaches for its elaboration. The role of optimizing and predictive models is discussed, and it is concluded that a predictive approach is preferred. Parallel, series, and cascade-type dialogues for the plan-making process are then examined. Procedures for designing a plan-making process for a given planning situation are examined in the second part of the paper. Four types of information concerning participants, constraints, relationships, and preferences are specified and applied in designing procedures. Each type of information can be expressed as a flow chart; the compatibility of these flow charts determines whether the plan-making process is practicable and to what extent an iterative process is needed to prepare and evaluate alternative plans. If iterations can be avoided in the planners' procedures, then the entire process is shown to be more efficient. A short example based on land use and transportation planning concludes the paper.

•OUR RESEARCH on the specification or design of plan-making procedures began with a review and analysis of experience with the preparation and evaluation of alternative metropolitan land use and transportation plans. The findings and documented analysis were published in 1970 as "Metropolitan Plan Making" (1). In one section of that monograph we recommended a cyclic, learning approach to plan preparation, evaluation, and decision-making. Decision-makers were advised to view the plan-making process as an opportunity to learn what alternatives exist, what their consequences are, and what objectives are served by these alternatives. Because a learning process implies a question-and-answer type of dialogue, the cyclic or iterative nature of this process is central to its success. The desirability of completing several cycles of the plan preparation-evaluation-choice sequence was evident in the planning programs reviewed.

In this paper, some further research results on the design of planning procedures are presented. Our more detailed findings have been published as "An Interim Report on Procedures for Continuing Metropolitan Planning" (2). This report consists of two major parts. The first concerns the design of plan-making procedures for a given situation, the subject of this paper. The second part proposes procedures for a continuing or ongoing planning process. The distinction is as much in the approaches taken to the problem as in the problems themselves.

In this paper and in two earlier publications (3, 4) the principal findings on procedures for a given planning situation are reported. Two additional papers (5, 6) present some of the principal results on procedures for continuing planning. These

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results are at present being tested and refined; subsequent reports and papers will document the outcome of this effort.

Our purpose in this paper is to present some findings on the definition and design of plan-making procedures for a given planning situation or problem. By plan-making procedures we mean the tasks and activities in which planners and decision-makers engage in order to produce a set of decisions concerning future actions and policies, which we call a plan. These procedures require time to execute; the implementation of a set of procedures over time is called a plan-making process. These plan-making procedures utilize models, methods, and techniques to produce required analyses, predictions, and evaluations. In part, then, the design of plan-making procedures is the problem of specifying how planners apply available methods and techniques, or invent new ones, in order to engage in problem-solving.

These procedures also assume the existence of an organizational and institutional framework for plan-making. Important questions, such as who are the decision-makers, whom do they represent, and what are their responsibilities, are largely assumed away here in order to focus on the question of what decision-makers do. However, as noted in the following, the institutional and organizational framework does place important constraints on planning procedures.

This paper is presented in two main parts. The first part defines an iterative plan-making process involving planners and decision-makers. Four general procedures are defined: search; prediction; evaluation; and choice and direction of further search. Several types of iterative processes are examined using this framework.

The second part of the paper takes up the problem of designing detailed plan-making procedures in response to a specific situation or problem. A classification is proposed for the types of information available for designing these procedures, and a method for organizing and analyzing this information is described.

An inherent difficulty of treating such a complex subject as the design of plan-making procedures in a short paper is that the result inevitably appears too superficial, general, and abstract to be useful to planning agencies. With this difficulty in mind, we attempt only to interpret our major findings here, and we urge the reader to pursue the technical details in the publications and reports cited. Our explicit objective throughout this research is to address operational problems of plan-making as found in metropolitan planning agencies. If we can stimulate these agencies, themselves, to be more concerned with the design of their own plan-making process, perhaps we have achieved some measure of success.

DEFINITION OF AN ITERATIVE PLAN-MAKING PROCESS

In a general sense, a plan-making process may be characterized as a dialogue or formal discourse among several parties concerning desired values of the performance characteristics of a system. By a performance characteristic, we mean any characteristic (function or combination of variables), say $C(x)$, of the system being planned and the performance, say $P(x')$, of that characteristic in some specific context. The following types of performance characteristics have proved useful in our research:

1. Empirical—$C(x)$ *does* have $P(x')$;
2. Projected—$C(x)$ *would* have $P(x')$;
3. Hypothetical—$C(x)$ *could* have $P(x')$
4. Preference—$C(x)$ *should* have $P(x')$; and
5. Political—$C(x)$ *will* have $P(x')$.

Thus the statement, "The peak-hour freeway operating speed is 25 mph", is an empirical performance characteristic. Operating speed is the characteristic; 25 mph is the performance value. The verb *is* denotes an observed value; alternately, the verb should be denotes a desired value. A more definitive treatment of these concepts is given elsewhere (*2*, *4*, *5*).

Our view is that plan-making is a dialogue about the performance characteristics of a system, in particular preference and political-type statements. The plan produced by this process is a record of these statements, together with all the supporting analysis and documentation. This record can reflect the situation at a point in time, or it can be a dynamic, continuing record of the dialogue. Languages for conducting this planning dialogue over time are one of the principal products of our research (5, 6) but are not described in detail here.

In the general case, this dialogue involves two groups:

1. Decision-makers—designated by the government as defined by the prevailing institutional, legal, and organizational framework; and
2. Planners—the group of technically qualified professionals retained by decision-makers on behalf of the government.

Clearly, the decision-makers may include representatives of various groups and interests, or they may choose to involve such groups in the plan-making process. The planners may include professionals of all types; our problem is to specify how these two groups interact in conducting the plan-making dialogue.

The simplest specification of the roles of planners and decision-makers is shown as Figure 1. Planners produce alternative plans consisting of (a) proposed actions for the government or public sector and (b) proposed policies concerning the actions of the private sector. Decision-makers exercise choices concerning various aspects of the alternative plans on behalf of their constituents and direct the search for new alternatives. In terms of the performance characteristic concept, alternative plans consist of alternative sets of performance values and their consequences. Making choices on alternative plans means reaching agreement over time on a specific value for each performance characteristic, subject to the values of other related characteristics. Note that these choices need not be made all at once but may be made over a considerable time period as either conditional or final decisions.

Optimization Versus Prediction

The next step in detailing the definition of the plan-making process is to expand the relationship between planner and decision-maker of Figure 1. Suppose that the decision-makers agree to consider some specific development problem. We wish to determine how they should proceed in general and how they specify plan-making procedures for the particular problem at hand. We assume there is a context for this problem, both in terms of previous efforts to deal with it and in terms of related problem areas. To fix ideas, we consider the problem to be preparation of a transportation system plan in the context of regional land use and watershed planning.

Our strategy in further detailing the plan-making dialogue is to explore the difficulties posed by the question, "How should the process begin?" In terms of Figure 1, how can planners propose actions and policies without direction from decision-makers? How can decision-makers give direction without some information on what actions are feasible? While it should be understood that no attempt to break this cycle can be totally successful, alternative approaches to the problem can lead to very different results.

Broadly speaking, two idealized approaches to this dilemma have been proposed—the optimizing approach and the predictive approach. The optimizing approach begins the dialogue between planners and decision-makers by assuming that a definitive statement of goals, objectives, and preferences is given by the decision-makers. The planners then search for an optimum action according to this statement, taking into account the consequence of each action. Various mathematical programming models and search procedures have been devised in attempts to implement this approach. One of the best examples in land use and transportation planning is the plan design model research of the Southeastern Wisconsin Regional Planning Commission (7, 8).

In contrast, the predictive approach begins the dialogue with a set of proposals by the planners. These proposed actions and policies may be in response to the planners' perception of society's goals, or they may include proposals for alternative sets of goals. In either case, the decision-makers exercise choices and formulate directions for further search based on their reactions to the proposals.

Of course, in practice both approaches are much more flexible. Both require several rounds of dialogue for the completion of satisfactory plans. In the optimizing case, these rounds are sometimes referred to as sensitivity analysis, meaning that incremental changes in variables and constants are made to determine the effect on the optimum solution. In the predictive approach, additional rounds constitute further searching of the action space. In this sense the distinction between the two approaches may be regarded as slight; however, given some additional considerations, the differences become sharper.

Without developing all the details here, we believe there are strong reasons for preferring the predictive approach. Our principal objection to the optimizing approach is that the information required, operational objectives, is precisely what is not known in planning. Plan-making procedures need to be structured to help decision-makers discover what their objectives are for the system. Moreover, any system plan involves many objectives, some of which are in conflict; the plan-making process is the mechanism for negotiating agreements over these conflicts. For these and several technical reasons having to do with optimizing models themselves, we believe it is not realistic at this time to structure the entire process in terms of optimizing models.

In contrast to the optimizing approach, it seems preferable to present a rich predictive picture and to allow the decision-makers gradually to form and express their preferences from these alternative pictures by adding alternatives and modifying them in the course of the dialogue. This mutual learning process is more flexible in resolving conflicting elements and obtaining concrete expressions of the decision-makers' preferences. This, in brief, is the predictive approach.

Search, Prediction, Evaluation

In expanding the concept of the predictive approach, consider the following three-part definition of the planners' role:

1. Search—specification of a course of action;
2. Prediction—conditional statements about the future; and
3. Evaluation—analyses of a course of action and its predicted consequences useful in resolving conflicts and providing a basis for choice.

These three procedures are shown in Figure 2 and discussed in the following.

Search is the least understood procedure of the plan-making process as far as formal methods are concerned. Architectural design is an example of an intuitive approach to the search problem, but it is not well developed as a formal process. Search may be defined initially as a discrete combinatorial problem. In so doing, all possible actions are defined; an alternative plan is one particular combination of such actions. In contrast, the optimizing approach identifies the optimum combination given an objective function.

The overriding questions of the search procedure concern how alternatives are to be selected from all possible combinations. This is a kind of optimal sampling problem; the more information that is available from the decision-makers, the more useful the sample will be to them. Key questions to be answered in drawing this sample are

1. How many alternatives should be prepared?
2. How different should the alternatives be?
3. At what level of detail should alternatives be prepared?

Heuristic methods may be useful for searching the combinatorial space for alternatives with properties requested by the decision-makers. In the second part of the paper, we examine some procedures for simplifying this search process.

Prediction assumes a modeling capability for making conditional statements about the future. The applicability of a given predictive model to a planning situation depends on the acceptance of several assumptions concerning the behavior of individuals, private organizations, and public institutions. These assumptions have a number of implications as follows:

1. Does the specification of the model result in stable model parameters?
2. What is the effect of the proposed course of actions on model stability; are the model inputs outside the range of the data on which the model was calibrated?

3. What changes are occurring outside the system being modeled that might affect the predictions?

Clearly, predictive models are most valid when the immediate future is the time period of interest, and the actions considered are quite similar to the present. Just how immediate and how similar are matters of ongoing discussion among model-builders and their clients? The procedures described in the second part of the paper incorporate the behavioral statements of models and help to clarify whether a model's assumptions are violated.

Evaluation in the predictive approach to plan-making takes on a somewhat specialized meaning. Since we have assumed that the plan objectives are at best only partially known, we maintain that it is not possible for the planners to develop single, comprehensive measures of each alternative, such as preference rank orderings. Although the planners may develop formal evaluation systems for assisting decision-makers in overall rankings, we suspect the synthetic abilities of decision-makers are far superior to any existing method of this type. Moreover, the concept of overall rankings conflicts with our assumption that decisions are made incrementally at the level of specific performance characteristics, conditional upon consideration of further alternatives designed to explore the implications of these decisions.

In this view of evaluation, we focus attention on two problems. The first problem concerns the resolution of conflicts among decision-makers and among performance characteristics. Evaluation supports the bargaining and conflict resolution procedure through supplying and interpreting needed information about alternatives. Although conventional procedures such as benefit-cost analysis may provide useful information to the decision-makers' bargaining process, many other types of information are also required.

The second problem of evaluation is improving the basis of choice. As search and predictive methods improve, the basis of choice for the decision-maker improves, but it also widens and becomes more cumbersome. The planners can assist here by presenting summary, as well as detailed, performance characteristics, thereby synthesizing the rich predictive picture of the future. This procedure may involve value judgments by the planner, and these need to be made explicit. In the predictive approach, then, some of the difficulties of the basis of choice are shifted to the problems of search and prediction.

Iterative Nature of the Predictive Approach

Using the search-prediction-evaluation framework expounded in the foregoing as the definition of the planners' role in plan-making, we can now consider more explicitly the iterative nature of dialogues between planner and decision-maker. Consider the following situation, which is probably the simplest possible case. The planners are asked to prepare two initial alternatives; they choose arbitrarily two sets of proposed actions. They enter the variables corresponding to each set of actions in a predictive model and obtain two sets of predictions for the alternatives. Then, they describe and summarize these results on a number of measures thought to be useful to the decision-makers.

One alternative may be outside the range of validity of the predictive model; for instance, the output may contradict the assumption that the parameters remain stable. Also, the decision-makers will probably not choose right away between the two alternatives but may suggest modifications to each or ask for a combination of the two alternatives. In any event, the planners need to reexamine their work following the first round of discussions with the decision-makers, as shown by the feedback arrow in Figure 2.

The iterative character of this process is necessary in order to consider conflicts, as already described. It is also important in the event the first alternatives are not very satisfactory, and to consider improvements if suggested. Finally, it is essential in case it is agreed that the alternatives cause the predictive model to operate outside its range of validity. In such a case, one would have to choose actions for the next round that are more likely to remain within range; this generally means alternatives closer to the existing situation. In case the decision-makers feel this would entail solutions that are even less satisfactory, one might conclude that the model is not appropriate; its range of validity being too small, it should be replaced by another model. The decision-makers might also conclude that they must lower their expectations.

These advantages are associated with the iterative character of the method. However, such iterations are time-consuming, and one would like to restrict them as much as possible. Accordingly, at the outset of the process one would like to be able to present alternatives that are as satisfactory as possible and that at least satisfy all the known constraints on the actions. In the second part, procedures yielding only such alternatives will be defined.

However, as seen above, in some cases iterations are essential. One would like in these cases to require that the planners redo as little of their work as possible; to achieve such a result, one might attempt to decompose the dialogue between planners and decision-makers into several different dialogues. One possibility, illustrated as Figure 3, is decomposition into independent, or parallel, dialogues. Then, if an alternative for Part I of the system is not satisfactory, a new iteration is not required for Part II. This decomposition is only possible if (a) the two parts of the system do not interact, (b) there are no joint constraints on the proposed actions of Parts I and II, and (c) the decision-makers are not interested in the relationship of Parts I and II.

A second possibility is decomposition into sequential, or serial, dialogues as shown in Figure 4. Here, Part I might refer to the main features of the system, while Part II refers to the details. A choice among major alternatives could then be made before the alternatives for the detailed system are designed and evaluated. The design for Part II would only take place once the choice of the design for Part I had been made.

If two systems are interdependent and therefore cannot be planned in a sequential manner, then a multisystem dialogue is necessary. A cascade-type multisystem dialogue is shown in Figure 5. This situation might apply when a single set of models does not provide for predictions of the consequences of each of the systems being planned. An example is planning for land use and transportation (Part I) and water, sewer, and flood control (Part II). If a single model is avialable for both systems, then the single-system situation described above would apply. The rationale for such integrated models is precisely to avoid the difficulties encountered in the multisystem case, for these difficulties can only be solved at the cost of additional iterations.

Suppose two systems are planned independently, as in the case of decomposition of a single system dialogue into independent dialogues. An alternative is presented for each system, within the range of validity of the model, and also perfectly satisfactory to the decision-makers. Iterations might still be needed for the following reasons:

1. The two alternatives are not compatible. For instance, their costs exceed the available budget. This is a symptom that a joint constraint on the action spaces of the two systems was neglected.
2. The alternative of one system violates the range of validity of the other system's predictive model. This is a symptom that interactions between the two systems were neglected.
3. The overall alternative, obtained by combining the alternatives for each system, is highly unsatisfactory. Indeed, the two systems might combine in a highly undesirable fashion; by modifying each system, one might achieve a more desirable overall alternative. This is a symptom that decision-makers are sensitive to the way the two systems relate and that this aspect was neglected.

Similar difficulties arise if the two systems are planned sequentially, except that difficulties of the first type would not occur. Under certain conditions, however, one should be able to design various systems independently or sequentially, evaluate them independently or sequentially, and decompose the dialogue or several dialogues into independent parts or sequential parts. As one can recognize, this can greatly simplify the plan-making procedures and reduce the dimension of the search for alternatives. We now turn to methods for designing such procedures.

DESIGNING THE PLAN-MAKING PROCEDURES

The iterative plan-making process defined in the foregoing is likely to be a time-consuming and somewhat cumbersome operation, even for planning a single system. If applied to a complex of systems, any attempt to be comprehensive is very likely to be unworkable unless steps can be taken to eliminate or reduce redundant or unnecessary activities. In this part, we explore the basis for procedures that are efficient in this sense and suggest ways in which such procedures can be designed for a given planning situation. The concepts underlying these proposed procedures are quite straightforward. Their objective can be thought of as designing procedures that minimize unnecessary processing of information by decision-makers and planners, but guarantee that

1. The alternatives presented to the decision-makers are feasible, in the sense that the actions specified to be taken are implementable; and
2. Every alternative that is feasible can be obtained by such a procedure.

The types of interactions and interrelationships examined here as a basis for designing these efficient planning procedures are as follows:

1. Real-world interactions among various elements of the system being planned and in particular between decision-makers' actions and the effects of those actions;
2. Legal, institutional, and fiscal frameworks within which plan-making takes place and in particular the constraints these factors place on actions or policies available to decision-makers;
3. Capabilities and competencies of planning groups in various public agencies and the communication networks linking them; and
4. Structure of preferences of decision-makers that can be expressed more or less independently of the problem at hand.

Designing efficient plan-making procedures involves some knowledge about the real-world interactions among the elements of the system being planned. This knowledge is assumed to be given in the form of a model or a system of models that specifies the predicted outcome for each action under the control of the decision-makers. However, decision-makers cannot choose actions arbitrarily, as they are limited by feasibility constraints such as legal requirements, budget limits, or regulations. The set of acceptable actions and their predicted outcomes, then, defines the set of feasible alternatives.

Next, information about the expertise and capability of each of the groups employed in the plan-making process can be used to facilitate its design. For example, a planning group for a particular system, such as transportation, requires inputs from other groups and provides output to still others. These kinds of interdependencies among group capabilities and their associated communications networks are basic information for the design of the plan-making process.

Finally, some knowledge about the decision-makers' preference structure is also required. This knowledge may be in the form of priorities about the various parts of the system, or it may take the form of indifference statements by decision-makers on the relationship of some parts of the system. However, what is not required in this approach is information about decision-makers' preferences, themselves. (The difference between preferences and preference structures is discussed later.) As the amount of this type of knowledge increases, the cumbersomeness of the plan-making process can be decreased through more use of independent and sequential dialogues.

In summary, the a priori information requirements for the design of predictive plan-making procedures are relatively light, as compared with the information requirements of the optimizing approach to plan-making. This in itself is important, for this a priori information is to be taken as given in the design of plan-making procedures and therefore must be agreed on by the decision-makers.

Using Flow Charts to Design Procedures

The four types of interrelationships described suggest a method for designing more efficient procedures. A method is needed to identify (a) precedence relationships among

Figure 1. A simple iterative plan-making process.

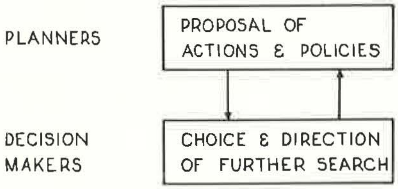


Figure 2. Predictive plan-making process for a single system.

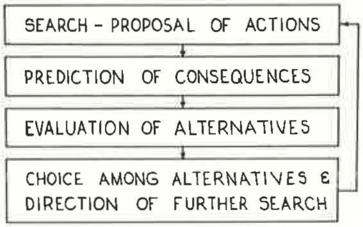


Figure 3. Plan-making process for independent dialogues.

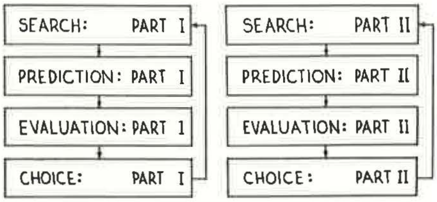


Figure 4. Plan-making process for sequential dialogues.

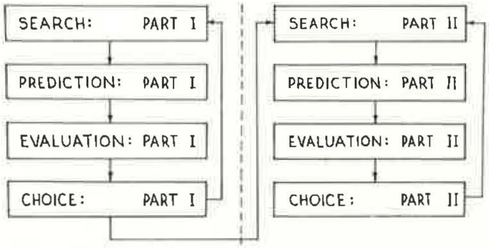


Figure 5. Plan-making process for a multisystem dialogue.

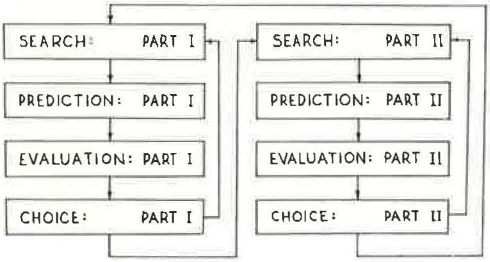


Figure 6. Flow chart illustrating concept of directed circuits.

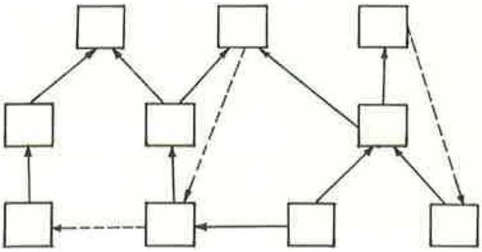


Figure 7. Planning group capabilities flow chart.

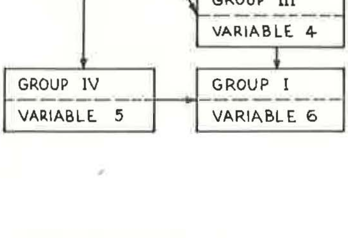


Figure 8. Flow chart guaranteeing feasibility with control variable subsets.

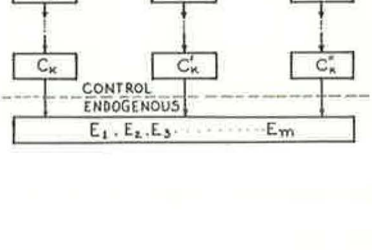


Figure 9. Flow chart of structure of decision-maker preferences.

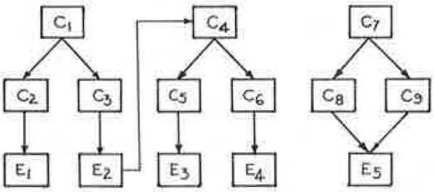


Figure 10. Planning group capabilities flow chart.

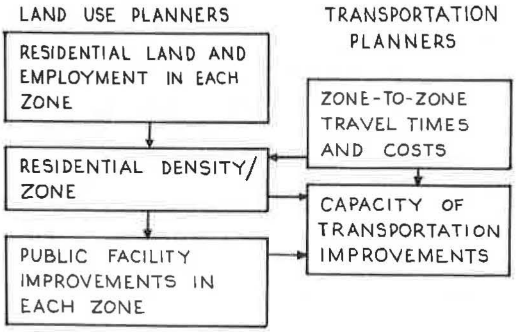
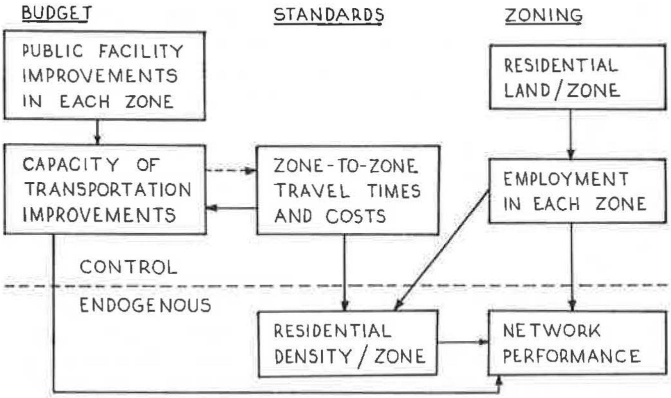


Figure 11. Flow chart guaranteeing feasibility.



plan-making elements and activities and (b) conflicts among these precedence relationships. The method for achieving this result is a natural extension of the critical path diagram or PERT chart (9). We now explore the use of flow charts, or more technically directed graphs, to display and analyze plan-making interrelationships. First, we examine the use of this approach in general and then apply it to each of the four types of interrelationships outlined above.

Consider that we may represent a plan-making activity, plan element or variable, requirement or constraint, or preference statement as a point or box in a flow chart. Moreover, we may represent a relationship from one element to another by an arrow; note that only directed, or one-way, relations are defined. (A two-way relation is represented by two arrows, one in each direction.) A flow chart (graph) consists of boxes (vertices) and arrows (arcs) and is a very general and useful device for displaying various types of information needed for designing plan-making procedures.

An important characteristic of some flow charts is that they contain no circuits; in such flow charts it is not possible to find a sequence of boxes and arrows that returns to the first box in the sequence. An example of a flow chart without circuits is illustrated by the boxes and solid arrows in Figure 6. By the addition of several dashed arrows, Figure 6 is converted to a flow chart with circuits. As another example, Figures 1 through 5 are flow charts with circuits. Flow charts with circuits involve iterations, whereas flow charts without circuits do not. We have argued that iterations are a desirable feature of a plan-making process if they involve decision-makers. However, iterations are also expensive and time-consuming; therefore, elimination of circuits may conserve planning resources. Given a choice between a flow chart with circuits and one without circuits, the latter should be more efficient. If the circuit does not include inputs from decision-makers, then as a general rule a flow chart without circuits is preferred.

Flow charts, then, are a method for organizing interrelations among planning elements and analyzing their efficiency. Because there are several types of interrelationships, there may be several flow charts involving the same variables in different ways. We wish to determine if these flow charts are compatible; that is, do the flow charts specify the same order relationship for each pair of elements? If the order is the same in each flow chart, then the plan-making process is workable in the sense that each flow chart can be followed to its conclusion. If the order of some pair of elements is reversed, then a conflict in the process will occur and the procedure will need to be redesigned. As with directed circuits, incompatible flow charts usually result in iterations that may increase the plan-making requirements without improving the effectiveness. Some applications of these concepts and some additional desirable properties of the approach are now considered.

Planning Group Capabilities Flow Charts

Inasmuch as one of the flow charts proposed here is similar to a critical-path diagram, we begin by considering the planning group capabilities flow chart. This flow chart portrays the capabilities and competencies of the planning groups in the various public agencies participating in the plan-making process and the communication network linking them.

In any plan-making process, technical expertise and capability of the planners play a critical role. On the one hand, many alternatives can be excluded as inferior on the basis of technical considerations, and much can be done to obtain optimal solutions to small-scale problems. Therefore, the planners' technical capabilities represent a source of efficiency in plan-making. On the other hand, these same technical groups may incorporate the inertia of an institution, for example, when confronted with new models or techniques. This problem of inertia is particularly serious in an area of technical expertise undergoing rapid expansion and improvement. Some individuals may become, or feel they have become, obsolete; their roles may need to be redefined to permit them to contribute to the process. Our objective is to develop methods for analyzing such situations in order that technical expertise can be properly matched to modeling capabilities.

The planners are usually divided into several groups, each being in charge of an area of the proposal within its special technical competence. Clearly, these groups cannot work without coordination, because the absence of coordination generally results in infeasible, uncoordinated alternatives. Moreover, some groups require information from others in order to design a proposal for their area of responsibility. However, coordination is costly in terms of money and especially in terms of time, because some groups have to wait for the work of others to be completed in order to start their own.

To analyze this problem, represent (a) by boxes the various tasks that each group performs and (b) by arrows the requirement that some tasks cannot be executed before certain others. Each task consists of a group determining the alternative values for a specified set of variables. The manner in which these values are determined depends on whether the task is a search, prediction, or evaluation type of procedure. Flow charts designating such tasks and their relationships are termed planning group capabilities flow charts; Figure 7 shows a simple example. A desirable restriction to place on the construction of this type of flow chart is that it not contain any directed circuits; this means no task is required to be performed both before and after some other task or set of tasks. If this is not possible, then iterations are required, thereby increasing the complexity and cost of the process.

Flow Charts Guaranteeing Feasibility

A planning group capabilities flow chart guarantees that the groups involved are able to prepare proposed values for the policy variables. But this does not guarantee that the proposal is feasible. What should be the flow of information between various planning groups in order to guarantee that the proposals obtained are feasible? Clearly, the answer to this question is contained in the various constraints placed on the actions and policies proposed in the plan. These constraints may be classified into two types:

1. Real-world interactions among the various elements of the system being planned, including both physical and behavioral relationships; and
2. Legal, institutional, and fiscal constraints defined by the governmental framework in which plan-making takes place.

A major element of the plan-making process is prediction of the consequences of each action under the control of the decision-makers. The knowledge for making this prediction is given in the form of a model or system of models. The inputs to these models include (a) values for the control or policy variables, determined in the search procedure with directions from the decision-makers, and (b) assumptions and data. The output or endogenous variables of the model are not subject to direct decision-maker intervention but must be indirectly manipulated through changing the values of the control variables.

Moreover, decision-makers cannot specify arbitrary values for control variables because they are limited by feasibility constraints such as legal requirements, budget constraints, or regulations, some of which may be imposed by a higher authority. These relationships may be conveniently represented in a single flow chart called the flow chart guaranteeing feasibility. We now consider a procedure for specifying the control variable portion of such flow charts.

Suppose that there are two sets of control variables, C and C', and two planning groups or agencies, the first in charge of C and the second in charge of C'. Now suppose a constraint on these control variables involves some variables from the set C and others from the set C'. The work of the first group must then be coordinated with the second group to guarantee the feasibility of the proposal. Two procedures can be followed that will guarantee feasibility: Group one prepares a proposal for its variables in C, and then group two chooses values for its variables in C' such that the combined proposal is feasible; or conversely, group two could specify its variables first, followed by group one. Such a procedure could be illustrated by a very simple flow chart with a box designating each group's variables and an arrow designating the order in which the groups propose values for their variables. Clearly, any flow chart with an arrow between group one and group two guarantees the feasibility of the proposal. Hence, there is a class of flow charts representing design procedures that guarantee the feasibility of proposals; because one would not like to present infeasible proposals to decision-makers, it is desirable that a procedure belonging to this class of flow charts be used.

At the same time, it is important that a procedure from the class of planning group capabilities flow charts be used. Therefore, it is highly desirable to determine whether among all possible procedures for designing proposals th[illegible]s one that belongs to both classes of flow charts. Such a flow chart always doe[illegible]ist. Indeed, all linear flow charts belong to the class guaranteeing feasibility; such flow charts consist of a linear sequence of boxes connected by arrows, all in the same direction. Linear flow charts always guarantee feasibility of proposals because decisions are made sequentially rather than independently. Among all possible linear arrangements of variables, there must exist at least one that is compatible with the planning group capabilities flow chart.

However, linear flow charts involve major inconveniences; they specify a procedure that is lengthy and requires a large amount of information transmission. Therefore, it is desirable to try to identify subsets of control variables that are independent from each other with respect to every constraint. These subsets can then be designed independently without violating any constraints.

Several of these concepts are shown in Figure 8; linear sequences of control variables are shown as C, C', and C''. Each of these subsets corresponds to a feasibility constraint; the arrangement of variables shown is one possible order of designing these subproposals that guarantees feasibility. These subproposals form the inputs to a model determining the value of several endogenous variables in the set E, which specify the consequences of the proposal.

Flow Charts of Structure of Decision-Maker Preferences

We now consider the last type of flow chart, which displays the preference structure of the decision-makers. This flow chart is another basis for partitioning the dialogue into independent or sequential dialogues, thereby greatly reducing the amount of information that needs to be processed at any one time.

The concept of preference structure can perhaps be best introduced by means of an example. Suppose that decision-makers take up the problem of making a plan for schools, hospitals, and other related public facilities. Upon discussion of these facilities they agree that it is important to locate such facilities in their proper relationship to households; however, they are not concerned with how schools and hospitals are located with respect to each other. Given agreement on this point, plan-making for schools and hospitals can proceed in an independent, parallel manner because the decision-makers' preferences are structured independently for these two plan elements. Note that it has not been assumed that the decision-makers agree on how schools and hospitals should be located, but only on the lack of relationship between the two types of facilities.

More generally, decision-makers' preferences for a given alternative plan are given by their individual utility functions for the values of the control and endogenous variables in that plan. If, upon discussion, it is agreed that the utility function for several variables can be partitioned into several partial functions, then the planning effort can be similarly partitioned. This information can also be displayed as a flow chart; an example is shown in Figure 9. The example shows that control variables C_7, C_8, and C_9 and endogenous variable E_5 can be considered independently of the others; moreover, consideration of C_4, C_5, C_6, E_3, and E_4 can be delayed until agreement is reached on C_1, C_3, and E_2.

The information contained in flow charts of this class is also useful in revising alternatives. It shows, from the decision-makers' viewpoint, what variables are affected by a change in a given control variable. For example, suppose the decision-makers are not satisfied with the value of E_4. The situation might be improved by changing only C_6. This leaves unchanged the decision-makers' level of satisfaction about all features except C_6 and E_4.

Compatibility of Flow Charts

We may now confront the flow chart of preference structure with (a) the planning group capabilities flow chart and (b) the flow chart guaranteeing feasibility. In order to find a desirable procedure for designing alternative plans, one tries to find three flow charts, one from each class, that are compatible; compatibility is achieved if the order of the boxes in one flow chart does not contradict the order specified by each of the other flow charts.

As discussed earlier, it is always possible to find flow charts of the first two types that are compatible by using linear flow charts. The flow chart of preference structure may provide additional information for the task of specifying the order of variables in such a linear flow chart. As was shown in Figure 9, it may be possible to avoid certain plan revisions if the third type of flow chart is available.

One may ask at this point whether it is always possible to find three compatible flow charts. The answer is that there always exists a compatible, but trivial, flow chart belonging to the three classes, namely the flow chart with all variables in one box. Accordingly, the design of plan-making procedures can also be viewed as the disaggregation of this trivial case. It may be that any non-trivial flow chart of preference structures is incompatible with any flow chart guaranteeing feasibility. This situation implies a loss of flexibility in the process of reshaping alternatives. However, this flexibility can be recouped by considering, for example, a plan-making process that requires iterations to ensure plan feasibility.

As a final example, consider the question of compatibility of two flow charts, shown as Figures 10 and 11, for land use and transportation planning. Figure 10 shows the information flow between land use planners and transportation planners. Figure 11 shows in solid arrows a flow chart displaying budget, standards, and zoning constraints as control variables with residential density and network performance as endogenous variables whose values are predicted by a land use and transportation model, given the values of the control variables.

Examination of the order relations of the variables in these two flow charts indicates they are compatible, which permits us to conclude that

1. The plan-making procedure is workable in that it does not assign to any planning group a task outside its competence, as specified in Figure 10; and
2. Any proposal prepared by this procedure will be feasible in the sense of satisfying the constraints depicted in Figure 11.

Now consider a modification of Figure 11 by replacing the arrow from travel times and costs to transportation capacity by the dashed arrow in the opposite direction. This implies that the standard on travel times and costs is dropped and that capacity limitations determine these variables. As a result of this change, Figure 11 is now incompatible with Figure 10, since travel times are needed by transportation planners to determine capacity in Figure 10. This situation, which is quite realistic, suggests that an iterative procedure is needed to determine not only capacity but also residential density and public facilities. This is true because it is now necessary to introduce an arrow from capacity back to travel times into Figure 10, thereby creating two directed circuits. Because these circuits add to the planners' work load and do not benefit decision-makers, they should be eliminated if possible.

TESTING AND APPLICATION

The findings described are largely conceptual at this stage. They are supported in our detailed report (2), together with a rigorous mathematical appendix (10) that includes some algorithms constructing compatible flow charts. We recognized some time ago that further development of these concepts should be in the direction of testing and applications. Research in progress, which is drawing on the experience of the Southeastern Wisconsin Regional Planning Commission, is providing useful information for testing and refining these procedures. By testing, we mean (a) observation of an actual plan-making process to obtain detailed procedural requirements and related information and (b) construction and analysis for flow charts of the observed process.

This should permit new insights and conclusions on the validity of the approach. Although our current studies in Southeastern Wisconsin are mainly directed toward the testing of languages for continuing planning (5, 6), the information obtained should be useful as well for testing the procedures set forth here.

Another area for further investigation concerns the role and structure of predictive models in the plan-making process. Predictive models are incorporated into our procedures in the flow chart guaranteeing feasibility. For this purpose, control and endogenous variables need to be identified. An examination of operational land use and transportation models suggests that the question of control variables has not been fully explored by model-builders. Without developing the details here, it appears that the basic structure of land use and transportation models will permit the definition of alternative sets of control variables, depending on the purpose at hand. Additional research on the structure of these models is being planned in order to define and explore alternate model specifications suitable for differing plan-making situations.

ACKNOWLEDGMENT

The support of Metropolitan Plan Evaluation Methodology, Phase III, by the Federal Highway Administration and the Office of the Assistant Secretary for Environment and Urban Systems, U. S. Department of Transportation, is gratefully acknowledged.

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