SYSTEMS ANALYSIS IN TRANSPORTATION PLANNING

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Introduction

The provision of transportation services within an urban area results in a wide spectrum of important and long-term user and community consequences. The extent of the impacts of the transportation system makes it necessary for the planner to understand and consider explicitly all of the relevant system consequences when he designs and evaluates an alternative transportation plan.

Until recently, the process of transportation planning has been concerned mainly with the direct impact of the future transportation network upon its users. Plans have been evaluated on the basis of their ability to reduce the total cost of transportation within an urban area. Transportation planning became a technique for projecting future travel demand and developing transport networks to serve it efficiently.

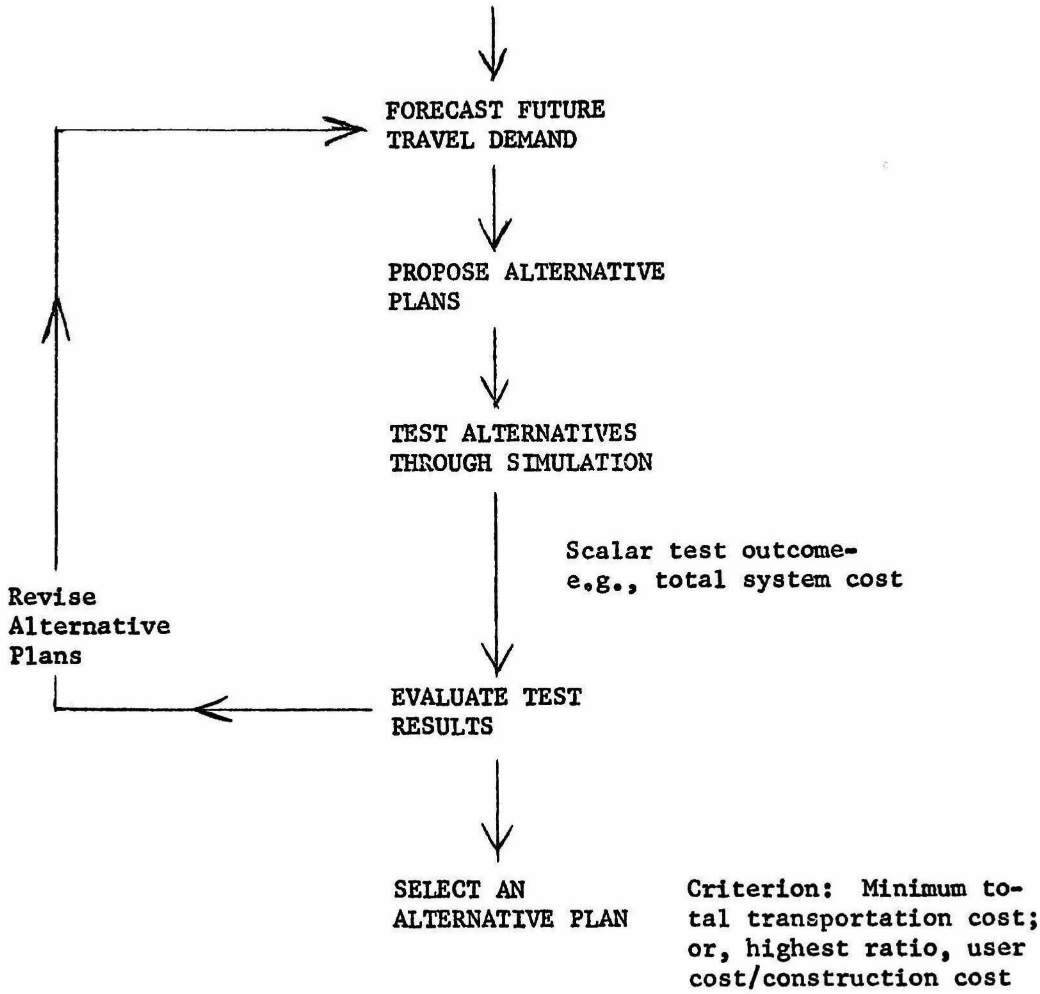
Development of Systems Planning

Figure 1 illustrates the general form of this process. Data describing existing conditions, as well as descriptions of expected future land use patterns, are combined to produce an estimate of interzonal travel movements in some design year. Based upon these anticipated flows, alternative transportation plans for satisfying demand are proposed. The operation of these alternatives is tested by simulating the flow of future travel on the planned networks. The outcomes of these tests, usually in the form of the total costs of transportation at some implicit service level in the design year, are used as the basis for evaluating alternative plans. Where necessary, these plans are revised. Finally, one of the alternatives, that which satisfies travel demands at the lowest total cost, is selected.

FIGURE 1

THE TRANSPORTATION PLANNING PROCESS

(Pre-Systems Analysis)



The result of such a planning process is a short-run solution to a long-run problem. The transportation system does much more than simply providing the potential for satisfying future travel demand. It has an important effect on the social, political, and economic environment. It helps to determine the future form of the urban area, divides or connects social units, and has an impact upon the lives of families living within its immediate micro-environment.

Because of this complicated chain of consequences, it has become increasingly clear that transportation services must be planned in a systematic, comprehensive manner. Figure 2 shows the stages in the evolution of the transportation system planning process. Earliest efforts were to design single sections of highways, such as bridges, tunnels, or by-passes. No consideration was given to the effects upon other portions of the transportation network. Later, attempts were made to plan entire routes. A single freeway was usually planned as a unit, and some consideration was given to the interfaces between the planned facility and existing transportation elements. More recently, efforts have been directed towards planning the entire transportation network for a single mode of travel. The Interstate Highway System is an example of this. Even today, some large American cities are carrying out independent design studies for mass transit and highway networks. The latest trend has been towards the development of the balances transportation plan, in which all modes are planned together as a single system.

The purpose of this paper is to emphasize that, because of the complexity of the consequences resulting from the provision of transportation services, this evolving trend towards horizontal expansion

FIGURE 2

EVOLUTION OF THE SYSTEMS VIEWPOINT
IN TRANSPORTATION PLANNING

Link Planning - single sections, such as bridges, tunnels, bypasses.

Route Planning - entire roadways between cities; complete design of a freeway.

Single Mode System Planning - designing a complete highway or mass transit network as a single system.

Multi-Mode Network Planning - development of the "balanced" transportation plan, in which all modes are planned together to take advantage of the special features of each.

of the scope of transportation planning is not sufficiently comprehensive. We have moved from the consideration of a single link or route to the examination of the complete transportation network. It is now necessary to expand the field of view in other dimensions, so that the totality of system impacts is given adequate consideration. While the horizontal expansion of transportation planning might be considered as a trend towards increasing systematization, the recognition of the other dimensions of transportation system consequences calls for the adoption of a realistic systems-analytic viewpoint.

Systems Analysis

Systems analysis is a term used to describe an approach to the study of large systems. A system may be characterized as a group of interdependent elements which function together for a purpose. Systems analysis is not a tool for answering questions, but a viewpoint from which to ask questions. It evolved from the problems of operations research analysts during the second World War. The operations researchers were concerned with developing the optimum or most efficient solution to a given set of problems. They began to realize, however, that in many cases the wrong problems were being solved. Often only a part of a system was optimized; this came to be known as sub-optimization.

In order to ask the relevant questions, it was necessary to view the entire system under study in the proper perspective, rather than looking only at one or more of its elements. It became clear, however, that the reason that methods of suboptimization had been accepted in the past was the extreme complexity of the most interesting systems under examination.

For example, the typical systems problem is the one of the chicken and the egg. Does transportation determine land use patterns? Or, is land use a function of transportation networks? The answer, or course, is that the relationship between transportation and land use operates in both directions. In the face of such complexities, new approaches were necessary. While they come under the name systems analysis, many researchers will come to understand them as the only logical way to solve difficult problems.

In the most elementary sense, systems analysis consists of looking first at the whole, rather than at the parts. As an understanding of the functioning of the entire system is developed, the most logical ways to separate it into its components will be devised. The next step is the study of the interactions between the system elements. This will lead to the conclusion that the whole is greater than the sum of its parts, for the components themselves have limited meaning. It is only when they are seen in the context of the entire system, with its inputs, flows, interactions, boundaries, and outputs, that the parts will have their true significance.

Consider, for example, an effort to understand the operation of an automobile. It would certainly be difficult to examine a pile of spark plugs, pistons, gears, and wires, and to deduce from these the way in which the automobile functions, or the best way to evaluate its performance. Systems analysis would call for the examination of the vehicle in the context of its operating environment. The various parts could be studied in relation to the entire system. As the investigation progressed, parts could be removed and examined in order to determine their function and their relationship to other parts. Such an approach would eventually lead to an understanding of the automobile.

Transportation Systems Planning

The transportation system might be considered to include the fixed and movable facilities which make movement possible, the flows of resources and information which promote the operation, control, and planning of transport services, the functional groups concerned with planning the future states of the system, and the interfaces of the system with its social, political, and economic environment. An analysis of the transportation system must consider the impacts of system changes upon the various aspects of its environment. An analysis of this nature differs from the more traditional approaches to transportation planning just as a partial equilibrium economic analysis differs from a general equilibrium study. The former would be concerned with the changes in the prices of transportation services which would result from a modification of the system. The latter would deal with the changes in the prices of <u>all</u> goods which would be affected by a change in the transportation system.

The ability to perform this kind of comprehensive analysis does not yet exist. Such an approach requires an understanding of the functional relationships between the transportation system and those elements of the environment which it influences. This understanding must be in sufficient detail to model the consequences of alternative plans. While some important system consequences can be modeled today, others cannot be measured or predicted, and still others remain unclear or unrecognized.

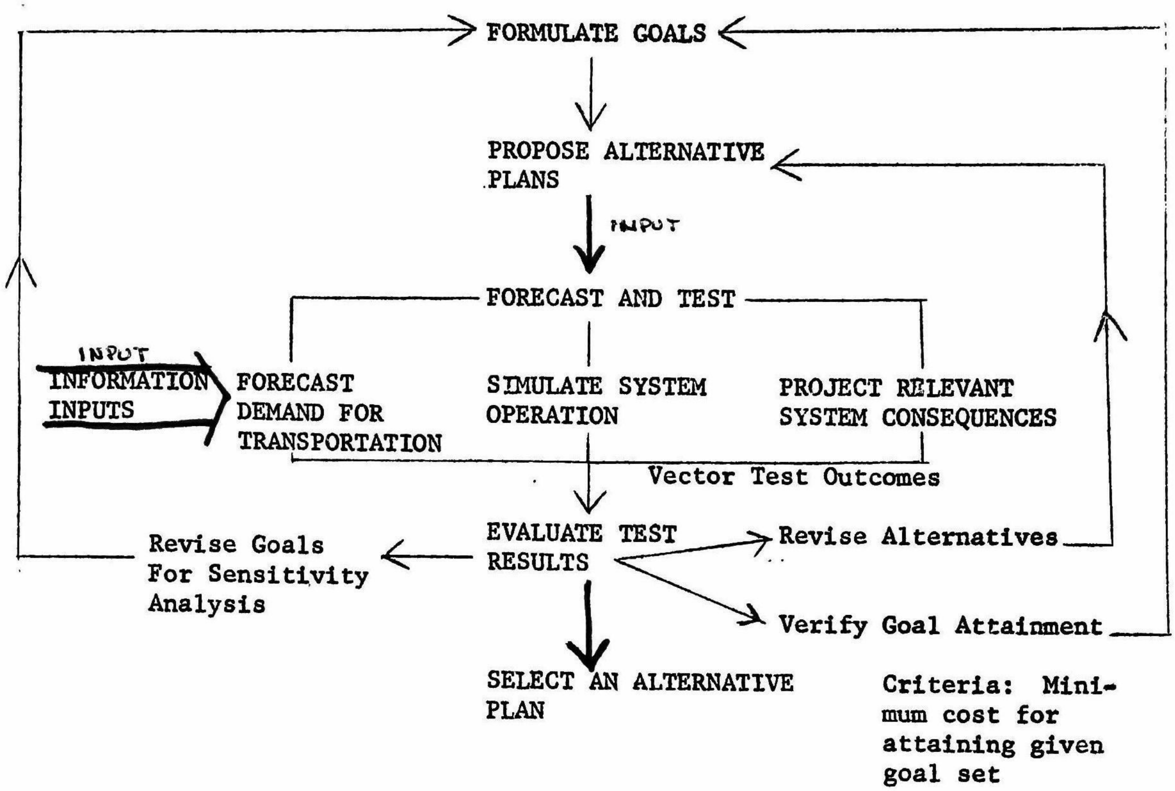
The difficulties associated with predicting and measuring the various consequences brought about by the transportation system, as well as the problems of combining incommensurate and immeasurable factors into a description of an alternative plan suitable for decision-making, place severe demands upon the planning process and upon the methods for evaluating alternative transportation plans.

These complexities prevent the planner from attempting to optimize all of the various system consequences. Instead, he must describe the characteristics of these consequences with which the community residents would at least be satisfied. In other words, a rather detailed specification of system goals is required. These goals must reflect the nature of the acceptable system consequences in all of the relevant impact areas. The logical criterion for evaluating alternative transportation plans, given that they satisfy the comprehensive goal set, would be the minimization of total costs.

Figure 3 shows the goal-oriented transportation system planning process which is coming into general use. A comprehensive set of system goals is formulated and, based on these, some alternative transportation plans aimed at achieving these goals are proposed. The proposed alternatives and information concerning existing and anticipated environmental conditions are inputs to a combined forecasting and testing process. The demand for movement is projected, and the operation of each alternative under the given demand conditions is simulated. At the same time the various impacts of the proposed networks upon the environment are forecasted. All phases of the forecasting and testing process are interrelated so that the projected travel demands, system operating characteristics, and system consequences are internally consistent. The results of the tests are

FIGURE 3

THE TRANSPORTATION SYSTEM PLANNING PROCESS



multi-dimensional, for they might include operating costs, the expected number of accidents, impacts on urban form, and the various social, political, economic, and aesthetic consequences of each alternative.

These test results are evaluated with respect to the set of system goals. Where necessary, plan revisions are accomplished. Finally, the goals may be revised and the process repeated in order to determine the cost-sensitivity of each system goal. The latter process is necessary in order to insure that the community recognizes the costs of setting goals at various levels. It may show that a slight revision in a particular goal would result in a considerable reduction in system costs.

System Evaluation

The fixed performance-minimum cost evaluation criterion differs considerably from the traditional benefit-cost analysis. The strategy in benefit-cost studies is to select the system which provides the highest ratio of benefits to costs. Two alternative systems could differ considerably in their benefits and costs and still have the same benefit-cost ratio. The criterion proposed here, in what is termed a cost-effectiveness approach, insures that each system performs at a minimum level consistent with the community goals. The performance or effectiveness of each alternative is fixed at an acceptable level.

An immediate conclusion is that the cost-effectiveness strategy amounts to an evaluation of system goals rather that simply a test of various alternative plans. The goals, of course, are specified levels of the anticipated system consequences. The plan selection process becomes the choice among possible future states of the urban environment.

This carries the analysis to a completion. It is clear that the provision of transportation services results in consequences which reach far beyond the boundaries of the transportation system itself. This calls for an analysis of the complexities of the system. The evaluation and selection process, as well as the planning process itself, are necessarily focussed on the set of comprehensive community goals. A logical approach to systems evaluation leads to a strategy which forces a choice between alternative states of the environment rather than simply between alternative transportation plans.

Making System Decisions

While it is useful to recognize that selecting an alternative transportation plan means in reality selecting an alternative future state of the urban environment, the act of bringing this notion to the surface does not necessarily solve any of the problems associated with transportation planning. In fact, it merely makes explicit many of the issues which formerly were hidden.

There remains a number of most difficult questions to answer. For example, what is the conversion rate between human lives and the provision of open space? That is, is it worth sacrificing some safety features to build an expressway around rather than through a part? Equally difficult, what is the dollar value of a human life or an acre of park land? The values of lives and parks are incommensurate; they cannot be logically considered in common units. Likewise, is the provision of a sensually pleasing highway worth the additional cost? The latter question is even harder to answer, because it concerns an intangible-aesthetic value. Highway safety can be measured in terms of lives saved or lost or accidents caused; parks can be measured in terms of acres or perhaps even the expected number of visits to them over a period of years. What is aesthetically pleasing to one man, however, may not be so to another.

The solution to these measuring and scaling problems is not immediately obvious. It is clear, however, that decisions of this nature are being made every day. In fact, we might say that it is this type of decision which men make best. It is not possible to place a dollar value (not a price) on a tweed coat. It is possible to decide whether or not a given tweed coat is worth its price. It also seems to be possible to decide whether a tweed or a madras is preferred at a given cost.

This analogy offers a potential solution to the complex problem of evaluating alternative transportation plans. The decision-makers must be provided with a complete description of all of the significant system costs and consequences for each of the alternative plans. The various impacts could be measured in terms of their most logical units: economic effects in terms of dollars; safety in terms of lives saved or lost; parks in terms of acres or numbers of trips; and aesthetic characteristics reflected by drawings, models, or word descriptions. The process of selecting an alternative amounts to a subjective decision. The decision-maker effectively uses his own units of evaluation and conversion to rate the alternatives. The point is that he does so with a full understanding of the consequences of the alternatives-the future states of the environment which he is purchasing-and in light of the community goals.

The systems viewpoint has not solved the problem. In fact, it has brought forth even more problems. The significance of such an approach is that it helps to eliminate blind decisions in which both the products purchased and the costs are not completely recognized. It is a complicated procedure because the systems involved are not simple. Properly used, the systems approach should provide for the logical and comprehensive planning of urban transportation facilities.