FORECASTING TRAVEL DEMAND FOR NEW URBAN TRANSPORTATION SYSTEMS

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The paper presents the experience gained and the conclusions reached by a University of Pennsylvania team who carried out the forecasting procedures for the minicar transit system as a part of a study by a larger group at the university. The technical problems in determining the system characteristics and the levels of service, in defining the travel needs of the study areas, and in developing and applying a method of travel-demand forecasting for a novice system are discussed in the light of experience gained in the minicar transit project. The new system was studied for the Philadelphia CBD and the low-income districts that surround the CBD on 3 sides. Major methodological dilemmas and limitations of market analysis tools are also discussed. Forecasts were made for manifest travel demand and latent travel needs.

•THIS PAPER presents the conclusions reached from a case study of the problem of forecasting demand estimates for new, untested urban transportation systems destined for use within an uncontrolled, competitive, and continuously changing urban environment. The system under consideration was one based on small vehicles available for rent by the trip, the hour, the day, or long periods of time by any qualified driver. The vehicles were called minicars, and the system was called minicar transit system or MTS (1, 2, 3, 4). The effort was carried out by researchers of the University of Pennsylvania as part of a larger project that included the development of the vehicle itself, the MTS, and the determination of the feasibility and desirability of the vehicle and the system as a whole. The project was financed by the Urban Mass Transportation Administration as part of its program in developing new systems.

THE PROBLEM

The technical problem in this aspect of the project was primarily based on estimating with satisfactory reliability the extent to which the new minicar system will be utilized by its prospective users. This simple definition of the problem is sufficient to indicate a number of particulars of the overall problem. The transportation planner was asked not only to forecast the potential demand for a new system but also to suggest what would be the location of the most desirable test and application of the new system. In the case of the minicar project, the efforts focused on testing the feasibility and desirability of such a new system in 2 parts of the Philadelphia region: the Philadelphia central business district and the low-income ring that surrounds the CBD on 3 sides. The 2 areas are to be taken together or separately.

A second major problem faced from the outset was the determination of both the technological system characteristics and the definition of the services that the system would provide for the study areas. It is of particular interest to note that, in developing a new transportation system and in testing the desirability and feasibility of such systems in the early stages of the effort, it is necessary for the transportation planner to undertake the responsibility of suggesting both the desirable technological characteristics of the new system and the type and pattern of services that the new system may be called on to offer. This was also true in the case of the minicar project.

These and several other problems form the core of any effort to forecast travel demand for new systems. The steps that ought to be followed were complicated and required a sequence that was supported by logic and was consistent with the availability of the data sets that were necessary for the completion of the project. Figure 1 shows the various steps and the sequence of actions that were developed and applied in the case of the minicar project in response to these methodological requirements.

What follows in this paper is a discussion of the various phases of analysis and the conclusions reached in performing the various tasks.

PROBLEMS OF AREA SELECTION AND LEVEL OF AREA ANALYSIS

Several problems of particular significance arise as soon as the area of the potential application of the new system is considered. One must immediately refer to the central goals of the entire effort and the initially postulated capabilities of the new system. For instance, in our minicar project the central goals of the effort were the alleviation of street traffic congestion and the provision of an additional means of transport to those urban residents who did not hiterto have a satisfactory choice of travel mode. Also, from the outset, the new mode of travel was defined as a means of serving short-to-median-length urban trips of those who can drive and of providing the service data cost somewhat below that of the private automobile and taxi and somewhat above that of the public transit system. In response to these 2 essential determinations—the central goals and the essential characteristics of the new system—the research team selected 2 areas for testing the initial system: the Philadelphia CBD where all types of urban traffic congestion occur in their worst form and the low-income districts that surround the Philadelphia CBD on 3 sides. The choice of the test areas or study areas was the start of an extensive analytical process to determine 4 essential aspects of each area, as follows.

1. Determination of the boundaries of each area proved to be critical in our effort in both areas. At least 2 major considerations enter here: One is the intrinsic characteristics of the area, and the other is the functional requirements of the system. With regard to the first consideration, it is frequently clear that neither does the CBD of a region have a demarcation line that separates it from the next block of activities nor do the low-income areas have a distinct demarcation point (physical or economic) that separates them from areas with slightly higher income levels. With regard to the second consideration, the requirements of a "systems testing" imposed 2 additional actions. First, a small "island" of high-income households in the midst of a low-income district or a park area in the midst of the CBD would have to be included in the overall outline of the study area. Second, the core study area would have to be related and functionally associated with the surrounding area with which the "study area" interchanges the vast majority of its trips. Thus, 2 study areas become apparent: the core study area (CSA) with which we were primarily concerned and the regional study area (RSA) within which the CSA is located and with which the CSA constantly interacts.
2. A second aspect of the problem was a conflict between our project objectives and the availability of data for each component of the study area. It soon became clear that restrictions on the outline, size, and even location of the study area ought to be accepted because of data requirements.
3. The third aspect of the problem that rapidly emerged was the appropriate level of analysis of the conditions prevailing in the study for the purposes of the project. As the analysis of the conditions prevailing in the study areas and of their travel needs was carried out, it became necessary to frequently impose severe restrictions on the individual analysis in order to avoid aimless analytical ventures that might be of interest but that had very little relation to the objectives of the project.
4. The determination of indexes of service deficiency was the fourth major aspect of the problem. This requirement is indeed of particular significance and is especially complex. It involves both the physical and the operational characteristics of the present and planned systems as well as an essential determination of "standards" and service levels that are either desirable or feasible or both. It seems that an incomplete, short-sighted, or utopian determination of standards or service levels may prejudge the outcome or even the evolution of the entire test of the new system. In our case we found particular difficulties in establishing widely acceptable and quantifiable concepts of latent travel demand for the low-income areas and in establishing satisfactory differen-iations between public and private concepts of requirements for service in both core

Figure 1. Forecasting procedure of minicar project.

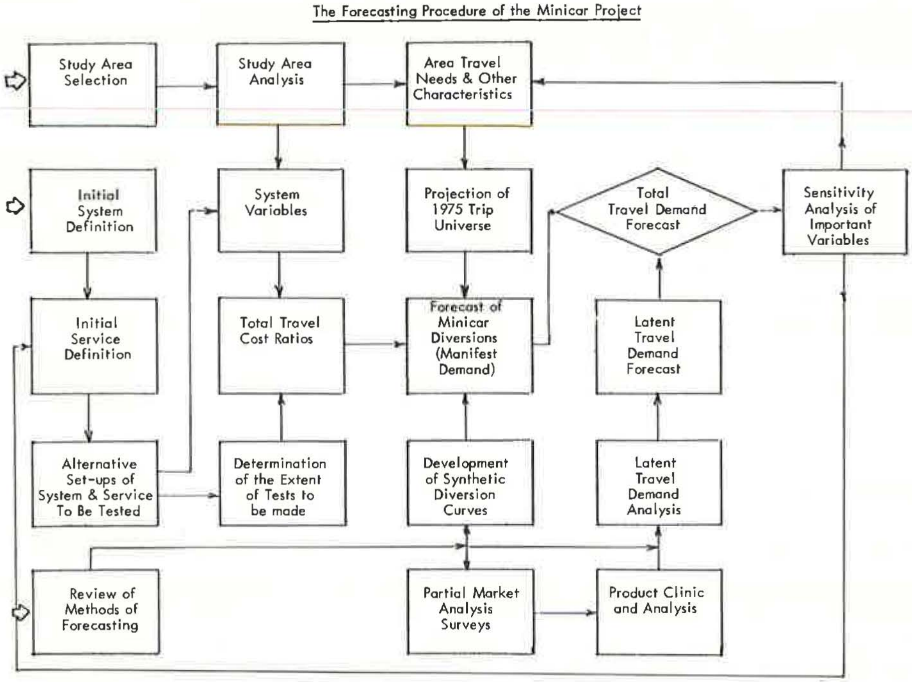


Table 1. Minicar system setups for low-income areas.

Setup	Minicar Fare (cents/mile)	Value of Time (dollars/hour)	Terminal Spacing (mile)	Automobile Parking Cost (cents)	Maximum Fee on Round Trip (dollars)
I	20	1, 2, and 3	1	—	2.00
II	20	1, 2, and 3	$\frac{1}{3}$	10	2.00
III	15	1, 2, and 3	$\frac{2}{3}$	10	1.50
IV	10	1, 2, and 3	$\frac{1}{3}$	25	1.00

study areas. Even the determination of the "travel needs" of the study areas proved to be particularly complicated when the introduction of a totally new system with smaller and different use limitations was taken into account.

SYSTEM DETERMINATION FOR TESTING

The system determination for testing involved 3 components. One was the outline and the "firming up" of the physical and technological characteristics of the system. In addition to the means of costing a trip, such characteristics in our case proved to be the vehicles' operating speed, capacity, maneuverability, driving requirements (i. e., licensed drivers required, physical availability in parking lots and garages (a minimum delay in picking up and delivering vehicles), and driving reliability. The second component was an early determination of the unit cost of travel in a manner that included all pertinent costs such as vehicle costs, costs of parking and storing, costs of accounting and billing, costs of repairs, accident costs, and all other overhead costs of the system. The third component of system determination for testing was the early areal distribution of the system associated with an early determination of the types of services (trips) the new system will be able, appropriate, and available to compete for.

All 3 components of system determination for testing proved difficult to define in our project. In general the more novice the system is and the more alternatives it makes possible, the greater is the difficulty in firming up a total system for testing purposes. In the case of anticipating adoption of a new system within the framework of a free urban society and in an open competition with all the other systems, the determination of the new system for testing purposes is as critical as any other aspect of the overall effort. The transportation planner can right there "kill" the project or, on the other extreme, delude himself into believing the superiority of the idea he is testing.

GEARING THE SYSTEM FOR TESTS

At the completion of the 2 first phases (system determination and study area selection and analysis), the stage was set for gearing the system for comparative simulation tests. The work in this phase could most reasonably start from a determination of what and how many combinations of systems and services will be tested. In our case we felt it necessary to test at least 2 alternative setups for the CBD and 4 setups for the low-income areas. Table 1 gives the setups for the low-income areas. Several elements can be varied at this early stage in the search for various definitions of optimum system. In the minicar system considerable variation was available in setting the fare levels, in determining the maximum cost of a trip, in assuming different values of time for different groups of users, in determining the frequency of system terminals and hence the level of availability of minicars, and in assuming parking cost for the private automobile. Additional items could be varied but the ones already included presented enough complications to restrict us from expanding the list.

The notions of optimum system were also quite variable and only to a limited extent subject to analytical methods of optimum determination. This is so because in only a few cases would the new systems be called on to simply maximize their revenue or to simply produce most efficient services. For most cases, the type of service offered, the group of beneficiaries, and the impact on other competitor or supplementary systems are of equal significance in current testings of new systems. In fact, concepts of this broader type have in the recent past cast unfavorable light on many new systems that otherwise would appear desirable and ready for development.

The determination of distinct combinations of services and facilities to be tested leads to the development of system variables that would, from then on, represent the system. This aspect of the undertaking produces a welcome clarification in the minds of the analysts with regard to what the new system can offer. The system variables express in essence the operating characteristics of the system and represent the dimensions along which the new system can be measured and compared both with expressed travel needs of the study area and with the capabilities of the competitive systems. For our minicar project, we found the need to carry investigations that measure out-of-pocket requirements, running time requirements, and excess time and cost requirements for the completion of the trip. Unfortunately, no measures could be carried out with regard to the system availability to all its potential customers or with regard to comfort, convenience, safety, and reliability of the new systems. Thus, we had to assume that these systems variables would not be any different from the ones characterizing the competitive systems and, therefore, would not produce any influence anyway.

The measurement of system variables involves both the new system and all the other systems currently in use or contemplated to be in use by the time the new system will be in place. The actual mechanics, however, involve both abstract or averaged measurements and specific measurement of interchanges for which more than one system will be available. Thus, it is an important step in the whole process to determine the extent to which detailed measurements will be carried out. There are 2 approaches at this point. The analyst can either produce a blanket measurement of system variables for all probable interchanges or select only a set of representative interchanges for which detailed measurements can be made. The choice depends on the availability of funds and time. The first approach is all inclusive and presents a plethora of measurement points. In our minicar project, we selected the second approach primarily because of limitation in money and time. However, we included enough representative measures to cover the spectrum of probable trip lengths and sets of circumstances that may influence measurements in the new system or the competitor system.

SELECTING FORECASTING PROCEDURES

The entire effort is brought to its most critical point at the moment the choice for a specific forecasting procedure is made. There are several approaches in forecasting travel demand for a totally new system. In general they can be classified into 2 groups: the manifest preference method and the expected preference method or alternatively the travel needs simulation method and the market analysis method. Both approaches include a number of variations and are subject to ad hoc combinations of methods. [The methods and techniques of the abstract-modes models can easily be seen as falling within the manifest demand classification because they clearly utilize a manifest data base (5, 6).] In general the market analysis approach would proceed with one of the many possible forms of questionnaires on the basis of which the potential consumer will be asked to express an a priori judgment and preference about what he would consider preferable and what he would do in case the new system becomes available to him. The exercise is accompanied with a brief description of the new system and with a request to express a choice, all other things being equal. One of the most sophisticated questionnaires in this group is the one that is usually called a discriminant questionnaire in which the potential customer is asked to express an incremental like and dislike for the various characteristics of the new system as part of a technique usually referred to as semantic differentials. Variations of this method are used by most major manufacturing companies (the automobile industry included) in testing what their new products will encounter in the market or how their new products must be improved (7).

The market analysis approach is based on market segmentation from the outset, and in many cases it is reinforced with a product clinic. The term "product clinic" is given to a special effort, usually carried on annually by the automobile companies, in which the new product is exhibited and explained to successive segments of the market. At the end of each routine, the potential consumers are usually asked to complete a questionnaire indicating their feelings, preferences, and choices on the basis of what they know, what they have seen, and what they have been told about the new product.

In contrast to these market analysis techniques, the analyst has available for his use considerable data that indicate what the potential consumers have already done in cases where a choice was involved. The approach is based on manifest behavior and preferences, consciously or unconsciously made. If, then, the analyst succeeds in relating the manifest choice with the circumstances within which the choice was made and with the relative characteristics of the competing systems, he can assume that in similar cases in the future the potential consumer will act similarly. This approach is the essence of modal-split analysis and projection carried out by most urban transportation studies. In doing so, the analyst has available several methods that he may employ such as correlation analysis, diversion curves, abstract-modes models, and stochastic choice models.

As the minicar system forecasts were carried out, the dilemma of the approach to be followed was felt in its full force. The new system was sufficiently novice in its physical outline and operating characteristics to warrant market analysis experimentations and product clinic findings. The new system was, however, sufficiently similar to present systems to render the findings of other modal-split studies very useful in forecasting usage. After all, cost variations and travel time variations have been in the heart of modal-split analyses of most major modal-split studies.

As a result of these realizations, the team proceeded by utilizing both approaches but placing major emphasis on the manifest preferences method. A number of market analysis studies were made for most segments of the potential market. In addition, a product clinic was held in a special room of the university for about a month to which more than 100 groups were invited in sequence. The market analysis studies were small in size and attempted to measure probable future preferences in specific cases. The product clinic participants were given the opportunity to inspect and experience the minicar itself, review the results of the first phase of the study, listen to additional explanations, and then carry on a conversation with key members of the research team. The invited groups varied from leadership groups such as councilmen and civic leaders to small street-corner groups and informal associations. At the end of each session each participant was asked to complete a questionnaire.

The main forecasting effort proceeded, however, by utilizing data and conclusions based on the 1960 home interview survey of the Penn-Jersey Transportation Study. The target date was 1975 for which a preliminary regional transportation plan and projection was made by the Delaware Valley Regional Planning Commission in the period 1963-66.

The application of a modal split approach in determining the minicar share of the manifest trips involves still many steps and assumptions that must be carried out before the process is completed. The first major commitment to be carried out was the exact method to be utilized in estimating the share of the minicar trips, among the methods available, the conclusion was in favor of developing a set of synthetic diversion curves. The correlation analysis was excluded because of both the need it has for empirical data in deriving the coefficients of the equations and the undue strictness of the relations that the equations convey. The stochastic approach was also rejected from the outset because of the undue articulation of the hypothesis and relations that the approach requires and that in no way could be met in this speculative and experimental study.

The set of synthetic diversion curves was developed by using the experience gained in the recent past in developing modal-split diversion curves in actual situations and by utilizing also a set of logical-commital statements that establish the 2 extreme points of each curve as well as its midpoint. Then by assuming the applicability of the economic principle of diminishing marginal returns, the team formulated a set of diversion curves approximating the shape of diversion curves of the recent past. Figure 2 shows the resultant curves for 2 sets of choices. These curves were then utilized in association with a composite system variable developed with the total travel cost of each interchange under consideration.

The total travel cost variable was formed as the key variable for the diversion curves, against which the share of minicar travel could be estimated. The variable represented the summary cost of all out-of-pocket costs, the time cost, and an approach time cost at the 2 ends of the trip. The minicar fare was explicitly counted on the basis of the assumptions advanced in each system setup for testing. The automobile costs were inclusive of operating costs and fixed costs of depreciation and insurance. Varying automobile parking costs were added. For transit and taxi trips, the fares of each trip were explicitly included. The total costs of each system were then made to form ratios that were further investigated with respect to trip length, value of time, level of parking costs, and amount of approach costs for each trip. Figure 3 shows some of the variations of the cost ratios with trip length and value of time for minicar versus automobile and minicar versus transit.

On the basis of this set of assumptions, presumptions, and partial calculations, the

Figure 2. Synthetic diversion curves for low-income areas.

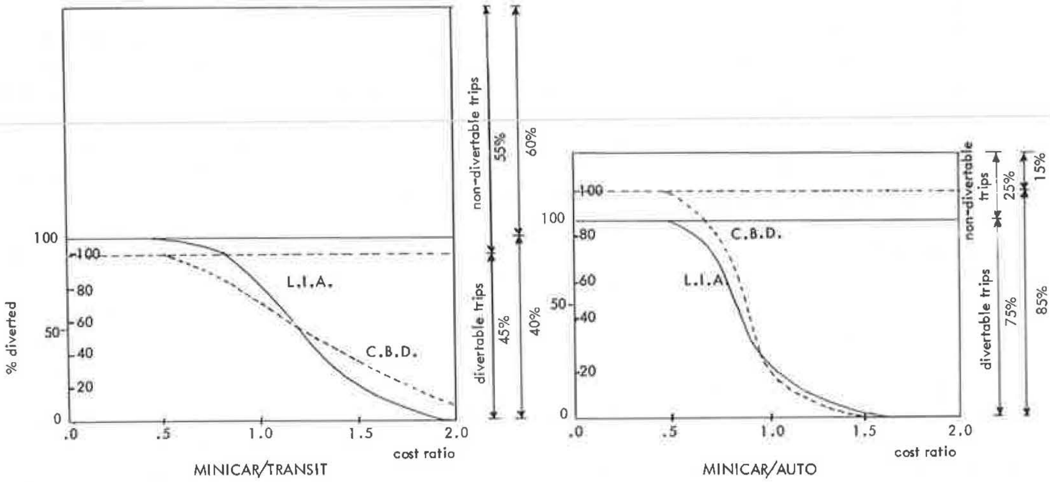
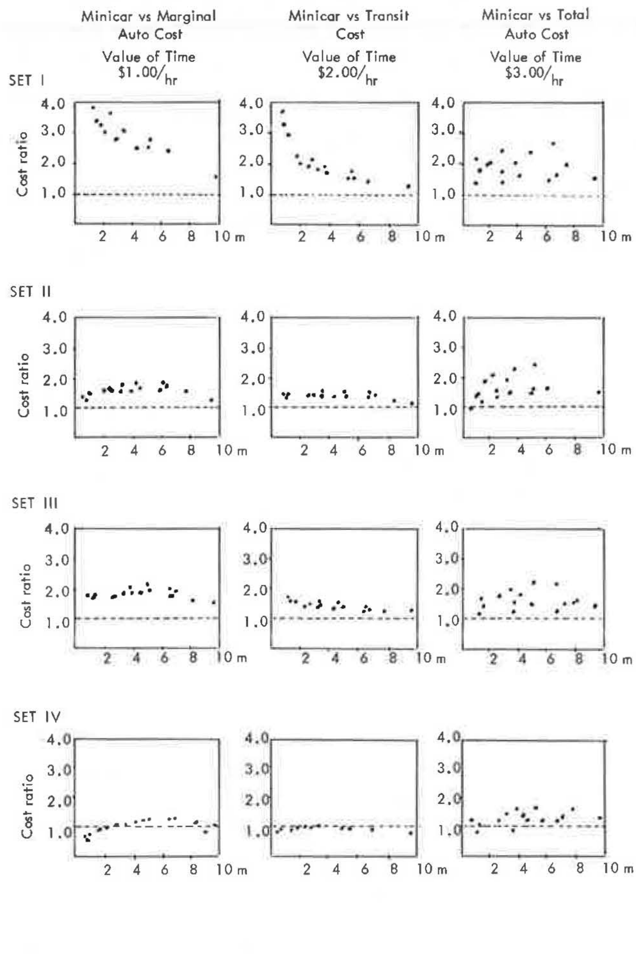


Figure 3. Minicar cost ratios.



forecasts for the share of minicar trips from the total manifest trip projection of the residents in the region were made for 1985. The essential question that the team was attempting to answer was, What would happen to the trip patterns by mode if, in addition to what exists and is planned in the mean time, a minicar transit system were in operation in the study areas in 1975? The first part of the answer was to be derived through these sequential and somewhat complicated steps. However, in addition to what one can expect to occur in shifting trips from one mode of travel to the other, there is a serious reason to expect that additional trips will be made in 1975 if the new system is in operation, because of the existence of the new system. What is introduced here is the possibility of realizable latent travel demand due to the characteristics of the new system. The essence of latent travel demand is that a real need and a desire to make a trip are surpressed because of the limitations imposed by the system on which the trip must be made. Thus, when a bus line stops operating after 10 p. m. transit trips that would be made at that time have to be postponed or altogether canceled if the trip-maker cannot make use of an automobile. The cost to the individual of the canceled or postponed trip cannot be easily conveyed but is nonetheless real. Environmental limitations or constraints are also equally frequent and real. Trips must be postponed, combined, or outright canceled if the trip-maker cannot bear the direct cost of the trip in money or time, regardless of any indirect benefits to the potential trip-maker. Thus, the need and desire for these trips constitute the latent travel demand for the given set of users and for the given set of circumstances. When the new system is introduced with its essentially different levels of availability, low cost, and high speeds, it is bound to make a proportion of the existing latent travel demand realizable and thus manifest for 1975. This is what other researchers some years ago called induced trips, i. e., trips that the new expressway systems were found to produce.

The methods of calculating latent travel demand are still in their infancy. They are usually based on measuring the elasticity of a demand function with respect to either the income of the consumer or the price of the commodity. A similar approach was followed in the minicar project (although the team avoided producing a mathematical solution by taking the partial derivative of the demand function with respect to the unit cost of the minicar trips). In general, the procedure followed was to "estimate" the elasticity of demand due to the price changes within the guidance we found in specifying the shift of trips from one mode of travel to the other due to price changes for manifest travel patterns. The forecast total travel demand was the summary of the 2 partial demand estimates, i. e., the manifest and latent travel demand of the study area.

SENSITIVITY OF DEMAND FORECASTS

The long sequence of steps required to produce a forecast for travel demand of a new urban system plus the extensive number of assumptions and presumptions that the analyst has to undertake in order to complete the missing pieces of information necessary to his work clearly indicate that at the end of the process he possesses an estimate with considerable limitation. This realization, together with the fact that a limited number of system setups tested represented only a small part of what can be devised and tried in the future, imposed a clear need to investigate and specify as clearly as possible the sensitivity of the forecast estimates to the several important system variables utilized in the process. This was exactly the concluding part of the minicar project forecasting effort.

Usually there are 2 types of variables: the variables that are endogenous to the new system (which are also under considerable design control) and the variables that are exogenous to the new system per se but endogenous to the study area. In the minicar project the endogenous variables were the minicar fare structure, the spacing of the terminals, and the conditions and delays of the vehicle pickup and delivery. Exogenous variables were the value of time, the automobile parking cost and availability, and the operating costs of automobiles and the fares of transit and taxis. The sensitivity analysis carried as part of this project imdicated that the forecast estimates were extremely sensitive to the endogenous and exogenous variables. Further, the type of trips attached to and generated by the new system proved also to be very sensitive to variations of many of the endogenous and exogenous variables. In fact, our analysis indicated that the flexible variables tended to be more important than the plain technological characteristics of the new system per se.

This sensitivity to system variables was considered to constitute both an important risk in introducing the new system and an important policy tool in influencing the success of the new system and directing the impact it may have on automobile trips, transit trips, and taxi services. In essence, extensive knowledge of what influences the new system would have, and of the way the various influences would be felt, was found to be an important element in managing such a system and in interweaving it within the fabric of other urban transportation systems and services.

CONCLUSIONS

The conclusions of this case study, above and beyond the specific findings of the minicar project, led the research team into a series of reappraisals of the entire effort. In many respects, the team realized time and again that the available methods and techniques in the field are indeed of limited ability in forecasting travel demands for new systems for use within modern urban areas. The need for relevant empirical findings was indeed pervasive. On occasion it seemed that nothing could make up for lack of data from direct experiment. Nonetheless, it was also felt in such early stages of research for a new urban transportation system even the most fundamental decisions (i. e., the most appropriate study area and the most pervasive technological characteristics of the system must be stressed) did not have sufficient grounds for a sound answer. Thus, the team concluded that the most productive approach would have been an interplay between office research and system simulation on the one hand and actual experimentation on the other.

Barring this interplay, the analyst would be advised to select an approach that utilized the most direct methods of analysis with the most feasible openness on the required assumptions and presumptions necessary to be made in the process of forecasting. The market analysis approach yielded limited results and helped primarily to increase the understanding of a few critical segments of the potential market. The product clinic was also helpful to a very limited extent for several reasons, among which the difficulties the team encountered in bringing in larger crowds and in communicating the whole purpose of the project were prominent. Concerns over "salesmanship," "profits," and "propriety" increased as the idea was transformed gradually from a pure speculative research notion into a physical, probable system. In overall terms, the transportation planning method that was based on past data from an origin and destination study and on findings of previous modal-split analysis proved to be the "saving method" that permitted the team to complete its efforts and to produce a set of forecasting estimates for limited use and some indication of their sensitivity to the important system variables. This was so because of the availability of several central concepts in this approach and the availability of a plethora of partially relevant data.

Among the numerous dilemmas that were faced in this effort, the ones related to the questions of Who will generate the system data? Who should make the critical assumptions? and What analytical tools should be selected? were the ones that permeated the effort from its beginning to its conclusion. It seems that these questions are bound to be in the center of concern of any similar effort. No hurried answers would be advisable to these questions because they are only partly technical. Their essential nature is social, political, managerial or financial or all of these. Thus, in most cases, the answers must come primarily from the sector that carried the responsibility of implementation or the group that would either be the potential users of the system or feel the impact of the system otherwise or both. The researcher or the planning analyst in these cases should be satisfied to take the back seat and not to make the numerous decisions that predetermine so much of the answer.

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