Resource Paper

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At the Urban Mass Transportation Administration (UMTA), forecasting demand for new transportation options and technologies is a frequent subject of conversation. The proposed innovative (and speculative) modes of urban transport range from automated bicycle paths to regional dual-mode systems, from public automobile systems using a quarter of a million vehicles to automated 4-passenger personal rapid transit (PRT) maintaining ¼-sec headways, and from slender 60-ft boats to fat 500-ft blimps. Non-capital-intensive proposals include automated information systems for transit passengers, road pricing for automobile drivers, automobile-free zones for pedestrians, dial-a-ride service for the handicapped, and transportation-sensitive land use zoning for developers. Among seriously considered capital improvements are improved buses operating on guideways composed of exclusive structures and tunnels and 12- to 20-passenger automated people-movers of a near-infinite variety of shapes, propulsion, suspension, and command and control.

Unfortunately, the fact that we discuss new options and technologies does not mean that we know exactly how to forecast demand for them. In fact, our treatment of the subject varies from day to day. At times we take a very global or federal view, examining the worldwide and national economic and environmental implications of new technologies. At other times we try to address the topic as, say, the Ford Motor Company would, so that UMTA can decide on the proper planting of research and development seed money as a catalyst for industry. Or we approach the problem as a local transportation planner or transit operator might. And sometimes we examine potential demand from the selfish and definitive point of view of the user.

The myriad supply-side variations multiplied by many different evaluation criteria result in a baroque view of the demand-estimation problem. One becomes humble and loathe to make general statements on how to forecast demand for any new method of moving people. Either the subject must be restricted to specific generic technologies, or the statements must be general and vague. This paper chooses both options. It relates primarily to technologies requiring significant risk capital and having large urban areas as their hosts, and it vaguely describes research directions that will lead to a better methodology for forecasting demand for such systems to lessen the risk of their costly replacement.

Although the discussion is esoteric, it is nonmathematical; there are no formulas. Most of the problem statement speaks to uncertainty on the supply side and to the methodological shortcomings from common demand forecasting techniques. The unexplicated assumption is that the traditional urban transportation planning (UTP) model chain is woefully unsuited to multimodal transportation planning. Suggested modifications are restricted to the technical components of the UTP process. Neither the problems nor the solutions described are always unique to new systems. Furthermore, computer models receive principal emphasis.

The overriding thesis is that, for the state of the art of demand estimation to improve significantly, 3 conditions are necessary: Information sources must be exploited, and a rich and readily accessible data base must be available for experimentation; a ubiquitous and powerful computer environment—both hardware and software—must support this experimentation as well as planning in general; and the transportation planning art and its models must be more streamlined and sophisticated (i.e., much quicker but no dirtier). Although these 3 conditions alone are not sufficient, without them demand modeling research and development will continue to be prohibitively expensive and its results of restricted use to transportation planning.

NEED TO ESTIMATE DEMAND

In general, there are 2 distinct reasons why demand forecasts are necessary evils: cost-benefit analysis and engineering design. No system evaluation or engineering design can be complete without demand estimates. The performance of all urban transportation system components depends heavily on demand levels. Thus, to make good, careful guesses of a new system's expected performance and viability, we must estimate how many people will use it and how much they will pay for the service. Costs and benefits are subjective concepts. The passenger's chief concerns are travel time, cost, comfort, convenience, reliability, safety, accessibility, and mobility. The operator thinks mainly of capital and net operating costs. Industry eyes market potential, and the government considers the nation's economic and social welfare. All these concerns relate to patronage.

A transportation planner needs good patronage estimates to feed his reiterative design process that configures the system. To measure performance and improve design, he is particularly concerned with vehicle and passenger flows and densities on each element of the network. He requires demand forecasts with both spatial and temporal dimensions. At different points in his planning process he requires information ranging from highly aggregate, 24-hour regional corridor volume estimates down to the number of people queuing up in the aisle of a subway station during the peak quarter-hour.

At UMTA, the concern over demand estimation cuts across all interest groups. The administration is charged with improving urban transportation at minimum cost—improvement as seen by the user and community and costs as seen by the operator and industry. Although it is generally agreed that new technology can help solve the transportation crisis, the great omnipotent giant—American Industrial Know-How—marches only toward profit. Thus, UMTA encourages and funds research that industry would otherwise consider too detrimental to near-term earnings. UMTA needs to know the expected utility of proposed transportation hardware before it can support a related research and development program. Utility implies demand. Thus, with every decision to research and develop (or not to research and develop) system X, UMTA tacitly makes a demand forecast.

FORECASTING FOR NEW SYSTEMS

Problem

Demand forecasting for new systems is more difficult than for contemporary systems, because we have no directly related experience to draw from. That well-intended quasi-tautologous statement is both misleading and useless. System "newness" is typically characterized by innovative hardware or by conventional hardware performing an unaccustomed function. In the former case uniqueness is visible in the system's information command and control system, guideway, vehicle, or terminal. The latter case is exemplified by a helicopter squadron serving suburban commuters. Forecasting difficulty, on the other hand, results from complex intermodal, economic, and societal characteristics of a system's host environment. It would, for example, be much easier to forecast demand for a PRT in a new town than for a bus line paralleling an existing rail line in one of our great cities.

In fact, in a negative respect, high cost and high risk make demand estimation slightly easier for new systems. Cruder estimates can be used. High cost can often be used to reject the system's selection out of hand. The "breakeven" patronage level would be much beyond the realm of possibility. High risk implies that expected benefit must be extremely high, and such order-of-magnitude levels can be tested with "quick-and-dirty" forecasting techniques.

What makes forecasting for new systems tricky business is the uncertainty of the supply side. Costs, performance, and unanticipated impacts are all problematic.

Supply-Related Uncertainties

Cost

The most general and frustrating uncertainty connected with new systems is their cost. The uncertainty here is infinitely greater than with conventional systems. A system's cost is probably the single most crucial factor determining its feasibility. Furthermore, operating costs must be (partially) matched by fare-box revenue, and fares impact on the demand that provides revenues. Thus, an expected operating cost must be estimated quite precisely before a realistic subsidy estimate can be inferred.

For example, the capital and operating costs of PRT have been agonizingly difficult to pin down. Capital costs of all UMTA-sponsored development efforts have overshot their manufacturers' original estimates. Being largely a product function of reliability and fleet size, operating costs are particularly difficult. There are almost no good data available to estimate reliability, and large fleet sizes and a variable reliability give catastrophic upper limits to expected maintenance costs, which could imply down-time and repair costs for automated vehicles that might exceed the cost of human drivers!

Performance

Expected performance is another crucial random variable suffering from uncertainty. Although reliability and safety are critical performance parameters, experimental data on these factors are usually too sparse to be trustworthy. Again, the most costly, sophisticated, and automated systems have the greatest uncertainty and, thus, a very high risk.

Unanticipated Impacts

The weaving of a new technology into existing urban fabric can cause unforeseen impacts of enormous magnitude. Placement of new systems must be planned with greater care and attention to detail. Techniques used for contemporary systems are inadequate. They suffer from taking history for granted. New systems bring new problems, ranging from citizen rejection to social catastrophes.

Public reaction is a crucial unknown. If the public stops freeway construction, will it be equally adamant against extensive guideways? Will labor unions raise a fuss and put an "engineer" in each PRT? Will vandals make a shambles of a driverless vehicle? Will passengers be or feel safe? These questions must be answered before demand estimates are meaningful.

Fortunately, the unexpected negative impacts of new technology are becoming more of a concern these days. No one would have guessed 50 years ago that the automobile would be killing 50,000 Americans a year, using 25 percent of the nation's energy, and poisoning all of the cities' air. If anybody had, a march on Detroit would have stopped production of the Model T.

Information Sources

As input to a new system's modeling or planning effort, there are too few dependable information sources. Unfortunately, most of the popular literature and much of the manufacturers' technical reporting on new systems do not realistically address the problems of risk and uncertainty. Such problems are often completely ignored or glossed over with some reverential reference to a limitless capability of technology. For example, an ex-aerospace engineer now in urban transportation personally assured me that "the command and control problems of automatically driving 75,000 vehicles around 500 miles of guideway at 60 mph and a ¼-sec headway posed much less of a problem than the electronic control present in a single F-111 aircraft!"

To reduce risk and uncertainty, the modeler of demand for new systems must seek information from attitude and behavior surveys, product laboratory experiments, prototype development activities, and urban demonstrations.

Attitude and Behavior Surveys

Valuable and relatively inexpensive attitude and behavior surveys are essential research tools, but they can only describe a frame of mind. In the case of new systems, this frame of mind necessarily comprises ignorance. What is the best technique to conjure up in a subject's mind the right image of system X? It is critical that a new system's potential level of service be accurately understood and properly juxtaposed against its competition's.

Product Laboratories

Product laboratories can be excellent data-gathering facilities. Simulators, mockups, movies, and computer-driven video displays can provide a subject with a realistic impression of system characteristics without a prototype having to be built. They serve excellently as a means of judging human factors for design purposes. It is possible, for example, to show the user a computer-generated movie of his trip to work in 1980 in system X and in his automobile. Output from traffic assignment simulations should be "dequantified" to give him a front-seat picture of the estimated traffic.

Prototype Development

Prototype systems such as those exhibited at TRANSPO 72 and UMTA's test track at Pueblo, Colorado, provide excellent data on physical characteristics and development cost. Reliability experiments and safety tests are run there. They also serve as laboratories in which a somewhat realistic user environment can be simulated. Controlled experiments with selected passengers reveal their acceptance of the hardware. Like product laboratories, prototypes are very useful, but they do not assist demand forecasting in the manner required by the transportation planner. These experiments primarily benefit the manufacturer. They tell him whether items such as noise levels, sway, leg room, and color are acceptable. These judgments are necessary to uncover objectionable design features and to reduce risk and uncertainty, but they usually provide little insight on how likely a person is to leave his car at home. That decision, of course, depends little on color, sway, or the like. It depends mainly on the system's competitiveness with respect to time, cost, and convenience. These are site-dependent factors and must be estimated through simulation or demonstration.

Demonstrations

By far the richest source of information on a new system is its construction and operation in the user environment for which it was designed. It is currently felt that there is no substitute for such a demonstration to obtain satisfactorily accurate estimates of safety, reliability, public acceptance, and construction and operating costs. A "successful" demonstration will certify its safety and qualify the system for UMTA capital grant funds. An urban demonstration like the Morgantown PRT project uncovers emplacement difficulties (political, physical, and fiscal) and can serve as fertile ground for behavior and attitude surveys. On the other hand, the scale of the experiment is typically too small to draw hard and fast conclusions with respect to demand. Someone once described demonstrations as building half a bridge. The research challenge, then, is to devise experiments to ascertain from half a bridge in city A the demand for a whole bridge in city B. An urban demonstration does, however, surface negative reactions. Do people feel unsafe on the system? Do vandals deface or destroy it? Is it unreliable? Are its environmental impacts intolerable? Affirmative answers to these questions, however, are used in system redesign rather than demand estimation.

Special Demand Considerations

Although all the problems of forecasting for contemporary options are present during the planning for new systems, additional concern should be given to the problems of modal interaction and latent demand.

Modal Interaction

Every large-scale deployment of a new system will (at least initially) be a retrofit. It will constitute yet another subsystem in the multimodal mosaic that typifies urban transportation systems. Its dependence on or competition with other subsystems is seldom properly considered. For example, a dual-mode system will increase automobile ownership and trip length. What will be the impact on the street and parking subsystems?

Latent Demand

The high risk associated with a new system requires a commensurately higher benefit to justify its selection. If this benefit entails a large reduction of travel time, we would expect a much greater amount of induced travel than that caused by a contemporary system with a lesser direct impact. If the new system satisfies a large portion of existing travel demand at significantly less cost, then there can be a significant increase in total travel. For example, the Interstate System saved a great deal of travel time for many trips. The dual effects were to free some household money (time) for rebudgeting while at the same time enhancing the relative attractiveness of products entailing highway travel. The result, of course, is increased demand not only on the Interstate System but on local roads as well.

Modeling Considerations

Successful (useful) models have 3 important traits. First, they are driven by simple, understandable assumptions. Second, they are optimal within the constraints of the specified budget for their development and application. Third, they perform as advertised. Usually these traits result from the model's restricting its attention to a specific problem. Thus, there will never be a panacean transportation demand model. The various characteristics of transportation design problems and the variation of budget and data base preclude the feasibility of a single "universal" model. Demand models for untried systems are the most difficult to build. They need special treatment, particularly in the model formulation and calibration stages. Better tools are needed for the modeler, so that he may effectively use the scientific method to develop cost-effective models.

Formulation

In structuring models to forecast demand, the modeler works within tighter constraints for new systems than for contemporary systems. The formulation of mode-specific models is difficult enough, but the new modes require "abstract" models that describe a system only in functional terms—no mode-specific parameters are allowed. The typical abstract, time-cost models have not performed very well in practice, and their failure is probably due to poor model formulation as well as bad data. We are not yet able to price time and convenience properly. Even the simplest case, the automobile mode, is poorly handled. For example, transportation planners do not associate different impedance rates with different driving conditions. Although we know that bus riders value waiting time higher than riding time, no one uses the fact that time spent in an automobile in stop-and-go traffic is more highly priced than smooth, uncongested driving time.

The usual treatment of cost in most demand models is inadequate for new system forecasts. These models typically accept point estimates of cost and output point estimates of demand. For new systems, the high level of uncertainty associated with capital and operating costs suggests a parametric approach. The model should accept ranges of assumed costs and translate these into demand curves that are a function of costs, fares, and the like. Such a parametric study graphically translates the cost uncertainties into the corresponding demand variability and also performs a useful sensitivity analysis.

A further weakness in typical demand models is the use of improper predictor variables. The most common example is the misuse of automobile ownership as an independent variable in modal-choice models. A modal choice in its own right, automobile ownership is affected by transportation system variables, both highway and transit. If new systems are going to drastically change the coverage and travel times of public transit, then it is conceivable in the long term that automobile ownership levels will be lower than those expected had the transit system remained at its past, low service level.

Calibration

The above problems are all part of one serious general problem. Demand models have been traditionally evaluated on how well they calibrate instead of how well they forecast. The result of this error has been models that use hundreds of different parameters associated with "independent" variables that are often more difficult to forecast than travel demand itself. The typical iterative calibration process often destroys a structurally valid model by tinkering with its parameters to a point where present-day bias is systematically ingrained in the model and, thus, invalidates its forecasts. Certainly, in the past 15 years, enough travel data have been brought together that we may now use time series data instead of cross-sectional data to evaluate proposed models.

Development Costs

The final demand-estimation problem to be discussed here is a practical one: the high development costs of the models. Usually, this money is ineffectively spent. Typical modeling efforts put too little effort into the important areas of model formulation and evaluation. They spend most of their dollars in data collection and software development. A great duplication of effort results. The cost of demand modeling is much higher than it should be, and the models are not so good as they could be.

After modeler inexperience, the principal cause of most costly "failures" in demand modeling is the formulation of models for which available data are inadequate. Such models have utility from a research point of view, but leave the transportation planner holding the bag. By and large, most successful efforts have been ad hoc in nature and have data limitations constraining model formulation. The best model is built for the data (budget) at hand. The modeler is usually charged with providing a forecast from a given data base. He fails if he uses his ad hoc assignment to seek the best of all possible models independent of data base and then complains that his model's uselessness is the fault of the data.

Improved Modeling Tools

The reason the millions of dollars spent on demand modeling have yielded so few useful general results is the ad hoc nature of the efforts. For reasons mentioned, the models have limited utility. This is not to imply that the efforts were useless. Quite the contrary, in most cases they provided useful numbers to the planning activity for which the model was developed. What is needed is the development of modular, generalized tools that will assist these ad hoc efforts. If we can significantly reduce development costs, more effort can be spent on model formulation and evaluation, and better forecasts can be developed.

The goal of UMTA's new-systems requirements analysis program is to provide some of these tools. In addition to demand forecasting tutorials, UMTA intends to provide a software "breadboard" into which almost any urban transportation demand model can be plugged at minimal cost. The package will include generalized network analysis modules that extract user-specified level-of-service measures from a multimodal network description. Powerful statistical, mathematical programming, and traffic assignment modules will be available to aid in the calibration and evaluation stages. A module accepting any user-written multimodal demand formulation will manipulate the vector and matrix data sets describing activity measures and transportation system characteristics in the manner required by the formulation. Graphics and data-editing modules will facilitate data analysis and "massaging." With such a system, the demand modeler will be better equipped to find good, inexpensive, ad hoc solutions for the planner and to advance the state of the art through research and experimentation.

RESEARCH AND DEVELOPMENT TOPICS

This section gives 5 sample research and development problems and objectives that would lead to an improved ability to model demand for new systems. One recommendation that overshadows and embraces the others is for a large and powerful time-shared computer with a nationwide telecommunications network to be made available to the entire planning community. It would be used both for research and for plan development. It would host a rich variety of general, transportation planning software. It would store for ready access all local land use, travel, and network data and be as convenient to use as a telephone.

Planning and Modeling Computer Laboratory

As mentioned above, 2 impediments to effective demand modeling are the data problem and software development. Researchers dilute their financial and cerebral resources in chasing down and shaping up a useful data base. This is particularly frustrating when there exists a plethora of urban transportation data that have been bought and paid for. The data exist, but they are not accessible because of their multitudinous locations and formats.

One simple act that could greatly relieve this frustration and many others is for UMTA to install a large time-sharing computer that would be available nationally for use by authorized planning agencies and researchers through local terminals. This computer would have resident a large and powerful modular battery of transportation algorithms, statistical and mathematical packages, data management tools, and survey and computer graphics software. Any agency using it would have available a rich and uniform data base, including improved origin-destination surveys, that would be immediately accessible to the entire planning community—federal, state, and local. Such a facility could make modeling easier, cheaper, and more effective. The fruits of successful modeling efforts would be more easily disseminated. Software built for that computer could be available to everyone, almost immediately.

With such a system, a national transportation needs study could become streamlined and routine. Also, the system would readily support the inference of national demand for new transportation systems. Local agencies selected on the basis of the representative nature of their study areas could be asked to construct a plan that assumed a certain new transportation technology to be generally available. These plans would be constructed on the central computer and would provide data points on which a national extrapolation could be obtained automatically.

UMTA capital grants analysts would have at their fingertips data relating to the technical study supporting a grant request. UMTA could also execute post facto analyses of each technical study on which a capital grant request is based. For example, after Metro is working, research would be undertaken to evaluate the demand forecasts. Although the original modeler might not be around to hear the results, other modelers will benefit substantially from such an analysis. Only in this way can we guarantee continued improvement of our efforts. Transportation researchers, including modelers of demand for new technologies and options, could gain access to results of thousands of surveys and network designs with which they could test their hypotheses.

New Origin-Destination Survey Methodology

The traditional origin-destination survey is an infamous exercise in money wasting. It must be replaced with a more cost-effective tool. It is tragic that a public agency can spend millions of dollars surveying travel behavior in an urban area and have none of those data available for analysis before 2 years have passed. A typical scenario is the following: After 3 months of interviewing, a truckload of interviews is entered into an archaic data processing chain. Months of keypunching and verifying move into months of edit checking. Zone numbers are related to addresses. More checking follows more fixing. A year later a factoring process begins and is followed by other accuracy checks and general wholesale handwringing on why census numbers and survey numbers do not match, and on and on.

Finally, once the data are available, they are relatively uninformative to demand modelers. The standard origin-destination survey usually asks the wrong people the wrong questions. It uses primitive sample selection techniques—uniform sample rates independent of the variance of the data sampled. As a result the modeler is overinformed on homogeneous zones and is left in the dark in the heterogeneous zones. The same, unrevealing questions are asked of everyone even though some households have more complex decision mechanisms at work or use totally different components of the transportation system. Questions must be redesigned and varied to elicit behavioral and attitudinal information. Was the traveler aware of his alternatives? Why did he decide against them? What would it take to change his decisions? What trips did he not take? What is the distribution of his household budget?

If modern attitude survey and sampling techniques were coupled with the use of time-shared computers and modern data-entry hardware, some useful data would be available 1 week after the first interview, and all data would be usable within 2 weeks of the last interview. The whole keypunching, editing, and factoring effort could go on simultaneously with the interviewing. And the resulting data would be more informative.

Automatic Network Abstraction

An important factor that has shaped the character of travel demand forecasting models has been the large size of the regional transportation networks. Networks with more than 4,000 nodes are becoming the rule, and there are many large regional and statewide systems with 10,000 to 15,000 nodes. With networks of this size, the data processing problem transcends the modeling problem. Simplistic techniques are used to keep computer costs at a reasonable level. The result is a sad paradox. The networks are at once too detailed and too coarse. They are too big for sophisticated models and too small to yield numbers related to ground truth. It is this writer's opinion that for analytical purposes these large networks are both inadequate and unnecessary.

Designing Through a Window

In this design process the regional transportation planner typically restricts his focus to a small section of a large network or to a small abstract version of an entire regional network. In the former case, he windows in on a particular subarea (e.g., CBD or corridor) and experiments with alternate link configurations until he is satisfied with performance within the window. In this process, he invariably discovers that, as currently coded, the network within the window is too crudely described to ascertain the causes or problems or to specify realistic, ground-related solutions. On the other hand, nearly all of the network outside of the window has more detail than he needs. He is interested only in the traffic flow through his window of interest. The appropriate volume of traffic will flow through the window if some network detail is maintained near the window, but, because most trips are short, detail can decrease as the distance from the window increases.

Correctly coded, a network yielding reliable results within the window would probably require 800 nodes and could accurately represent an entire detailed network of more than 20,000 nodes. A network as small as 800 nodes is amenable to sophisticated algorithms in lieu of the crude traffic assignment models now used. More important, it can be processed fast enough for a time-shared computer to give real-time response. The planner could modify, add, and delete links in the window and request and receive, in effect, the results of a regional traffic assignment in seconds.

The rub is that, as soon as the planner has finished with one window, he moves on to another, and the 800-node network used for the first window is exactly the wrong one for the second. The solution here is to have the computer perform the appropriate network abstraction automatically, in real time. As the planner moves his window across the region, the computer can "abstract" the large, 20,000-node, detailed network into the 800 nodes for the specific window to be analyzed. An arbitrarily fine level of link detail could be maintained inside the window, and the link aggregation would gradually increase with the distance from the window. Design changes within the window can therefore be made and recorded in as great a detail as desired, but in future analyses that detail will be invoked only when relevant.

This technique allows the network data base to be as detailed and as large as necessary. The planner could, for example, use a census dime-file as a point of departure for analyzing present conditions and planning for the future. For the first time, the regional transportation planner's network description could be a realistic portrayal of what is on the ground. The network can be multimodal. Transit links could include vehicle frequencies, fares, and park-and-ride stations. Highway links could include parking facilities. With an 800-node abstraction of such a network, analytic and algorithmic potentials are immense. The results of using the tailored 800-node network could be both faster and more accurate than the traditional approach using the 20,000-node network.

An automatic, dynamic network abstraction technique is a necessary component of a responsive, on-line, interactive transportation planning design tool. The argument is that 800 nodes are always enough—if they are the right 800 nodes.

Sketch Planning

An important additional use of the network abstraction tool would be the creation of a region-wide abstraction. That is to say, the entire network is squeezed into the window. The detailed network would be aggregated to a uniform level of detail, requiring fewer than 800 nodes. The planner could then do transportation "sketch planning." In this mode, he would be designing with abstract links to ascertain required corridor capacities and first-order level-of-service measures for strategic planning purposes. The ability to abstract existing networks gives him the further ability to compare alternatives with the present net in a direct manner and also would provide him with an appropriate point of departure for the construction of future alternatives. The same capabilities would provide him the ability to aggregate a detailed future design for purposes of comparison and the input to processing routines requiring a small network.

With this size of network and at this level of detail, there probably is a solvable network equilibrium problem—solvable for 2 reasons. First, the network is small enough for a powerful (slow) algorithm to be cost effective. Second, the results would be meaningful. At the detailed ground-truth level, equilibrium in any simplistic mathematical sense is nonsense. Vehicular traffic, like molecular flow, behaves predictably only above a certain level of aggregation. The greater the aggregation is, the greater the likelihood is for a single, steady-state equilibrium solution. The remaining problem is to relate the solution flows on aggregate links to those on detailed links. Research should provide a reasonable means of estimating reasonable detailed link speeds, if not precise volumes.

Disaggregate Models and Monte Carlo Techniques

It has been known since before the first origin-destination survey that most urban travel demand is essentially household based. To forecast it most reasonably is therefore to establish relations of household members, their household characteristics, and the transportation system and, thence, to predict their travel behavior. These household models replicate observed behavior better than traditional aggregate models. They can directly address the distribution of a household's resources among its people and goods. Furthermore, they require less calibration effort than the aggregate statistical models in common use. To date, however, these disaggregate models have not been in wide use. One reason is that the best disaggregate models do not readily yield a total demand forecast in the form that aggregate models typically output. Another is that they require input data in a slightly different form.

Disaggregate models can readily provide not only more accurate but more useful and usable data than their predecessors. For example, a disaggregate household model could be used to perform an origin-destination survey for 1990. Using frequency distributions of the socioeconomic characteristics of each zone, a Monte Carlo technique could generate the "independent" variables of a random household. The model would then fill in the travel behavior data. Computer-built households would be sampled until variability reached an acceptable level. The computer would then factor the 1990 survey on the basis of the observed sampling rates for the many socioeconomic categories implied by the probability distributions. The result of the run would be a data base that could be aggregated and analyzed in many more ways than a simple set of trip tables or link volumes. Realistic scenarios of life in the 1990s could be called up and displayed. To the same degree that a present-day origin-destination survey can describe travel behavior of the present, the computer's sample could be used to describe expected future behavior. To reflect uncertainty, replicated simulations would provide forecasts in the form of probability distributions.

Relatively precise estimates of heretofore difficult variables such as walk time and automobile availability could be inferred easily with such a technique. A rigid analysis zone system is no longer required. There could be as many sets of zones as required to readily describe the study area—income zones, density zones, redevelopment zones. The computer can determine which zones are applicable to a sampled household. Indeed, the concept of the traffic analysis zone as we use it today would be meaningless.

In lieu of reiterating the lengthy detailed Monte Carlo simulation to ascertain appropriate equilibrated times on links, one could use output from an aggregate demand model applied at the regional abstract network level described above. Abstract link volumes could be related to the detailed links composing them to get a reasonable first cut at link speeds, transit vehicle frequencies, and line routings. If the accuracy of the coarse estimate could be assumed adequate (perhaps through iteration), an abstraction of the Monte Carlo simulation network could be compared to the coarse traffic assignment for additional "screenline" factors. Thus, the detailed simulation does not concern itself with detailed equilibrium—that never occurs anyway. It is used to obtain a finer grained demand estimate, ascertain loads on actual facilities, and provide richer data for evaluation.

Demonstration Planning Studies

Much of our ignorance concerning demand for new systems is propagated by the fact that the country's most experienced and knowledgeable professional transportation planners seldom seriously consider innovative transportation modes. This is probably as it should be. Most of these experts are designing real systems for real cities. They avoid high-risk solutions; their clients do not want them. The city's budget and common sense make planning for anything but a proven technology an academic or foolhardy exercise. Couple this with the fact that most problems of a new technology are unknown until a planner actually attempts to design its emplacement in a real city, and one understands why the loudest proponents of new technologies have the least knowledge of the transportation problem, why misinformation and overly optimistic claims are the rule, and why the manufacturers' literature constitutes a shaky base for demand estimation.

How can we get the right people considering new systems? I propose demonstration planning grants. We need these research planning grants as much as hardware demonstration grants. They would fund all or part of a full-fledged technical study that would pretend system X were available. These paper studies would often be dead ends, and none would lead to a traditional capital grant request; but they would be very useful in examining the potential for a new system. These studies would be much more numerous than actual demonstrations. They would act as a sieve to preclude useless, overrisky hardware experiments and would highlight the knowledge gaps to be filled with a promising demonstration.

In addition to being academic, these planning simulations would differ from the usual technical studies in the way they describe new systems. Instead of using estimated cost figures, as in the case of contemporary systems, they would parameterize capital and operating costs. As a study output, each would provide estimates of maximum costs for which the system could be considered viable. These estimates would furnish industry with research and development objectives. Performance characteristics such as maximum headway, minimum average speed, and vehicle and guideway sizes could be handled similarly. Thus, these efforts are more supply-side oriented and "backward seeking" than are typical technical studies.

SUMMARY AND CONCLUSIONS

This paper has argued that ignorance and ineptitude present in most urban travel demand forecasting are greatly accentuated in our attempts to predict the acceptance of new transportation technologies and options. Although the discussion has been restricted to capital-intensive alternatives, the same arguments apply to improvements that have lower emplacement costs. Our ignorance can be reduced by the systematic design and exploitation of attitude and behavior surveys, product laboratories, prototype developments, and urban demonstrations. Our ineptitude can be lessened through access to a national time-shared computer laboratory containing a comprehensive data base and software library.

This ubiquitous laboratory could enable the modeler to exercise the scientific method effectively in his research and development efforts. Its resident, streamlined network algorithms and data management modules would reduce the cost of model development and application and increase the quality of the output by an order of magnitude. Furthermore, the laboratory could host numerous planning activities, including demonstration planning studies, that involve early and serious deliberations on new systems. Such studies would provide test beds for new models, help industry gather useful data on requirements, and greatly increase our knowledge of the expected problems and impacts of new transportation modes.

The above are but a few suggestions offered with the dual hopes of accelerating the slow-motion black art of transportation planning and of raising our understanding of new systems above that of hopeful manufacturers and uninformed dilettantes.