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Volume Author/Editor: H. James Brown, J. Royce Ginn, Franklin J. James, John F. Kain, and Mahlon R. Straszheim

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Chapter Author: H. James Brown, J. Royce Ginn, Franklin J. James

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Land-Use Modeling: Current Problems and Future Directions

THIS CHAPTER ATTEMPTS to identify and evaluate some of the major problems common to land-use modeling efforts. While the discussion relies heavily on the survey of land-use models for Atlanta, Southeastern Wisconsin, Detroit, Puget Sound, and the San Francisco-Oakland Bay Area presented earlier, it also draws on the study group's experience with land-use modeling in other metropolitan areas. In addition to the five areas mentioned, members of this study group have in-depth knowledge of land-use modeling activities in Chicago, Pittsburgh, Boston, and Philadelphia (Penn-Jersey); in London and Tyneside, England; Melbourne, Brisbane, Perth, and Adelaide, Australia; and in Tel Aviv and Haifa, Israel.

The following critique of land-use modeling divides logically into two parts. The first is concerned with technical and methodological problems; the second, with the difficulties of organizing research and building models for transportation planning.

TECHNICAL AND METHODOLOGICAL PROBLEMS

The earliest land-use models, such as those developed for the Detroit (1952) and Chicago (1956) transportation studies, used physical measures of land use—acres of land by type and square feet of building area. Recent studies, such as those surveyed for this study, are far more behavioral. They analyze and forecast employment and population levels. This is a major improvement. Still, the analysis is hampered by the virtual absence of data describing changes in metropolitan development at a useful level of disaggregation—by type of household, type of employment, or by location. In particular, insufficient effort has been made to model the underlying reasons for locational decisions by households and firms. Existing models would be better able to explain the changing pattern of urban growth if they paid more attention to these determinants.

It can be argued that there are important differences between structural models (those built to help us understand the processes of urban development) and forecasting models (those built to predict future development). Forecasting models, such as those described in this paper, may be adequate for many purposes as long as their predictions are accurate, even if they do not explain observed behavioral patterns. They are adequate, however, only so long as there are no major structural changes, for example, changes in zoning or the transportation network. In short, predictions made from mechanistic forecasting models might be able to reproduce the present locational patterns but still be incapable of predicting changes in location in a changing environment. Ultimately, the best forecasting model would be one that had a well-articulated behavioral or causal structure. But no truly satisfactory structural model of urban development has been developed as yet. Therefore, the case can still be made that a good forecasting model will provide better predictions than a poor structural model.

Cross-Sectional Bias

Any realistic lag structure designed to represent decisions as to land use or location almost surely spans many time periods. Physical investments in buildings, streets, sewers, and other urban structures are highly durable and, in general, are modified or abandoned slowly over time. Accordingly, the usual practice of estimating the factors influencing locational choice from a single cross section of data can result in substantial bias. Parameters developed from such cross-sectional studies can reproduce the existing location pattern, but are rarely suitable for modeling changes in land-use patterns over time.

In short, the existing land-use pattern is the result of decisions made over a considerable period and under varying historical conditions. The considerations affecting recent location decisions were probably different, or at least valued differently, from those that were important in earlier periods. Technological change is a major reason for the difference. For example, in the early 1900s most goods-producing industries receiving raw materials and other inputs from outside the urban area and shipping finished products to other areas would undoubtedly have located on a rail siding. Today many firms find truck transportation preferable and therefore are no longer as limited in their locational choices. Nonetheless, large numbers of such firms are located on rail sidings for historical reasons, and analysis of cross-section data may give this factor (accessibility to rail services) far more importance than it currently deserves.

Similar biases may result from technological changes within an industry. Changes in production, materials handling, and relative factor prices strongly favor single-level layouts for most manufacturing and wholesaling activities. These more spacious layouts require far more land space, and parking lots for employees' cars increase space requirements still more. Again, parameters estimated from cross-section samples tend to be averages of current and historical effects of land-space requirements, with the historical often predominating. Central cities contain few vacant sites large enough for modern plants, and the difficulties and cost of assembling sites all but prohibit the construction of new production facilities there. Still, central cities contain many industrial plants, and these dominate the cross-section analyses.

In general, the parameters derived from cross-section analysis will tend to produce forecasts that are more attuned to existing patterns than future ones. This results in assigning too large a portion of new activities to built-up areas and too small a portion to new or developing sectors of the urban area.[1] Existing activities tend to be returned to their present location despite real-world forces encouraging them to seek relocation. This predicted behavior is contradicted by time series data, which indicate that most new manufacturing plants are being built in suburban areas and existing firms are moving to new locations. Total employment at the original location may decline only slightly, remain stable, or even increase somewhat as a result of different activities moving into vacated space; however, the characteristics of the new employees may be considerably different from those of the old employees. To be roughly right in the aggregate may be insufficient for policy planners, who often need to understand the changes in composition and their causes.

To make accurate forecasts of locational decisions, it is necessary to

[1] For a further discussion of employment forecasting from cross-section data and a detailed critique of the Delaware Valley Planning employment allocation models (successor to Penn-Jersey), see John F. Kain, "The Location and Movement of Jobs and Industry," in *The Metropolitan Enigma: Inquiries into the Nature and Dimensions of America's "Urban Crisis,"* Cambridge, 1968.

understand the influence of various zonal characteristics that determine such changes over time. The use of time series data and changes in industry location may give parameter estimates that more adequately capture intertemporal changes in locational determinants. Backcasting (using the model to estimate location patterns in an earlier period), even at a more aggregate level, could provide a crude check on the stability of the parameters estimated from a single cross section and provide some indication of whether land-use determinants have changed. Where time series data have not been developed, which is all too commonly the case, models should be tested for their sensitivity to changes in the estimated cross-section parameters.

Interdependencies and Their Sequential Representation

Because urban systems are extremely complex, many variables and innumerable behavioral interrelationships and interdependencies seem relevant to land-use models. The first problem of modeling is to decide which of these relationships are important. To make this determination, we need to know a great deal more about the forces underlying urban development. And in order to formulate the interrelationships in sequential order, a substantial amount of experimentation and testing of hypotheses must be carried out. This implies extensive new research and increased communication between researchers and modelers.

After the important interrelationships have been specified, they must be incorporated into a model. The problem of conceptualizing and empirically estimating the interrelationships are greatly simplified if a sequential or recursive model structure is employed. Locational decisions are therefore represented, in most models, as sequential rather than simultaneous. Occasionally, an approximately simultaneous result is obtained by iterating a sequential set of relations.

In one of the models reviewed, for example, a family first decides on the type of housing it desires and then examines locations that offer this type of housing. It is clear that the real decision process is not so easily separated. If less attractive housing is available in a more desirable location, the decision might be made in the reverse order: location first, housing type second.

The order of the decisions can affect the characteristics of forecasts from the models. If the location preference is addressed first, the model would tend to forecast higher and higher densities (unless density constraints are used in the model), while the reverse ordering (housing type first) would tend to forecast lower densities.

The point of the above example is not to question the usefulness of the sequential technique or to suggest that reverse ordering of the decisions would produce a superior approximation. The point is, rather, that the representation of simultaneous or highly interdependent phenomena (such as housing type and location) is a necessary part of modeling and that it is a very sensitive and difficult problem. To a large extent, good modeling hinges on the ability to identify and represent such subtleties.

Industrial Location

All models surveyed recognize the critical importance of industrial location in determining metropolitan spatial structure and the location of households. Yet land-use modelers have devoted surprisingly little effort to analyzing the determinants of industrial location. It is actually only a slight exaggeration to claim that most existing land-use models are no more than models of residential location or population distribution. The location of basic industrial employment (as contrasted with retailing and service employment) is often determined ad hoc or simply based on the hopes and aspirations of the planners. Only a few planning efforts have made serious attempts to model the determinants of basic industrial location choices. For the most part these attempts have been quite limited and crude, particularly in behavioral content. Even worse from the standpoint of objectivity or scientific progress, analysts are often placed under great pressure to produce land-use–transportation studies that present projections favorable to the area or to some particular sector of the study area. This is seen most clearly in some employment projections for the CBDs of central cities. Organized groups, such as CBD associations, and political leaders are often concerned about the psychological effects of adverse projections. They can sometimes succeed in forcing study staffs to develop optimistic projections for certain sectors, against the staff's better judgment. Projection "errors" of this kind can cause large errors in capital investment choices in transportation. Consequently, there is much to be said for insulating the modeling and forecasting efforts from pressure groups.

Housing Stock Adjustments and Changes in the Character of Residential Areas

Most of the residential location–land-use models developed to date can be characterized as metropolitan growth or extension models. They have been primarily concerned with forecasting the extent and location of new peripheral development. Changes in built-up areas have been virtually ignored and there have been almost no attempts to systematically study or model the adjustment processes by which the stock of residential structures is adapted to new uses over time. Existing models have concentrated on explaining or projecting the determinants of housing demand and thereby have slighted the determinants of supply[2] and the effects of changes in demand on the housing stock and the character of areas.[3] Yet these adjustment processes are central to any analysis of housing markets.

New construction accounts for only a fraction of the housing supply during any time period and is sharply limited in its location. The relatively small body of research that exists on housing stock adaptation[4] is evidently not well known to those building land-use–transportation models and is not easily incorporated into existing models. Yet the changing of neighborhoods, especially in the central city, has a dramatic effect on several urban problems.

Housing Segregation: The Race Issue

Though its impact is not adequately understood, housing market discrimination has a substantial effect on metropolitan development. The residential location choices and travel patterns of nonwhites are dominated by segregation and seem to be markedly different from those of whites. Housing market discrimination affects housing prices and the attractiveness of various locations and thereby influences the residential location decisions and travel patterns of whites. Yet most land-use–transportation models fail to recognize race or the profound effects of discrimination.

One consequence of housing market discrimination is to make suburban jobs less accessible to Negroes segregated in central cities. In recent years there have been numerous proposals to improve access between the ghetto and suburban employment locations. The Department of Housing and Urban Development (HUD) and the Depart-

[2] The Southeastern Wisconsin model does try to simulate the supply of new housing by reflecting the independent decisions made by developers. The possible conversion of the existing housing stock was not addressed.

[3] One of the models did introduce a simple process for residential "filtering."

[4] Examples of investigations include Ira Lowry's formulation in "Filtering and Housing Standards: A Conceptual Analysis" in *Land Economics,* 36, No. 4, November 1960, using the economic investment approach; W. Grigsby's *Housing Markets and Public Policy,* Philadelphia, 1963; and W. Smith, *Filtering and Neighborhood Change,* Berkeley, 1964.

ment of Transportation (DOT) have several demonstration projects under way or in the planning stage. Although it has been hypothesized that the transportation gap between central city ghettos and suburban jobs is partially responsible for high Negro unemployment rates, these issues have not been considered in existing land-use–transportation studies.

Modeling Focus

The most useful models have been those built to answer particular questions. A model's form, the variables considered, and the time intervals used all depend heavily on the questions being asked. Thus far, there is no such thing as an all-purpose model to answer all questions about urban growth and development. Planners and modelers must therefore agree on what questions should be dealt with.

For instance, planners and model builders must determine whether a specific model should be directed toward defining future conditions or toward understanding the transition from a current to a future condition. The two objectives may require different model structures and certainly use different time intervals to forecast the spatial distribution of activity. Traditionally, transportation planners have been concerned primarily with designing an "optimal transport system for the future." The models then were developed to forecast future land use in some target year with no regard for the pattern developing in the intervening years or the effect of transportation investment decisions on this development. Similarly, there has been little or no attention paid to the adequacy of the transportation system in the intervening years, or to the best phasing of transport investments.

Testing the Models

Another issue is the extent to which transportation planners have accepted the land-use forecasts as accurate and error-free. Because of the models' admitted shortcomings, it is most important that tests be made of the sensitivity of the results to different control totals and parameter estimates. Both trip forecasts and land-use forecasts should be tested in this manner.

No one will ever invent a method for making perfect forecasts of regional employment and population. Thus the standard question "How much error is acceptable?" can be answered only in terms of how much of the model's projection of land use is affected by changes in inputs and whether planners consider the resulting variance in the land-use projections as acceptable. Furthermore, sensitivity tests for changes in the level of parameters or changes in the form of equations would provide valuable insights into the model's robustness.

Continuous study and planning at the local level facilitates the process of testing and updating. One might expect that time series data, so desperately needed for urban studies, would be developed from such efforts. This ongoing process of analysis should identify presently unrecognized trends and relationships. As the models are modified on the basis of new data, their forecasting accuracy and structural content should increase. Only in this way—continually testing against new data, respecification, and reestimation—will truly useful models be developed.

PROBLEMS IN ORGANIZATION, PLANNING, AND THE STATE OF THE ART OF MODELING

Organizational Problems Affecting Modeling

The quality and relevance of land-use modeling in transportation planning crucially depend on the competence of the professional staff and the organization of the research and planning activities. Local planning agencies have increasingly employed transportation and planning consultants to develop their land-use models and transportation plans. Over the years several of these firms have acquired a great deal of experience and developed skilled transportation planning teams. A few very large consulting firms have experts in most of the problem areas associated with transportation and land-use planning, but in most cases the needed skills and knowledge are widely scattered. Consultants tend to specialize in certain parts of the overall problem. Therefore, a decision to hire consultants to construct a land-use model often implies a decision to fragment the modeling effort by giving it to several different consultants.

Currently, modeling is much more a problem of design than of production. It relies heavily on trial and error. As new ways of specifying the interrelationships are developed, the design of the overall model is modified and remodified. The model structure tends to be continually redefined and efforts are constantly redirected toward newly discovered critical areas. For the model to be effective, however, the various submodels must be internally consistent and the final model must be an appropriate "aggregation" of the different individual efforts. This implies extensive interaction among developers of the individual submodels or components. When a modeling effort is fragmented among several consultants, this is exceedingly difficult to achieve, and it is often necessary to force the several submodels together in a highly unsatisfactory manner.

Some local agencies try to solve the problem of model coordination by contracting the entire modeling effort to a single consultant. Thus, the problem of articulating the several components of the model is solved, but planning agencies using this approach are likely to end up with a model that is a complete mystery to them. Consequently, the local planning agency will generally be unable to modify the model to reflect new information. It will be even less able to alter the structure of the model or the techniques used in its construction. As parts of continuing studies, such models are likely to be useful only for the initial forecasts. For future planning or altering existing plans, the planning agency will either have to return to the consultant who developed the model originally, develop its own models, or simply make do without modeling assistance.

Furthermore, when models are developed completely by consultants, the local agency misses the improved understanding that comes from having to carefully specify, examine, and evaluate the important forces behind urban development. It is indeed a significant loss, since one of the greatest benefits obtained from the construction of land-use models is the understanding or learning from experience gained by the builders in the process of actually constructing the model.

In short, there are strong arguments for having the local planning group develop the models. In order to build such a model local planners would be forced to examine the structure of their community and seek to identify and quantify the forces affecting their area. The experience and insight gained by this exercise would be immensely valuable to any continuing planning program. Having local planners do the modeling would also increase the likelihood that variables and emphasis, particularly important to the specific area, would be introduced into the models. It is possible that the resulting models might be less sophisticated than those developed by consultants; however, the involvement and experience gained by the local group could far outweigh the disadvantages of not having a more sophisticated or innovative model. Of course, in building the model, the local planning staff might well draw on the special skills of consultants and thus take advantage of the best current techniques. The difficulty with the present practice is that consultants all too often replace local planning agencies rather than assist them in planning. Of course, a decision to build models locally may also imply that planning staffs must be upgraded in technical and quantitative skills.

At present, in most local planning programs a rather confused and uneasy combination of goals can be identified. Local areas want models useful for their planning programs. The better consultants, on the other hand, are chiefly interested in advancing the state of the art, and therefore may view the local planning studies principally as an opportunity to accomplish their research. Within the present institutional framework, the goals of planning and research are often competitive rather than complementary.

Ideally, research and development should be continued, but not as part of planning studies. Researchers might have more success in increasing the body of knowledge about the processes of urban development if they were relieved of the severe deadline pressures of particular planning programs. Besides, if the two goals were further separated, models more appropriate to local planning purposes might be developed and a better and more lasting relationship between researchers and planners achieved.

Documentation

Evaluation of the land-use models developed for public agencies is made extremely difficult by their limited documentation. None of the studies considered in this survey provided sufficient information about the structure, weaknesses and shortcomings, or predictive ability of their models to permit a comprehensive review or evaluation. This is true not only of the widely distributed final reports but also of the supposedly more detailed technical papers and memoranda. The study group encountered large and critical gaps in the descriptions of the models. Only extensive follow-up and discussions with the planning staffs (who, however, gave generously of their time in these efforts) made it possible to make any headway in filling these gaps.

The extraordinary amount of time and effort necessary to interpret, define, and understand current work in land-use modeling makes any substantial interchange of ideas between workers in this field very difficult. Advances as well as mistakes are lost in present documentation. Conversely, some failures result in such bad publicity that a basically sound approach is abandoned. Clearly, improved communication and documentation are prerequisites for accelerating advances in modeling efforts.

It is not hard to explain why there is such a serious lack of adequate documentation. The modelers are faced with an extremely difficult assignment and are under strong pressures to get results. Under these conditions it would be surprising if they allocated much of their limited budgets and resources to the time-consuming job of carefully documenting all their efforts. In addition, many model builders, wishing to give the best possible impression of their work, gloss over the problems and present their effort as a polished and perfected product. This "sales requirement" leads to a different presentation than that required for the systematic and efficient long-run development of the basic techniques. The problem arises both from the difficulty of evaluating the quality of work in an area of this kind and the general lack of technical competence of clients. Many model builders obviously feel that if they honestly explain the problems and limitations of their necessarily primitive and incomplete models, the clients will fail to appreciate the models' usefulness or will hire consultants who promise more.

To be of real value in advancing the state of the art, a report on a specific model must present considerable detail and clearly identify weaknesses and shortcomings as well as strengths. The models' problems should be pointed out in the reports, and methods used by the model builders to handle these problems should be extensively discussed. In most cases, the really tough problem areas are common to all these efforts; progress in handling them will require a great deal of communication among model builders.

The use of profit-making consultants introduces additional problems of communicating research findings and empirical methods. There are good reasons why profit-making consultants cannot be expected to improve the documentation process. Many regard their modeling expertise as privileged and feel that disclosing such information could affect their competitive position. One consultant said that his reports had been intentionally written in an obscure manner. He explained that his company had been working some twenty years to develop its approach and he saw no reason to release such information. He did not see his firm as having any responsibilities for educating others in the development and use of land-use models.

Other consultants view documentation as a way of advertising their abilities and seem quite willing to include extensive explanations of modeling innovations. Unfortunately, their audience often neither requires nor desires the details considered necessary by other researchers. The step-by-step procedures and the results of each calibration effort are expensive to document and produce little in the way of advertising returns. It is also true that failures are commonly omitted and modest successes presented in the most favorable light.

Neither of the above situations questions the honesty or integrity of the consultant. Rather, the comments reflect the need for an incentive structure that encourages adequate documentation and its widespread distribution. To a limited extent, professional associations and agencies such as the Highway Research Board disseminate research findings and information on innovations in model building. However, such outlets are inadequate. The type of documentation required is usually too bulky to be accepted for publication or public presentation by such organizations. Only the more important and successful innovations are ever presented at meetings or in the journals. Even then, the paper or article is more likely to be couched in theoretical terms, with only summary attempts at practical application or specific testing. And since no honor is attached to reporting a failure, honest but doomed attempts are repeated again and again, often at considerable expense.

To offset some of these problems, sponsoring agencies commonly dispatch representatives for periodic monitoring. This has tended to produce documentation suitable only to the scope of the monitoring agency's interests. Usually, funding agencies are more interested in successfully completing the contract than in disseminating information; hence, the reports are often of limited use in advancing the state of the art.

One possible solution might be to employ "reporters" to follow and thoroughly document each study. This could be done by transportation consultants, university faculty, or similarly qualified persons. It should be emphasized that their function and responsibility would not be research, but carefully detailed reporting and documentation of methods and important innovations. They would be responsible for reviewing all documents, published and unpublished, produced by the study staff and for obtaining clarification of poorly documented material. Continuity is of the utmost importance in this function. Ideally, these reporters would be assigned to particular studies from conception to completion. Federally financed planning groups would be required to cooperate fully with the reporters and to make copies of all internal and external documents available to them.

A major difficulty of this reportorial approach, however, is that it would underutilize the knowledge and skills of the analysts actually engaged in research. The analyst is the one most capable of documenting his work and providing detailed discussions of methodology and empirical findings. What is needed are incentives to insure that analysts and study staffs give adequate attention to documentation. It might be argued that this could be accomplished by including funds for better documentation in the budgets of study agencies. This incentive already exists to some degree, although it does not seem to have been very successful. The study staffs tend to use the additional funds for further analysis and research, and continue to skimp on documentation. The difficulty is that documentation and adequately written presentations on the methodology and findings take more effort and are less satisfying than actual analysis. Incentives for complete documentation simply do not exist.

Another possible solution is to have an outside agency act as a research monitor. Under this approach, the funding federal agencies might make an appropriate nonprofit organization, such as the Urban Institute, responsible for documentation. The local planning groups would be required to document all their modeling and submit the information to the monitoring agency. This agency (e.g., the Institute) would judge whether the documentation is adequate. Should the monitoring agency consider it inadequate, it would be empowered to require the local planning group to provide further information.

An arrangement of this kind might considerably improve the quality of documentation. Furthermore, with the collection centralized in one agency, one would expect more of a systematic review and a more efficient distribution of reports.

The most obvious difficulty with this suggestion is that to be successful the operation depends largely on a working relationship between local planning groups and the research monitor. The extent to which the monitor is taken seriously by the planning groups depends, in part, on the lead taken by the federal government. The funding agency must recognize the importance of documentation and make its concern clear to the local groups.

The responsibilities of the monitoring organization must be clearly defined. The monitor, for instance, should not see its role as evaluating the researchers' efforts, nor should the researchers feel that the monitor is evaluating them.

Basic Research

Many of the problems described above result from uncertainties about how to structure land-use modeling, and from a general lack of knowledge about the behavioral determinants and processes of metropolitan development. A good deal of basic research is needed to determine the relevant variables and important relationships.

The present stage of development in land-use modeling and the relatively limited emphasis on basic research reflect the incentive structure implicit in federal grants-in-aid programs for land-use and transportation planning. These incentives encourage particular cities and their consultants to analyze exhaustively their own problems. The state of the art has been advanced slowly through these ongoing planning efforts, as permitted by budgets and the competence of consultants. In fact, with the present incentive structure, it is remarkable that so much progress has occurred. Research and modeling have been, to a considerable extent, "bootleg efforts," continually forced to justify their role within the planning effort. Because of the pressures of the planning process, research has necessarily been slighted.

Experimentation and real research is accompanied by high risks. It is difficult to expect planning agencies or consultants to undertake these risks in view of the rather specific requirements to produce an operational model or a forecast within a limited time period. Still, only through progress in basic research can progress in transportation modeling and planning be expected.

TOTAL COST AND ALLOCATION OF STUDY BUDGETS

Comprehensive urban transportation studies vary greatly in terms of total costs. The costs depend primarily on the size of the metropolitan area and the complexity of the study design. Costs tend to go up as study designs become more comprehensive and sophisticated. The trend toward larger study budgets was accentuated in 1961, when legislation was amended to make Housing and Home Finance (HUD) "701" funds available for transportation planning. The "701" funds could be used for somewhat broader purposes than the "1½ per cent" highway funds, which had been the principal source of financing for "comprehensive" urban transportation studies before 1961. The "701" funds, in particular, permitted a substantial expansion in the collection of land-use statistics and in the scope of land-use modeling.

While precise cost data are not available because of many difficult problems of imputation and consistency of definition, the six studies considered in this survey ranged in cost between an estimated $1.77 million (Puget Sound) and $5.54 million (Bay Area Transportation

Study). Most available cost estimates for "comprehensive" transportation studies must be regarded as lower-bound estimates representing forecast budgets rather than actual expenditures. Invariably, the costs of these studies exceed their estimates by a large margin. For example, the original cost projection for the Penn-Jersey study was $2.45 million; more recently Zettle and Carll placed the costs of this study at $4.5 million.[5] The higher figure is still only an estimate since the study is not completed—there will probably be further cost increases before it is finished.

Comprehensive metropolitan transportation studies are costly undertakings. The "expenses" can be seen in a more reasonable perspective by recognizing that the $2 million to $6 million cost of a major transportation study is about equivalent to the cost of one mile of a centrally located freeway.

The high costs of metropolitan transportation studies can be attributed primarily to the large-scale surveys used to obtain travel data. For example, the *Prospectus* of the Penn-Jersey Transportation Study,[6] one of the most detailed presentations of study costs available, provides $610,000 for home interviews alone. Projected data collection costs for Penn-Jersey rise to just under $1 million when the truck-taxi, roadside-survey, and screen-line counts are added. This budget does not include anything for key punching, tabulating, or processing the hundreds of thousands of trip records obtained from the surveys. The estimated costs of these data preparation and processing operations amount to nearly another one-half million dollars. Up-to-date budgets on actual expenditures for the Penn-Jersey study have not been published. However, $2 million is probably not a bad estimate of the actual total cost of collecting and processing the trip data. These $2 million include no funds to develop behavioral models for explaining present and forecasting future traffic, and no funds for collecting and processing land-use data. They cover only the collection, preparation, and initial processing of trip data. Furthermore, the Penn-Jersey expenditures appear to have been exceeded by the Bay Area Transportation Study (BATS). The BATS report of actual outlays, as of December 31, 1968, estimated total expenditures for its home interview survey at $1,609,023 (including data preparation and basic data

[5] Richard M. Zettle and Richard R. Carll, "Summary Review of Major Metropolitan Area Transportation Studies in the United States," Berkeley, November 1962.

[6] Philadelphia, December 11, 1959, pp. 19–21.

reduction). An additional $478,528 was spent for roadside interviews, and $82,664 was spent on a truck-taxi survey.

In comparison to the sums allocated to the collection and basic processing of trip data, the budgets of these "comprehensive" urban transportation studies for developing land-use models and forecasts are inadequate. The Penn-Jersey *Prospectus* allocates only $8,000 to studies of employment patterns and trends by industry and area, and $16,000 to analyses of industry location factors. These analyses were to be based on a program of land-use data collection estimated at $50,000. Again, actual expenditures may have been considerably larger than those budgeted. Nevertheless, if changes in land use are as crucial to transportation planning as our previous arguments suggest, study allocations for the development of land-use models appear seriously inadequate.

It should be noted, however, that the Penn-Jersey transportation study devoted far greater resources (both absolutely and relative to its total budget) to collecting land-use data and developing land-use models than any of the earlier studies and all but a few of the more recent ones. Thus, the pattern of expenditures of most other "comprehensive" urban transportation studies is even less advantageous to analytical efforts than that of the Penn-Jersey study.

Specifically, the experience of the major studies considered in this survey does not appear to depart markedly from that described for Penn-Jersey. Less detailed budget data were available for these five studies, but a crude breakdown of expenditures for them is presented in Table 8. The percentages should be thought of only as reasonable approximations. Even so, the data support a rather consistent expenditure pattern, which is quite similar to the one found by Zettle and Carll in a survey of metropolitan transportation studies.[7] While the fractions may not be precise, the heavy allocations for data collection and basic processing dominate the study budgets.

Estimates of the direct costs of land-use modeling were available for some of the studies. Southeastern Wisconsin spent about $125,000 (6.2 per cent of total), and the Bay Area (BATS) about $228,000 (4.7 per cent of total). These cost estimates exclude data collection and only represent expenditures for the design and calibration of the models. (Southeastern Wisconsin has undertaken further model designs since preparation of this report; those expenditures are not included in the above total.)

[7] Zettle and Carll, "Summary Review," 1962.

Table 8
Transportation Study Budget

Atlanta Study (1961–68)	
Total budget[a]	$1.75 million
Data collection and processing	36%
Analysis and models	24%
Planning functions	34%
Miscellaneous projects	6%
Southeastern Wisconsin Study (1963–66)	
Total budget[a]	$1.99 million
Data collection and processing	62%
Analysis and models	14%
Planning functions	16%
Miscellaneous projects	8%
Bay Area Transportation Study (1968 on)	
Total budget	$5.54 million
Data collection and processing	60%
Analysis and models	18%
Planning functions	14%
Miscellaneous projects	8%
Detroit TALUS (1968 on)	
Total budget	$4.70 million
Data collection and processing	46%
Analysis and models	19%
Planning functions	20%
Miscellaneous projects	15%
Puget Sound Transportation Study (1960 on)	
Total budget[a,b]	$1.77 million

NOTE: These budgets and their breakdowns are approximate. Percentages shown, while based on actual budgets, are judgmentally derived because of classification problems.

[a] This total is an estimate of the entire project which was completed before January 1, 1969.

[b] Further breakdown is not available.

The estimated total study costs shown in Table 8 must be regarded with a certain caution and the percentages must be approached with even greater reserve.

But even if there are errors in the estimated costs presented in the table, it is obvious that the dominant cost in these studies has been that of gathering and reducing original data. Earlier (i.e., pre-1960) studies allocated, on the average, about two-thirds of their budgets for this function. With the availability of "701" funds, the growing recognition of the importance of land-use modeling, and the establishment of continuing planning agencies, this proportion has been reduced to approximately one-half.