Urban Transportation Planning System: Philosophy and Function

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This paper describes the philosophy behind and the functional requirements of a computer-based system for urban transportation planning. It begins with a view of the current transportation problem and the resulting new demands on the planner. After outlining a planning framework composed of three analytical activities, long-range planning, short-range planning, and system surveillance, it outlines the functions of a software system, the Urban Transportation Planning System, that would effectively support the transportation planner of today. Such a system is presently under development at the Urban Mass Transportation Administration.

Sometime in the 1950s a certain Hudson Valley transportation planner, a direct descendant and namesake of Rip Van Winkle, dozed off over his drawing board to sleep for the traditional 20 years. While this latter-day Van Winkle dreamed his unimodal dreams, undisturbed by social and environmental nightmares and unaware of energy crises, his more lively colleagues slaved away.

On awakening in the 1970s, he sleepily looked out of his office window and immediately perceived the apparent ineptitude of his old colleagues. It was obvious that while Van Winkle had slept, Americans had invested trillions of dollars in automobiles, roads, parking facilities, traffic signals, policemen, traffic courts, hospitals, insurance companies, tire factories, oil industries, drive-ins, and billboards—all in deference to the private automobile and highway system. Yet in spite of this enormous capital expenditure, congestion still paralyzed the cities, which smelled awful and looked worse than they had 20 years before.

Coming to their own defense, his fellow planners argued that they should not be faulted for the current state of affairs. They had been misguided in their ignorance of the issues. No one had urged them to consider costs and benefits except those who had supported the popular demands for more cars and more roads. They had lacked both the technical and fiscal wherewithal to plan, much less to build, for anything but the automobile.

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It was not until the 1960s that the planners had admitted that urban man does not move by car alone and that transit is also necessary. Like an aged football player abruptly recalled from retirement to substitute for the limping superstar, public transportation was dusted off, given an aspirin, and sent into the dying seconds of the game. Renamed mass transportation (perhaps to connote the movement of slugs rather than people), it was ordered to reduce congestion so that automobiles might go faster. With less than 1 percent of the capital budget spent on the automobile and highway system, it was asked to solve the problems of the automobile as well as those that the automobile had caused. And to make matters worse, it was given no federal subsidy for operation.

After Van Winkle rubbed the sleep from his eyes, he dutifully examined the records for the 20 years of his nap. Something of a student of human nature and of history, and now with the freshest mind in the business, he was neither surprised nor alarmed by the misconceptions or the misdirections. He regretted the waste of time, money, and talent, but he understood it in terms of the political economy and was not disposed to judge it harshly.

Van Winkle was most disappointed to see that the present planning procedures differed so little from those he had been using when he dozed off. He saw that the technical expertise needed to solve problems (problems unknown in the 1950s) had increased by an order of magnitude. It was immediately clear to him that he would need new methods to deal with ideas that he had never heard of priority lanes, congestion pricing, dial-a-ride, personal rapid transit, environmental impact statements, energy conservation, quality of life, Urban Mass Transportation Administration (UMTA) capital grants, and others. The problems were new and the ground rules for their solutions had changed, but Rip saw that the present-day tool kits held the same tools that had rusted to pieces in his battered old box as he slept.

We must now let our brave old friend, and our newly awakened planner, go back to work. We should acknowledge our debt to Van Winkle's perspective as we begin to describe the current concerns and goals of UMTA. That historical perspective is very important to us, as UMTA research and development begin to reflect the recent federal awareness of the very different planning problems of a new era with new complexities.

LESSONS LEARNED

Certainly there are four lessons that Van Winkle's experience teaches us, and we must learn them with him if future transportation planning is to be successful and save our urban transportation systems from inexorable decay.

The first lesson is that the transportation problem can be solved only at the local level. It is apparent that the problem was made worse by the federal tilt toward highways during the last 20 years and by federal policies that earmark funds for specific modes, regardless of local needs and desires, which aggravates rather than ameliorates the situation. Any effective solution will probably require a better use of the automobile as well as vastly improved public transportation.

The second lesson is that we must make better use of the transportation resources that we have and not automatically assume, in response to a problem, that what we need is more. Our superb highway system is 50 percent underused about 90 percent of the time. Too often roads are conceived of as providing for the movement of cars and trucks, rather than of people and goods, while in fact at certain times it is advantageous to ban cars and trucks from some segments of the road system. Public transportation passengers, pedestrians, and cyclists should receive much higher priority in the planner's mind and on the city's streets.

The third lesson is that urban transportation planning, implementation, and operation must be coordinated without an artificial administrative and jurisdictional partitioning of functions and responsibilities. Planners must guide builders. Operators must trust planners. Planners must be informed by builders and operators. In the past, these people scarcely knew one another, but today they must work together.

The fourth lesson is that the planner must consider a much larger set of options and issues. He must look for more and better transportation alternatives. The evaluations of these alternatives will, in large measure, be based on nontransportation issues. Not only are the problems of today more acute, but also the constraints on feasible solutions are tighter. More technical expertise is required.

Today, the planner must plan a system, not merely design appendages to growing freeways. He now must justify his recommendations with lengthy alternative analyses and examine vastly different and sometimes radical proposals. He must describe and defend the numerous potential impacts of a proposed plan to impatient politicians, a vociferous press, and a suspicious public whose questions are selfish, diverse, and microscopic. A decision to build will never again be based on a simplistic travel time measure. Many other criteria, often conflicting, must be addressed.

NEEDED: IMPROVED PLANNING TOOLS

Since Van Winkle refuses to give up despite the staggering problems of urban transportation, the least we can do is help him to replace his rusty tools. And as we awaken with him into a new era of transportation planning, his clear view of the stunning differences between the 1950s and the 1970s can help us decide what kinds of tools are needed.

The traditional planning techniques now in common use are slow and costly: slow because they use a hunt-and-peck system to find a good plan, and costly because of long turnaround times and high data costs. Their most serious weakness is their inability to evaluate multimodal planning alternatives accurately and responsively. At best, they plan effectively for one mode, the private automobile.

Local planners are keenly aware of these shortcomings. They must respond quickly to local policy questions. Despite their inadequate resources, they must proceed and plan with what they have. Piecemeal efforts of local planning agencies to improve tools often cost more than their marginal success is worth. The federal government's research and development of improved planning techniques will be especially valuable and welcome at the local level.

UMTA RESPONSES AND PLANNING PHILOSOPHY

For as many years as there have been large computers available, state and local agencies have used them for planning. UMTA research and development can help local planners best by packaging for their use the best research and development products in computer software. In this way UMTA can require local planning to improve and can provide the technical and fiscal support for that improvement.

Accordingly, in 1972, the UMTA Office of Research and Development began a program to

1. Research and develop improved planning techniques,
2. Implement these techniques in generalized computer software,
3. Pilot test software in urban areas to ensure its appropriateness and demonstrate its utility,
4. Distribute the software to local planners, and
5. Provide technical backup by training users and responding to queries from the field.

The result of this program will be the Urban Transportation Planning System (UTPS). UTPS is a package of computer programs for site-specific planning of multimodal transportation systems. The package is evolutionary and is being constantly enlarged and updated. Its ultimate goal is a streamlined, easy-to-use set of modular tools applicable to several planning activities.

Two considerations affect the design of UTPS. First, variations in local issues and resources create many different planning situations, and no one model fits them all. Second, to be easy to use and yet adequately sophisticated, the technical complexity must in large measure be invisible to the user.

To accommodate the variety of planning situations, UTPS distinguishes three overlapping, sequential, and iterative planning activities: long-range planning, short-range planning, and system surveillance (as shown in Figure 1). The first provides a context for the second; the second precedes implementation; and the third monitors performance to feed information back to the first two. Each is discussed below.

Long-Range Planning

There are two types of long-range planning. One searches for a strategy and the other articulates in some detail a design within a selected strategy. These are called strategic (or sketch) planning and tactical planning (Figure 2). Both involve both manual and computerized processes. Where computerized, each entails the design, coding (for computer consumption), evaluation, debugging, and improvement of a transportation system concept (Figure 3).

Sketch planning is the preliminary screening of possible multimodal configurations or concepts with varying assumptions as to alternative futures. It is an aggregate, multivariate system evaluator and comparer. It is especially necessary for long-range regional planning (10 to 20 years), and at minimum data costs gives preliminary estimates of the capital and operating costs, patronage, wide corridor-traffic flows (by mode), service levels, and land development implications of possible multimodal networks. It also estimates such factors as energy consumption and air pollution. It compares all these data with those available about other networks and provides the information needed for broad policy decisions.

The demands on such a strategic model for long-range planning are challenging. First, it must make it very easy and fast to evaluate credibly an alternative strategy. The far future options are limitless, scores of them must be considered, and thus each must be done quickly. Second, the model must be able to simulate the performance of modes that are as yet unspecified. Third, it must deal explicitly with uncertainty. Two of the most difficult uncertainties are those associated with socio-economic and land developments, and those associated with the costs and performances of new transportation technologies.

Figure 1. Planning process.

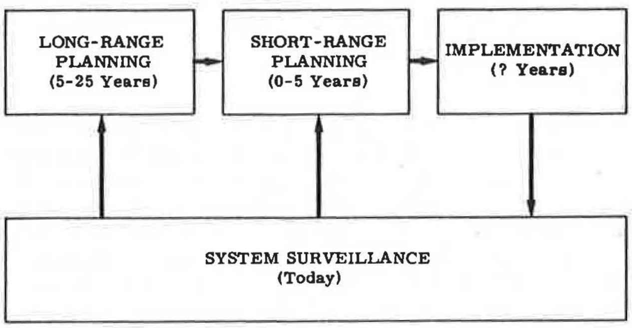


Figure 2. Planning types.

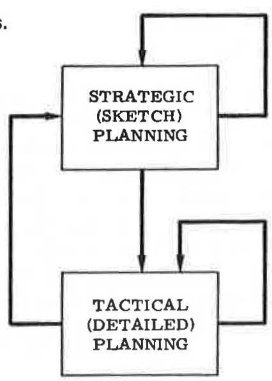
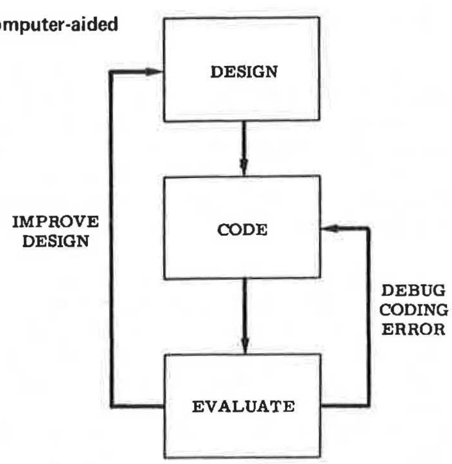


Figure 3. Computer-aided design.



Sketch-planning input is characterized by a small (less than 800 nodes) but rich abstraction of an (abstract) multimodal network. By using highly aggregated measures, it compares a large number of proposed policies in just sufficient analytical detail to support strategic decisions. Trip generation, distribution, modal split, and assignment—traditionally four different technical steps—are handled in a single step. Supply versus demand equilibria are explicitly considered. Outputs are related directly to issues. A single system alternative is evaluated at less than 10 percent of the cost of existing long-range planning techniques.

The planner remains in the sketch-planning mode until he or she completes his comparisons of possibilities or finds a strategic plan worthy of consideration at the tactical level.

Tactical planning treats the details appropriate to midrange (5 to 10 years) planning and identifies the best configurations within a given strategic concept uncovered in the sketch-planning phase. The input and analytical techniques are close to those of the state-of-the-art regional and corridor-planning studies of today. Inputs include the location of principal highway facilities and delineated transit routes. These feed a network model that addresses any automobile versus transit vehicle interaction. Disaggregate demand forecasting techniques are applicable here.

In contrast to sketch planning, tactical planning can provide disaggregated cost and benefit measures that relate more accurately to the citizens and resources affected. At this level of analysis the outputs are estimates of transit fleet size and operating requirements for specific service areas, refined cost and patronage forecasts, level-of-service measures for specific geographical areas, and where necessary, a program for staged implementation. Household displacements, noise, localized pollution, and aesthetic factors can also be evaluated.

The cost of examining an alternative in midrange planning is 10 to 20 times its cost in sketch planning, although default models, which assume away certain data requirements, may be run for a relatively inexpensive first look. Apparently promising plans can be analyzed in further detail, and problems uncovered at this stage may suggest a return to sketch planning to accommodate new restraints.

Short-Range Planning

As in long-range planning, there are two distinct types of short-range planning activities. One is the quick evaluation of broad, areawide transportation strategies, and the other is the preparation of a detailed delineation of an optimal system design reflecting a given strategy. In the former, the difference from long-range strategic planning is that the short-range case requires more accurate cost versus benefit estimates, but fortunately greatly improved accuracy is obtainable. In contrast to the long range, the feasible transportation options in the short range are very limited, and the costs and capabilities of individual system components are accurately known. In addition, in the short range, human behavior and demand for transportation are less difficult to forecast. Thus, a much more precise evaluation is possible. Some examples of the kinds of policies a short-range strategic model can address are (a) areawide dial-a-ride service, (b) widespread designation of automobile-free zones, (c) road-user taxes or increased gasoline taxes, (d) order of magnitude increases in transit fleet size or exclusive guideway (lanes), and (e) broad changes in parking policy.

Detailed delineation of the plan and the expected costs and benefits of the system are required prior to a final decision to implement. The outputs of long-range tactical planning models and short-range strategic models are usually too abstract for engineering design purposes, but as the time to implement projects draws near (5 days to 5 years) detailed simulations can be used to refine design parameters. Some examples of activities at this stage are

1. Detailed evaluation of the extension, rescheduling, or repricing of existing bus service;
2. Simulation of bus priority lanes or signal systems;
3. Analysis of passenger and vehicle flows through a transportation terminal or activity center; and
4. Comparison of possible routing and shuttling strategies for a demand-activated system.

Analysis at this detailed level can be prohibitively expensive except for subsystems whose implementation is highly probable and in which such design refinements bring substantial increases in service or significant reductions of cost or uncertainty. It is effective in planning only when the large number of exogenous variables can be accurately observed or estimated.

Surveillance

Besides permitting a continual scrutiny and evaluation of transportation services, performance, costs, and use, the data from a good surveillance program support near-term planning to eliminate problems such as overloaded links, inadequate transportation opportunity, and the underuse of existing resources. Knowledge of the current state of affairs is a prerequisite to any planning. It is essential that existing highway and transit systems and their users and the environment be monitored to ascertain the service provided, to whom, and at what cost. Such data are needed for supply-and-demand model verification and calibration as well as for system evaluation. In addition to the traditional traffic counting, user-oriented surveys of such things as convenience and travel time must also be maintained. Information about the citizen's travel patterns and socioeconomic attributes are also needed.

The development of good short-range planning and surveillance tools brings the greatest return for the model-development dollar. This is especially true because the strong tradition of pure highway planning, which is preoccupied with long-range, capital-intensive programs, is of little help in the evaluation of immediate-action programs. Short-range planning requires the tools and analytical techniques that are needed to evaluate and to optimize the use of a city's existing transportation resources, and the development of these tools has high priority at UMTA.

UTPS FUNCTIONAL CHARACTERISTICS

To support the planner in the four stages identified above, UTPS acts as a highly interactive system that uses time-shared computers with on-line graphics terminals and is vastly different from the present slow-motion, error-prone batch operations. Interactive browsing through network and land use data, both digital and graphic, speeds up the planner's evaluations. Maps, charts, and graphs replace the millions of numbers that now overwhelm him. Graphic input via an electronic tablet speeds his data entry and run setup. An interactive network design model allows him to specify or to modify his plan virtually instantaneously. Many analytical processes are run while the planner waits at the cathode ray tube, which gives instant turnaround. To guarantee successful execution, longer analyses that require batch processing are dry run interactively before submission. Later the planner interactively browses through the outputs of the batch process.

The UTPS program library includes data-management routines, graphics routines, algorithms for statistical and mathematical programming packages, and specific planning models, all of the software needed to examine transportation supply and demand at each of the three planning levels described above. UTPS modules meet uniform software design standards, and adherence to those standards allows UTPS to add new software and provide improved analytical techniques as they become available.

Among the most important modules are those for system evaluation, demand estimation, network aggregation, data acquisition, and data management.

System Evaluation

The system evaluation tool is an open-ended set of analytical reports and graphics selected for the use of local planners, who may also include their own processes and reports on local issues. UMTA adds new reports as national issues arise. Local planners can compare significantly different network conceptions and make detailed analyses of the minor perturbations of a given network. They can evaluate present and proposed systems according to current and future demands. The other modules described below also directly support system evaluation.

Demand Estimation

Planners making demand estimates may choose from three kinds of models: off-the-shelf default models for local use without site-specific parameter estimates, default models with locally calibrated parameters, and user-made models that can be integrated into existing modules with little programming effort.

Algorithms for establishing supply-and-demand equilibria provide the capacity to determine route and mode selection equilibrium, origin-destination demand equilibrium, and land development-transportation equilibrium. The software supports the development, calibration, and application of both aggregate and disaggregate models.

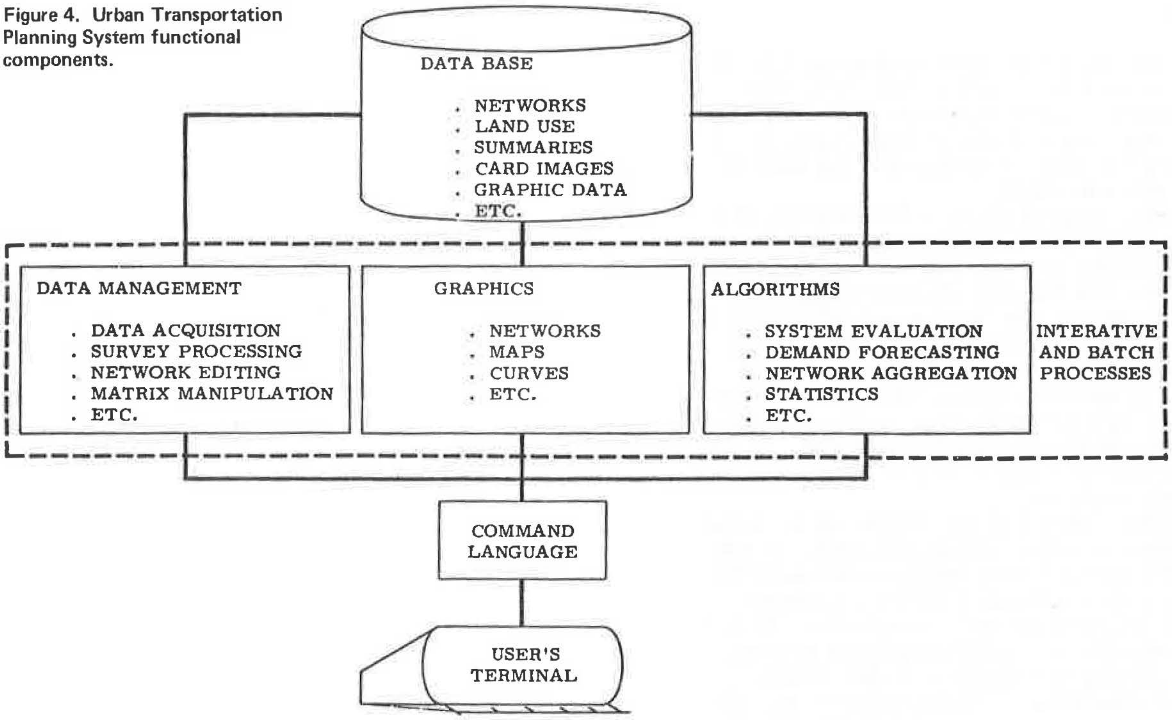
Network Aggregation Models

Among the improved tools being researched are the network aggregation models that are useful at all levels of planning. The automatic reduction in size of the coded network description speeds the computing process by providing the data base that is most efficient for an analysis. There are three network aggregation techniques: subarea windowing, regionwide abstraction, and subarea focusing.

Subarea windowing is the most straightforward technique. There is software that physically extracts a subarea of the network and collapses the external demand for it to within its periphery. This technique can be used for detailed analysis and short-range planning when external demands are assumed to be fixed.

Regionwide abstraction is technically more difficult. The computer reduces detailed networks to a specified

Figure 4. Urban Transportation Planning System functional components.



level of abstraction by aggregating links, nodes, and zonal data, yielding a network amenable to sketch planning. This permits movement from the tactical or short-range stage back to the sketch-planning stage and thus allows rapid macroscopic evaluations of detailed networks.

Subarea focusing is the most difficult technique because it combines windowing and abstraction. A subarea of interest is windowed, but the links outside the window are not deleted but abstracted, so that any modification of the internal network of the subarea can have the appropriate effect on external demand. This is accomplished by increasing the network abstraction as the distance from the window increases. Subarea focusing greatly improves the effectiveness of traditional long-range (tactical) planning by reducing its cost and increasing its accuracy.

Data Acquisition

While data collection is essential to planning in general and system surveillance in particular, the notoriously large sums of money spent for data acquisition should be channeled into more productive analyses. To do this, planners need more efficient data-gathering techniques. UTPS must couple modern sampling techniques with the power of an on-line, time-shared computer and modern data-entry hardware to speed the collecting, editing, and correcting of data and reduce their cost. A disaggregate travel demand data base is available to researchers to eliminate the need for more data in certain cases. Detailed network coding manuals show the planner the quickest way to input the characteristics of his or her transportation system.

Data Management

The data-management system is used to specify network and land use configurations, edit data, and evaluate systems. A good data-management system must allow the planner to execute programs and interact with the data base without detailed knowledge of the design of the data base. It should also be possible to provide a common source of data for all UTPS modules, allow efficient data-base modifications, avoid a proliferation of data files, and furnish a repository for output from computational modules.

Besides the many computational similarities (e.g., matrix manipulation), there are many common data requirements, such as network descriptions, land use data, and graphic data, among the three levels of planning analysis. Therefore, the data preparation time and user-training time are reduced and the software is fully exploited. At any time, the user may modify the basic network or land use data by using the interactive network design program. The modifications can be additions, deletions, or the updating of any or all elements, but the basic integrity of the original design and its predecessors is preserved in a treelike file structure. At any time, the planner may analyze any version of the network. In UTPS a single data base might contain scores of networks, all quickly available for analysis.

The planner can design his network while describing it to the computer in a natural, graphic fashion. He sits at a cathode ray tube and uses a stylus or lightpen to draw the network. He draws it either by explicitly entering nodes, links, transit lines, and such, or alternatively by circumscribing geographical areas of homogeneous service that is described parametrically (e.g., street spacing, number of bus stops, and such).

The UTPS package can generate maps, charts, or graphs. When the software processes a request for graphics, it preserves the results in the graphics file of the data base. The file contains the points, lines, and annotations that constitute the graphic in a standard format. The planner may browse through the available graphics at any time, recalling, combining, modifying, or displaying those needed, without the expense of regeneration. Attribute or land use data can be overlaid on network plots and the graphic directed to a display tube or hardcopy plotter.

CONCLUSIONS

All of the components and capabilities described above are among the current future objectives of the UTPS development effort. All are at present in a research or development stage. A few initial products have already been released to the planning community, but most are scheduled for future delivery.

In its present, skeletal state, UTPS (Figure 4) is 13 software modules and the attendant documentation to form a fairly powerful suite of programs that run in the batch mode on the IBM 360/370 series of computers. It basically comprises a traditional transportation model and best supports long-range tactical planning, but it can provide limited service to the strategic or short-range planner. It includes highway and transit network analysis models, demand-forecasting models, matrix manipulation, and limited graphics capabilities. It can be installed easily at the user's computer facility and is being continually improved.

It is hoped that, within 3 years, UTPS will evolve to include all of the capabilities discussed above. It will be in a form that allows it to be fairly readily installed on non-IBM computers and will exploit minicomputer and nationwide computer network technologies. The result will be a ubiquitously available software system, which will aid our Rip Van Winkle and other federal, state, and local planners who search for effective solutions to today's complex and vexing transportation problems.

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