A Planning Methodology for Intelligent Urban Transportation Systems

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The University of California
Transportation Center

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EXECUTIVE SUMMARY

Urban transportation Planning is facing challenges and opportunities in the rapid developments of intelligent transportation systems. Such systems are characterized by real time information feedback in their operations and management, and by increasing levels of automation of their various components. The challenges to planning stem from the increased range and added complexity of the choices available to transportation planners. The implementation of IVHS technologies, many of which have system-wide implications will require a change in the institutional arrangements that are currently at work in transportation planning. Recent legislation, such as ISTEA and the California Congestion Management Program, has also posed a challenge to transportation planning as it requires specific processes and imposes certain mandates.

The opportunities for transportation planning are many and stem from the availability of information, communications, and computation technology. These same elements which add *intelligence* to the transportation system can be engaged to add intelligence to the planning process itself.

We have developed a framework for integrating planning and analysis in a computer supported environment that facilitates deliberation and consensus seeking. The planning process conducted with the aid of an intelligent facilitator benefits from on-line analysis capabilities that are integrated into a unified computer system called PLANiTS. It is constructed around four components: a *policy and goals* base that helps define the objectives and criteria of the planning process, a *strategy and action* base that assists in the search for actions to improve transportation systems, a *knowledge* base in which data, information, and knowledge about the transportation system reside, and a *methods and tools* base in which planning analysis and operations analysis models are integrated. The last two are supported by an expert system that searches the knowledge base for relevant information and assists the planners in selecting appropriate methods of analysis. These bases are used to support a deliberative process in which alternative strategies are analyzed and evaluated and decision makers are assisted in reaching resolution concerning plans and programming of projects.

Transportation actions are represented by planning vectors $PV(A,Y,E)$ that are constructs containing elements of proposed actions A, evaluation criteria Y, and environment descriptors E. Searching through the knowledge base, PLANiTS uses techniques of case based reasoning and pattern recognition to match proposed planning vectors with similar cases. Further, an expert system advises the planners on the adequacy of available knowledge, the need for primary data collection, and the appropriate selection of models for evaluating the proposed planning actions.

The proposed planning methodology involves extensive use of knowledge bases in assessing transportation actions. It involves on-line access to knowledge and to modelling capability. By placing the planning process in a computer aided environment, PLANiTS aims to make it more transparent and to give users the opportunity to seek consensus on the basic assumptions, criteria and models of analysis, as well as the programming decisions.

The development of a knowledge base for transportation planning represents a major undertaking. The aim is to capture the knowledge available from the very rich data sources that exist in transportation and from the experience gained through field operational tests and demonstration projects of new technologies. This is done through methods of data base management and expert systems. We believe that PLANiTS presents a significant opportunity to advance the state of the art in transportation knowledge representation and management, and for integrating the myriad of models used in analyzing transportation systems.

The positive feedback obtained concerning the PLANiTS system have encouraged further steps in its development. The current effort is focused on programming the architecture of PLANiTS, and on developing a prototype. Effort is also underway on developing a framework for knowledge representation and management for transportation planning.

To support deliberations and consensus seeking, PLANiTS includes a decision making support component. A number of different approaches to computer supported decision making and deliberation support systems have been explored. We believe that these techniques have the potential of enhancing the process of deliberation and consensus building that is necessary to arrive at programming decisions. Specifications for a system suitable for transportation planning have been defined, as have the determinants of a prototype for inclusion in early versions of PLANiTS.

Specific research on PLANiTS currently includes: 1) the development of a prototype intended to test the system and to demonstrate its use; 2) the development of a framework for knowledge representation, case based reasoning and expert system techniques in transportation planning and a prototype knowledge base for use in PLANiTS; 3) the development of a computer platform for the integration of planning and operations models into a methods base for PLANiTS; and 4) the selection of decision support techniques for integration into the deliberation and programming elements of PLANiTS.

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Chapter 1

INTRODUCTION

Urban transportation has been the subject of renewed interest and increased attention in recent years. The continued growth in scale and complexity of urban transportation activities and their impacts on the urban environment have renewed the decades long search for solutions to the *urban transportation problem*. One important contemporary element of this search is what we might call the technology revival. The last few years have witnessed a rapid increase in the development of transportation technology. The search for solutions has extended to the boundaries of today's scientific and technological know-how and has included, most notably, highway automation, and the use of information and computer technology for the management of transportation systems. The emergence of these technologies as a promising new pathway for transportation is probably the most significant development in the field since the introduction of urban freeways. These developments have resulted in the launching of what has come to be known as Intelligent Vehicle Highway Systems, IVHS. Broadly defined, IVHS implies a transportation system that functions with real time feedback. Information technology would be utilized in combination with modern communications and computation technologies to advance the state of the art in transportation systems management and use. These technologies would also be utilized to optimize a system in which increasing proportions of the functions are automated. The anticipation is that IVHS technologies would improve productivity, enhance safety, and reduce the adverse impacts of urban transportation systems. It is also anticipated that new opportunities for innovation in transportation and in the organization of urban socio-economic activities might be brought about by IVHS

These developments pose a particular challenge to transportation planning. A central question is whether the processes, methodologies and tools currently in use are appropriate for planning advanced transportation systems of the types being conceived in the IVHS arena. The system integrating effects of some IVHS technologies, as well as the real time feedback mechanisms implied in their operations pose a real challenge to the planning models used to estimate impacts and to assess effectiveness. These same features pose a challenge to the planning process itself, particularly at the local level. Many of the IVHS technologies envisaged require far more coordination in programming and in operations among local communities than is currently the case. Advanced methods of system management, including such things as automated, differentiated pricing systems will raise important questions of regional versus local optimization. All these issues will require a planning methodology that is as *intelligent* as the transportation systems it is intended for.

The need for a new planning paradigm goes beyond the concern with evaluating the impact of new technology. Indeed, other recent developments, which themselves are perhaps not unrelated to the emergence of IVHS, have made it imperative that such work be undertaken. Prominent among these is recent legislation, such as ISTEA and CAA, which mandate planning processes at various levels including urban, regional, and State. There are also cogent reasons for seeking new techniques and processes for transportation planning. Current methods rarely satisfy the needs of the planning and programming processes that have become a part of urban governance. Analysis models are rarely used effectively in informing these processes, and the gap between the methods researcher and the policy analyst remains fairly wide.

On the positive side there have been significant developments in recent years in computer aided planning and decision support systems. Computer based support systems have been developed for complex deliberative and negotiating processes of the kind that has become common practice in transportation planning. These systems have typically been applied to private sector problems, but they hold much promise for application to transportation. Decision Support Systems have also been developed and successfully applied to complex, multi-objective planning processes in many fields including environmental planning (Guariso and Werthner 1989); and large scale public works, and recently to transportation (Cohn and Harris 1992). These methods hold much promise for urban transportation planning in the IVHS era. One of the goals of this work is to explore how such techniques might be developed for urban transportation planning.

OBJECTIVES

The objectives of this research have been to explore the current transportation planning process in California, to understand the challenges and opportunities posed by IVHS; and to develop a framework for a transportation planning methodology that responds to them. In developing such a methodology, our goal has been an integrated computer platform for performing the necessary analysis and modeling involved in planning, as well as for supporting the deliberative processes that are involved in making programming decisions. In this report we present the framework for a transportation planning process for the IVHS era, the elements of a transportation planning methodology and the general architecture of a computer platform for integrating analysis and deliberation.

We define transportation planning to include the entire range of transportation decision-making regarding transportation improvements and policies. This would include identification of problems, investigation of potential solutions, analysis of alternative projects and programs, analysis of improvement opportunities, and scheduling and funding. Policies, such as a a trip reduction ordinance or road pricing, and services, such as transit or information, would be included, as well as physical improvements, such as call boxes and new freeways. Also included in our definition of planning is the decision-making process itself, the means by which deliberations take place, tradeoffs are made, and resolution achieved.

In the next Chapter we report on the results of a brief inquiry into current transportation planning practice in California. This is followed by Chapter 3 in which we present a framework for transportation planning in the future. In Chapter 4 we present PLANiTS, a computer model for integrating planning and analysis. This is followed by three Chapters in which we discuss in some detail some elements of PLANiTS. Chapter 5 covers the Strategy and Action Base; Chapter 6 covers the Data and Knowledge Base; and Chapter 7 covers the Tools and Methods Base. In Chapter

8 we discuss the framework of a computer aided system for facilitating the process of deliberations and consensus building. Finally Chapter 9 concludes this report with a brief discussion of the steps we are following to complete the development of a prototype of the PLANiTS system.

Chapter 2

CURRENT URBAN TRANSPORTATION PLANNING IN CALIFORNIA

In an effort to study the current urban transportation planning process in California we reviewed contemporary literature on transportation planning and related subjects such as decision analysis, political theory, and organizational theory. Interviews were conducted with county, city, regional, and state transportation planners, and with developers of new technologies. The purpose was to determine how planning is currently taking place, and to assess attitudes and knowledge about new technologies and the issues that arise in their implementation.

Motivations for Transportation Improvements

Planning is not always the result of a rational determination of needs. The planning process is not as neatly defined as the planning theorist would have it. The logical progression of steps and of causal relationships often gives way to the competition for scarce resources, or to the pursuit of opportunities. Planning is often mandated by a political process that is driven by different concerns that are presumably higher than those of the system being planned. It is sometime driven by funding opportunities, as is not uncommon in urban transportation where Federal and State programs mandate and fund planning. Because few large projects are undertaken without such funds, the funding mechanism largely determines the realm within which local and regional decisions regarding transportation improvements are made. Opportunities for transportation improvements also arise in new land development programs, or in the rehabilitation of older developments. Mandates, such as those relating to services for disabled people and congestion management, also require planning activities in transportation. Stake holders in the political process, either special interest groups or individual politicians, play a very important role in shaping the perception of needs thereby focusing attention on, and gaining support for, particular transportation improvements.

Recent legislation has played an important role in shaping the current planning process. First, the *Congestion Management Legislation* in California requiring county-wide congestion management agencies (CMA) and plans (CMP), has resulted in more coordination between cities, counties, and the public. It has also placed greater emphasis on land use and demand management. This has generally been viewed positively by planners. However, the results of this coordination and emphasis are yet to be seen. Many planners are concerned that there are no effective incentives or sanctions. The legislation requires compliance with the process rather than with the goals--that is, with the preparation of deficiency plans, rather than with the control of increasing congestion. Second, *ISTEA* increased the funding and role of regional transportation planning agencies. In the San Francisco Bay Area, the Metropolitan Transportation Commission (MTC) has responded by strengthening its links with counties and cities and the public. It has created an advisory panel of interested citizen and business groups, academics, and local transportation officials to provide policy and technical guidance. It has also created a partnership of local officials to implement selected regional projects. Most importantly, it has created a new process for prioritizing and programming transportation projects throughout the region. This process involves county and city planners to a greater extent than ever before. This has increased coordination between counties in much the same way that the congestion management legislation has increased coordination between cities. Local and MTC planners alike viewed the funding and programming process that took place this year as an improvement over previous years.

ISTEA also provides more flexible funding, allowing some highway funds to be used for transit, and encouraging multi-modal projects and new technologies. However, relatively little funding is earmarked for new technologies. As a result of the increased role of the regional transportation planning agencies, California Department of Transportation (CALTRANS) has been doing less urban planning, instead focusing on implementing local and regional plans.

Structure of the Current Process

Much of the following discussion is based on interviews conducted with 16 planning officials at various organizations in California. A summary of these interviews is shown in Table 2.1 (a summary of the comments made during these interviews is shown in the Appendix 1). The agencies interviewed cover a range from a relatively small city transportation department, Concord, serving a population of 110,000 to a large MPO, MTC, serving a population in excess of 5 million. The planning functions performed by these organization vary widely and it is clear that no single agency can cover the whole spectrum of planning and programming alone. It is noticeable that very few of these agencies are currently involved in "new technology" actions. It is also noticeable that few of these agencies have a strong interest in analysis.

Most see planning as a process of political bargaining and conflict resolution. Most have narrowly focused goals and seek to maximize opportunities to their immediate jurisdiction. We have attempted to characterize the planning process as currently practiced in Figure 2.1. As this diagram suggests, but can not really illustrate, it is not an orderly, step-by-step process, but rather a messy, iterative process with much feedback between levels. As noted earlier, there has been more coordination between agencies and greater concern for public participation since ISTEA and the congestion management legislation.

Congress provides the overall policy direction for the country, determining the level of funding for transportation, programs to be emphasized, and mandates to be met. The Department of Transportation influences, interprets and implements the legislation. The California legislature and CALTRANS perform similar functions within the state. Transportation policies and funding levels are sometimes also established by the initiative process, such as Proposition 111, which increased the gasoline tax and required county congestion management programs.

Projects generally originate where the needs are perceived, at the city or county level or with a transit agency. Projects that affect more than one county may lead to creation of an interagency group to plan and implement. The regional transportation planning agency (RTPA) may coordinate or manage such an effort, such as MTC did with the high occupancy vehicle lanes on I-80 between the Bay and Carquinez Bridges.

Table 2 1 Summary of Interviews

Name	Organization	Population Served	Transportation Planning Functions	Key Decision Makers	Planned Action on New Technologies	Role of Analysis
Farhad Mansourian	Marin Public Works/CMA	225,000	CMP	Countywide Planning Agency (CMA) Board	None	Limited
Carol Williams	Marin Planning Department	225 000	Long range plan	Board of Supervisors	None	Moderate
Fred Vogler	Marin Planning Department	225,000	Transportation element of countywide plan	Board of Supervisors	None	Moderate
Chuck Purvis	MTC Planning	5 600,000	Regional travel demand model		None	Important
Joel Markowitz	MTC Advanced Systems Applications	5,600,000	Evaluation and implementation of advanced technologies	MTC Partnership	Trying to implement 6 system management technologies in the region	Limited
Bob McCleary	Contra Costa Transportation Authority/CMA	735,000	Coordination, conflict resolution CMP	Transportation Authority (also CMA) Board	None	Limited
Brigid Hynes-Cherin	San Francisco Transportation Authority	725,000	Funding, programming funds, coordination, CMP	Board of Supervisors, PUC (for MUNI)	Providing information for interested decision-makers	Limited, but increasing
Chris Brittle	MTC Planning	5,600,000	Regional transportation plan (RTP), air quality plan, coordination, special studies, regional modeling, CMP compliance	MTC Work Program Committee, MTC Commissioners	None	Limited
Ben Chuck	Caltrans Public Transportation Branch	5,600 000	Planning TSM measures to mitigate effects of freeway construction		None	Important
Hank Dittmar	MTC Legislation and Finance	5,600,000	Advocating legislation, financial analysis for RTP, programming funds	County CMAs, MTC Partnership, MTC Commissioners	None	Limited
Eugene Leong	Association of Bay Area Governments	5,600,000	Supplying regional economic and demographic forecasts		Encourages staff to telecommute (70% have computers at home)	
Dennis Fay	Alameda County CMA	1,200,000	Long range transportation plan, CMP, project programming	CMA	Educating the CMA and the CMA TAC and CAG about new technologies	Moderate, but increasing
Therese McMillan	MTC Planning	5,600,000	Long range planning, staff support for the Partnership	MTC Partnership, MTC Work Program Committee MTC Commissioners	Educating the Partners (CMA managers, Caltrans, etc), including new technologies in the long-range plan	Limited, but increasing

Tom Clausen	Concord Transportation Department	110,000	City traffic improvements participate in countywide planning and Central Contra Costa County sub-regional planning	He Director of Public Works City Council	None	Important
· Mike Evanhoe and Andy Nash	Santa Clara County CMA	1,400 000	CMP, 7-year Capital Improvement Plan, planning regarding the interaction between land use and transportation	CMA, CMA Technical Advisory Committee (City public works and planning directors and city managers)	TOS (Caltrans project), City of San Jose is installing an automated traffic signal system-ultimately 1000 locations), ramp metering	Moderate

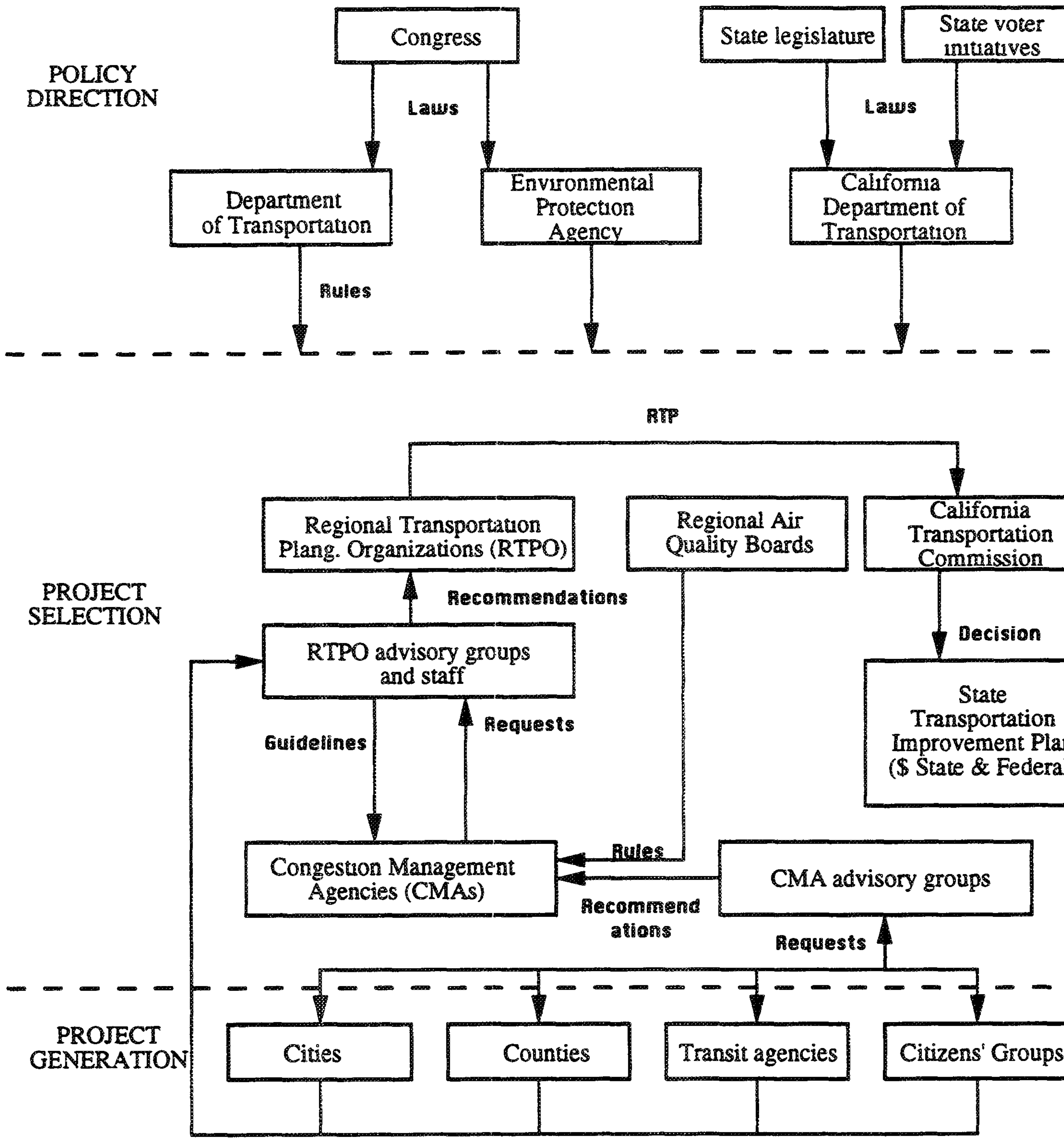


Figure 2.1 Transportation Decision-making Process.

Projects that will utilize federal or state funding are submitted by the cities and county to the county's Congestion Management Agency (CMA) for inclusion in the capital program of the Congestion Management Plan (CMP). Generally the RTPA will provide the county with an estimate of the amount of funding available to the county. Then city and county staff people will get together to decide which of the submitted projects to recommend for inclusion in the capiptal program. The CMA governing board approves the capital program, which is then submitted to the Regional Transportation Planning Agency (RTPA). Then RTPA and county staff people get together to decide which projects to recommend for the Regional Transportation Improvement Plan (RTIP). The whole planning process has been greatly influenced by the Congestion Management Legislation and ISTEA, and is still in a state of flux. For example, the Metropolitan Transportation Commission in the San Francisco Bay Area has recently been holding public meetings throughout the region to get public and agency input at the beginning of the planning process for the 1994 Regional Transportation Improvement Program. Presumably, the comments from these meetings will be fed back to the counties as they begin their deliberations regarding their 1994 RTIP submittals.

A key aspect of this process is allocating funds from various federal and state programs to transportation projects. The RTPA's take the lead in this process, and recommend a program for funding to the California Transportation Commission, which makes the final decision regarding state funding and some federal funding.

The Role of Analysis

All urban counties in California now have some type of travel demand model of the UTPS type, such as EMME/2, MinUTP, or TRANPLAN. These models are there presumably to be used for assessing the effects of new development, in compliance with the mandate of the congestion management legislation. However, as mentioned above, analysis and transportation modeling are not key concerns of most local planners, and the use of models appears more as a procedural formality rather than an inherent part of a rational planning process.

Because of limited funds, local planners must concern themselves primarily with obtaining funding for projects already judged to be needed. The type of analysis on which such judgements are made depends on the project. Justification for a local road improvement may be based on current counts and estimates of trips to be generated by future development. Alternative improvements may or may not be seriously considered. Analysis for large scale projects, such as a new segment of freeway or a new rail line, generally involve projecting travel demand, evaluating the performance of various alternatives, estimating costs for the best alternatives, and an assessment of environmental effects. The quality of these analyses depends on the extent to which they include the full range of alternatives, the objectivity used in making assumptions and selecting alternatives, and the skills of the analysts. Generally, studies for large-scale projects are done by consultants, and in some cases by the RTPA staff. Various models of highway operations may be used in designing improvements to roads or signalization. These are generally used to determine how to design a facility rather than to decide what type of facility to build or where to locate it.

Currently, analysis is not an integral part of the process of decision making regarding funding allocation by MTC, although there seems to be an intention to move in the direction of such integration. Overall, the role of analysis in planning and in resource allocation decisions seems limited. Comprehensive systems analysis is almost totally absent.

Attitudes Toward New Technologies

Table 2.1 shows that only five out of sixteen planners interviewed showed enthusiasm for new technologies. The current focus appears to be on interagency cooperation, land use, transit, and demand reduction, as required by the Congestion Management legislation. This lack of enthusiasm for new technologies appears to result from a belief that they would be too expensive or that they would not work. There is also the commonly held belief that new technologies are concerned only with one half of the transportation problem, the supply side, and do not attend to the demand side. Although this is not totally correct, if supply actions are taken in isolation from demand management and land use/transportation issues, then new technology, and indeed the whole IVHS initiative will not be well received and will have uncertain chances of success.

MTC has recently formed an Advanced Systems Applications Division, which was instituted in order to take advantage of opportunities offered by ISTEA. Its purpose is to implement demonstrated technologies throughout the region. It is currently promoting a pavement management system, an emergency call box system, automatic fare collection, centralized transit information via telephone, a traveler information system, and transportation control measures, such as optimal signal timing.

The planners whom we interviewed stressed the need to show that new technologies will work, through the use of demonstration projects. A new technology will be adopted if it has been demonstrated to solve a problem that people perceive. Local governments are not likely to take the risk of implementing a new technology on their own; they will need to share the risk with the state or federal government. Most CMA managers interviewed thought that a state agency should take the lead in evaluating and promoting technologies. The recently expanded role and scope of the Division of New Technology, Materials and Research at CALTRANS represents a significant commitment on the part of State Government to take on this role.

Synthesis of Findings

There are some important lessons to be learned from this brief inquiry into current planning practice. First of all it is clear that analysis plays an inadequate role in planning and decision making. In order for analysis to play a more meaningful role in this process it would be necessary to expand its scope beyond the demand analysis focus that characterizes most UTPS modeling. Impact analysis, operational analysis of system performance, as well as economic analysis are among the many dimensions along which to expand the scope of modeling in the planning process. The integration of all these modeling elements into the actual deliberation and decision making process is another pre-requisite for ensuring that analysis does in fact support planning. Despite its complexity, modeling has to remain a transparent, and visible element of the planning process. The integration of modeling into decision making requires that the deliberation process encompass elements of modeling. Modeling assumptions, prediction scenarios, and the objectives of optimization models are among the modeling elements that should result from deliberation and that need some consensual support if model results are to be of any use.

Another important lesson is that the introduction of IVHS technologies is not seen as simply an incremental expansion of the set of options available to transportation planners. There is uncertainty, doubt, and sometime outright misgiving regarding new technology. Therefore, it is imperative that a planning methodology be developed that would permit a thorough analysis of IVHS elements within the overall context of exploring the broader set of transportation solutions. More importantly, it would seem desirable that a mechanism be found to integrate the knowledge accumulation about IVHS technologies into the planning process. The current lack of knowledge and the absence of experience are probably to blame for the general apprehension about IVHS technologies that is to be found among local transportation planners.

The multiplicity and complexity of rules and requirements mandated on to the planning process by the myriad of laws and regulations has tended to bureaucratize the planning process, often at the expense of adequate attention to the real issues and tradeoffs that face planners. The use of computer based decision support systems might help disentangle the convoluted procedures and assist planners in focusing on the important issues.

Chapter 3

A FRAMEWORK FOR TRANSPORTATION PLANNING IN THE IVHS ERA

The Challenges and Opportunities of IVHS

We seek a planning methodology that responds to the challenges of recently mandated processes, and that can support the complex decision making process that must take place in programming transportation actions. As mentioned earlier, the emerging new technologies of IVHS, pose challenges to transportation planning, but also present opportunities for adapting appropriate planning processes. To develop a framework for transportation planning we need to recognize the process as a complex, multi-actor political negotiation and consensus building. We also need to recognize that analysis and modeling, while important elements of the process, have a limited role in the decision making process. Thus one of the objectives of the proposed methodology is defining the proper role of models and analysis within the decision making context, as well as developing a logic for model selection.

To define a planning framework for the IVHS era, it is necessary to adopt a meaningful definition of IVHS. This is a complex subject and one that continues to evolve as IVHS gains momentum in the research and development community, as well as among the agencies that develop and implement transportation policy and programs. There is little disagreement that IVHS represents a stage in a continuing search for improvements to transportation technology. As such IVHS can be sid to include all that is new in the way transportation systems are built and managed. Indeed, in many respects it is difficult to find the difference between some of the technologies referred to as IVHS and their predecessors. For example much of what is now considered Advanced Traffic Management Systems, ATMS, is by and large a continuation of a long tradition of traffic management improvements including the development of computer models such as FREQ and TRANSYT and encompassing the popular TSM of the 1970's.

What sets IVHS apart from earlier developments are two fundamental features. One is the use of real time information and feedback for the management and operation of the system; and the other is the introduction of automation. The first of these involves the use of advanced communications, computation, and information technologies to permit users and operators of transportation systems to optimize various aspects of the system. Traffic managers can use these technologies to integrate system management and control, particularly between freeway and city street sub-systems; individuals can use real time information to better integrate trip making decisions into the complex of urban activity scheduling, resulting in better use of limited system resources, and possibly at a better level of service. The introduction of automation also changes transportation systems in a fundamental way. Beginning with driver aids such as collision avoidance and hazard warning, these technologies can improve safety and efficiency; possibly resulting in improved traffic streams with fewer incidents and reduced adverse environmental impacts. Moving on to more extensive applications would yield automated highways where significant capacity gains are added to the safety and environmental impact gains.

In addition to system gains such as these, it is normal to expect these new features of transportation systems to inspire off-system, second order gains that can far outweigh them. The introduction of advanced information technology into the use and management of transportation systems could inspire fundamental changes in the way urban activities are conducted, creating opportunities for doing things in ways that have not been thought of yet. Likewise, the introduction of automation can make possible innovations in the design and manufacturing of automobiles and their propulsion systems resulting in significant gains. Perhaps the most important impact of IVHS technologies is in their role in catalyzing innovation in the way we do things and the way we use transportation to do them.

All this represents challenges and opportunities to transportation planning. In order to support decision making regarding intelligent transportation systems, the planning process itself must be intelligent in the same way they are. If the transportation system is to have real time feedback in its operations, then the planning process must include models that reflect that feedback. Information that is available in the IVHS environment for system operations and management, should also be available for system analysis and planning. The continuous feedback in IVHS system operation should be echoed by continuous forecasting in the IVHS planning models. The introduction of new elements of information technology, communications, and automation into transportation systems should be reflected in the way the planning process conceives of and analyzes transportation options. The wealth of technological option that will become available in transportation suggests that the planning process should be capable of dealing with a *continuum* of options rather than a discrete set of alternatives. It should be capable of efficiently searching through this continuum and matching options against policies and objectives in order to ensure that no opportunities are missed. Finally, all this added complexity must be somehow integrated into a complex decision making process, and one as we saw earlier, that is apprehensive about new technology and ambivalent about modeling and systems analysis.

A Framework for Transportation Planning

These challenges and opportunities suggest a planning process that can take advantage of the wealth of information available in IVHS, and that has at its disposal the analytical power to use this information intelligently. The process we propose aims to integrate planning and analysis and to provide a computer based platform within which complex analysis and deliberation are supported.

The basic principle of the proposed planning framework is the intelligent use of knowledge to support deliberation and decision making (Figure 3.1). To operationalize this principle we introduce two important features of the planning framework. The first is to recognize transportation planning is a deliberative, dialectical process that seeks agreement on programming decisions. The second is to recognize the necessity to supplement models with expertise and with a knowledge base that becomes richer as experience with new technology is gained. The methodology proposed to implement these principles is computer based and uses an interactive on-line environment to facilitate deliberation and to integrate it with analysis.

Transportation Planning as Deliberation. Transportation planning is primarily a

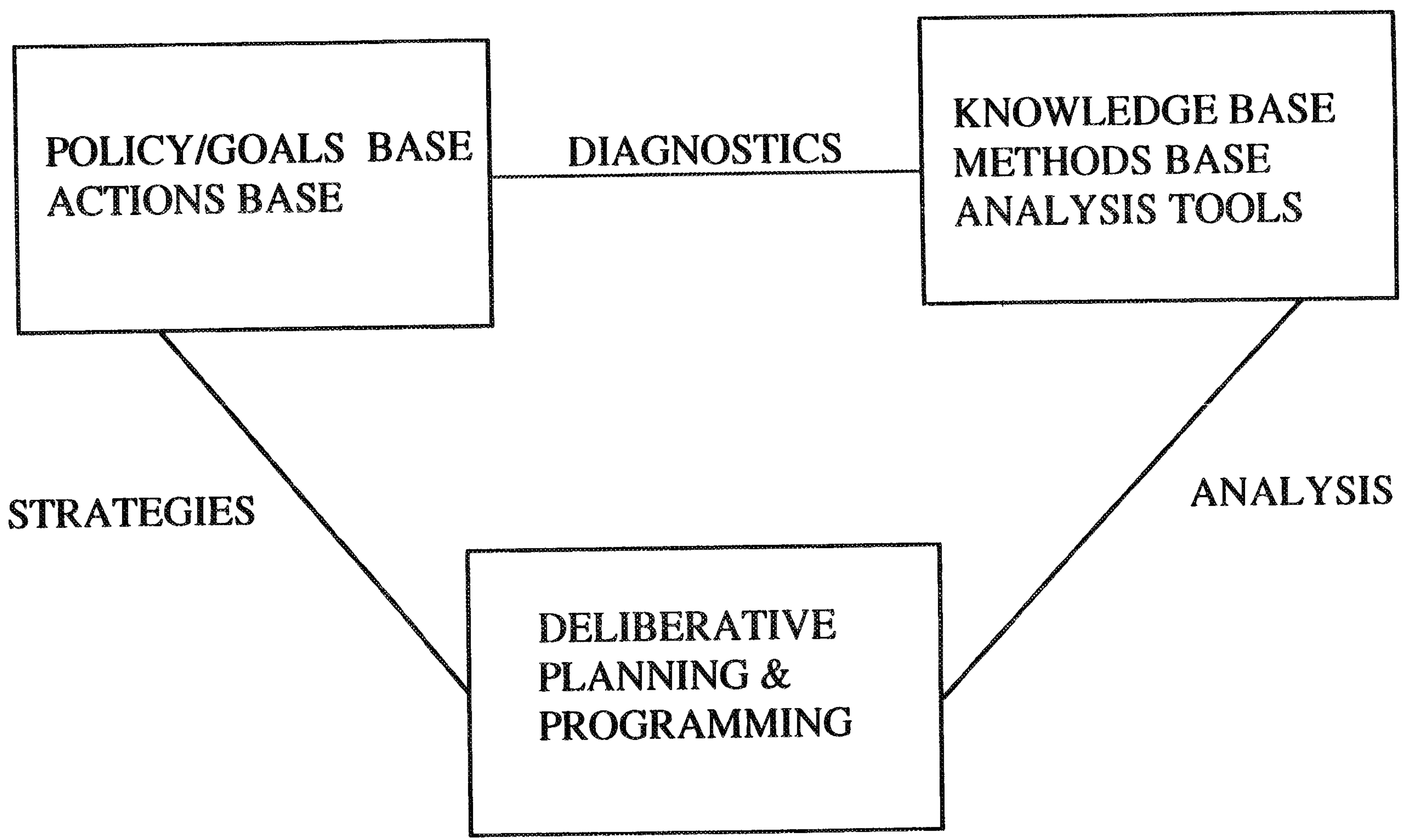


Figure 3.1 Process components.

deliberative process of negotiation and consensus building that is supported, rather than driven, by rational analyses and projections. The contemporary context of transportation planning is one where there is a diverse group of actors and stake holders who are driven by different motives and are advocating conflicting objectives; who have different value systems with which they measure their expectations from the transportation system and with which they judge its impacts; and who are all vying for a common, usually limited, resource pool. It is a context of dialectical tension between opposing forces. Recent legislation has made it mandatory that planning be multifaceted, multimodal, and multi-agency. The broadening of the scope of transportation planning, and the decentralization of transportation planning powers have brought many actors into the planning and decision making processes, and has made consensus seeking a central feature of these processes.

To deal with this aspect of planning we place at the heart of the methodology a computer based intelligent facilitator and decision support system. Planners work with the system in an interactive on-line environment to facilitate deliberation, to synthesize positions, and to seek consensus. This consensus seeking is not limited to the final stages of the process when people come to agree on what to program for implementation, but is dispersed throughout the process. Planners need to consider goals, criteria, constraints, models, and predictions before they can accept the results of analysis and come to a consensus on programming. Of course, the methodology cannot guarantee that consensus will be achieved, but it facilitates the process of seeking that consensus. Using its rich knowledge base and powerful analytic tools this computer based intelligent facilitator seeks to discover win-win propositions, to clarify trade-offs in meaningful, and when possible, quantitative terms, and to support trade-off analysis whenever optimal solutions are not possible.

Expert Knowledge Base in Support of Planning. It has always been true that models cannot totally replace expertise and human judgement. While modeling is an essential approach to the analysis of complex systems, it remains inadequate as an intelligent support base for planning and programming decisions. Recent developments in computer science and in data base management techniques have made it possible to assemble large quantities of data regarding the behavior of complex systems and their environment, and to extract from these data bases useful knowledge. Expert systems have been developed and applied in many fields, including transportation, to store knowledge and expertise in such a way as to permit its use efficiently within the framework of a computer based decision support system. Effective use of such a knowledge base makes it possible to avoid repeated collection of data and calibration of models, thereby reducing the time and cost required for analysis.

Central to the proposed planning methodology is a knowledge base and a methods base that are connected by a reasoning element and that are open to external intervention by the users in a interactive manner. Commonly used UTPS-type models would reside in the methods base and would be called upon when appropriate, such as when knowledge in the base is insufficient to address the question at hand.

Another important aspect of the use of an expert knowledge base in the proposed methodology relates to the IVHS environment. In a fully developed IVHS based urban transportation environment, we would expect a fully connected system with real time feedback used in its operation and management. Such information systems provide a very valuable resource to measure and monitor behavior and from which to build a knowledge base for planning. The opportunities that IVHS presents for enhancing transportation planning are potentially immense, and the proposed methodology aims to take advantage of them.

Computer Supported Deliberation and Analysis. The proposed methodology integrates analysis and decision-making in an interactive environment. This requires a substantial computer aided decision support system. The computer system includes two main elements. One is the knowledge and methods base. It includes the data base and database management system, the knowledge base and the collections of methods, and models and tools that perform analysis. It also includes an expert system that assists the user in selecting the level of analysis needed to supplement knowledge from the knowledge base. The other element is a computer based deliberation support system. This is a system that facilitates the sharing of information, ideas, and views as part of the deliberation that takes place in planning and decision making.

The computer support of the process permits the search through rich data and knowledge bases, and allows the users to explore alternatives from an array of technologies and other interventions that reside in what is called the Action Base. The system can be operated in a group environment where users from different organizations work together to explore alternatives and seek consensus on planning decisions. The system provides quick response analysis and interpretation. It can also be operated separately by individual users either privately, or as part of shared, networked computer environment.

Chapter 4

PLANiTS - A SYSTEM FOR INTEGRATED PLANNING AND ANALYSIS

Deliberative planning and analysis with expert knowledge base and modeling, supported by intelligent facilitation, will be integrated into a single computer environment. This environment will be based on a software platform that will support the integration of models for planning and decision making. This platform is named PLANiTS, *(Planning and Analysis Integration for Intelligent Transportation Systems).* The general architecture of this system is described in increasing details in the following paragraphs and Chapters.

We expect that this system will change the way in which planning is practiced by providing appropriate information and analytical resources throughout the planning process to all participants, from staff analysts to environmental activists. We expect more informed, but not necessarily less contentious, debate. We expect more refinement of projects and more debate about basic conflicts, such as between those favoring and opposing growth. Questions will arise, such as the effect of increased highway capacity on growth, for which we do not yet have answers. There will be more opportunity for creativity, less opportunity for special interests to control the process. We expect that the system will be used in ways that we can not now imagine.

Overall Structure of PLANiTS

As shown in Figure 4.1, the overall structure of PLANITS consists of four interacting bases that drive and support an integrated planning and analysis process, which itself is made of two modules: a deliberative planning analysis module and a consensus building and programming module. We begin by describing each of these components briefly. The following Chapters discuss some of these bases in more depth. The first two bases which initiate the process are the Policy and Goals Base and the Strategy and Action Base:

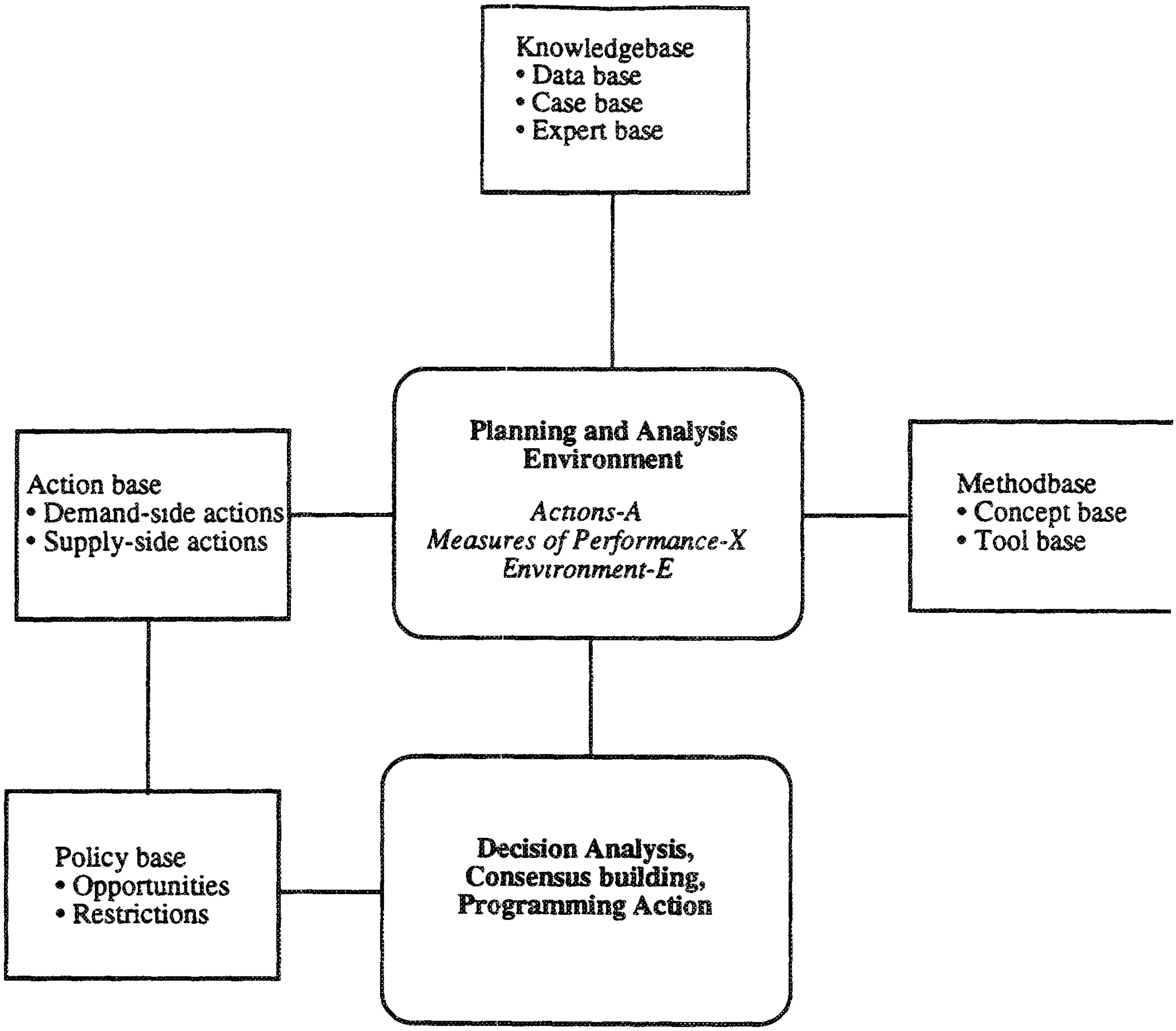


Figure 4.1 System components for PLANiTS.

The Policy and Goals Base. Planning and programming deliberations rest heavily on fundamental policies, goals and objectives. These deliberations are often hampered by the lack of clarity, much less agreement on what those are and how they rank in terms of their relative importance. The Policy and Goal Base is where we identify, catalogue and represent the overall policies, mandates, and requirements of the planning process. For example, requirements such as those found in congestion management legislation, would reside here and be used in the selection of strategies and actions, their analysis, and the deliberations on their programming. Measures of performance, and other criteria for evaluation also reside in this base and influence many stages in the process. Also entering in this base is information on funding opportunities for various actions intended to meet different policy goals.

One way to represent this information would be in the form of a matrix as shown in Table 4.1, which represents some of the funding opportunities and mandates that have been written into recent legislation. Combining funding resources and constraints with actions and goals in this matrix format would help define opportunities and guide the selection of actions. Typically funds are available for certain actions and can only be used for them. For example, federal funds were allocated during 1970s for HOV lanes but few HOV facilities were actually completed. As a result, funds remain for HOV construction and cannot be used for anything else. Information about the funds will be included in the opportunities matrix; in this case the action is pre-specified--construct HOV lanes. Thus, the policy base will have information on projects which have to be initiated in order to receive funds.

It is expected that throughout the deliberation process users will need to refer back to this base in order to explore policies and mandates and in order to take stock of objectives and constraints, especially during conditions of multi-criteria evaluation of projects.

Strategy and Action Base. This base contains a catalogue of possible actions that individually or in combinations make alternative transportation actions that are to be planned and analyzed. Strategies, often in the form of projects or actions are either generated exogenously (e.g., projects defined by local planning agencies) and

Legislation	Measures of Performance							
	Opportunities				Requirements			
	CONGESTION	AIR QUALITY	SAFETY	ACCESSIBILITY	CONGESTION	AIR QUALITY	SAFETY	ACCESSIBILITY
Federal								
ISTEA	●	●	●	●				?
Air Quality						●		
...								
State								
Congestion Management					●			

● Size of the sphere indicates the extent of resources or requirements

Table 4.1 Policy base matrix.

proposed for programming; or they are derived internally within PLANiTS through a brainstorming activity in which the transportation problems are diagnosed and alternative strategies generated (Figure 4.2).

The action base tends to be more technical in nature and contains a pool of possible actions and technologies that could be tested in association with proposed strategies. To expand the set of actions typically found in a transportation plan, we will construct a taxonomy of IVHS technologies that would contain actions that can enrich exogenously generated projects. As experience with IVHS technology builds up over time the action base will become richer with more articulated actions and techniques. An illustration of how the action base can be used to strengthen the project generation stage of the process is presented later in this Chapter.

Data and Knowledge Base. This is a multi-layered warehouse of data at various levels of information and knowledge content used to support PLANiTS (Figure 4.3). Methods of knowledge extraction and case based reasoning are used to convert data into relevant knowledge that is generic (i.e., more generalizable than the data from which it derives). This knowledge is used to support the brainstorming process of system diagnosis and problem definitions. It is also an important resource for enriching the knowledge based expert system which advises on the selection of models methods of analysis. We describe the data and knowledge base in greater detail in Chapter 6.

Methods and Tools Base. This base is also multi-layered. It contains a methods base with analysis methods of different levels of intensity and specificity. The first layer is simply the expert system which attempts to address analysis on basis of information in its base. If more detailed analysis is necessary, then the methods base will provide options varying from aggregate simulations to detailed disaggregate models that are more detailed and more specific in nature (Figure 4.3). The Methods and Tools Base also contains a set of tools which provides analysis support through statistical and network models. As we describe further on, the results of applications of detailed models will be fed back into the knowledge base and the expert system. Thus, with repeated applications of PLANiTS both the knowledge base and the expert system will

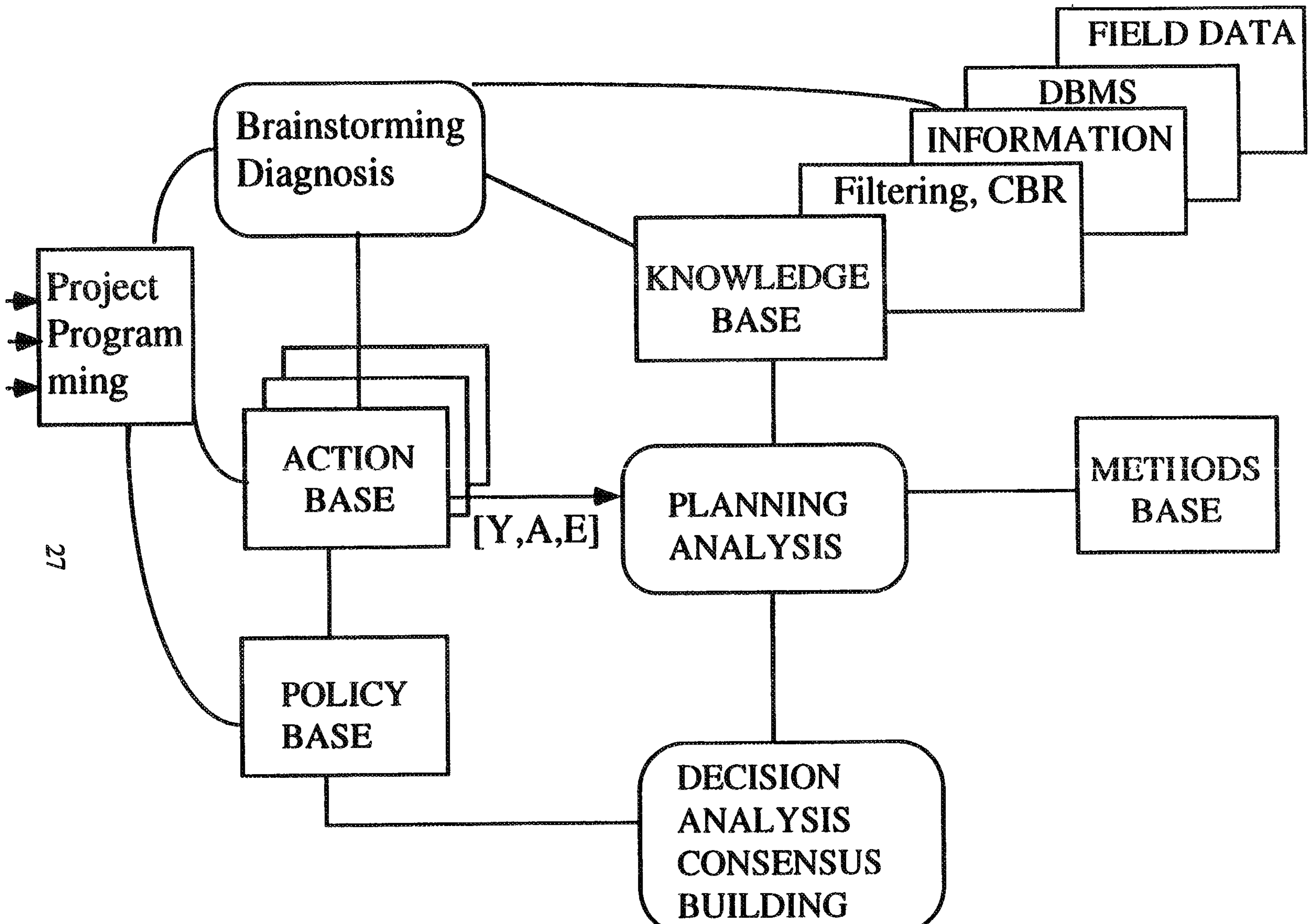


Figure 4.2 Brainstorming and diagnosis in PLANiTS.

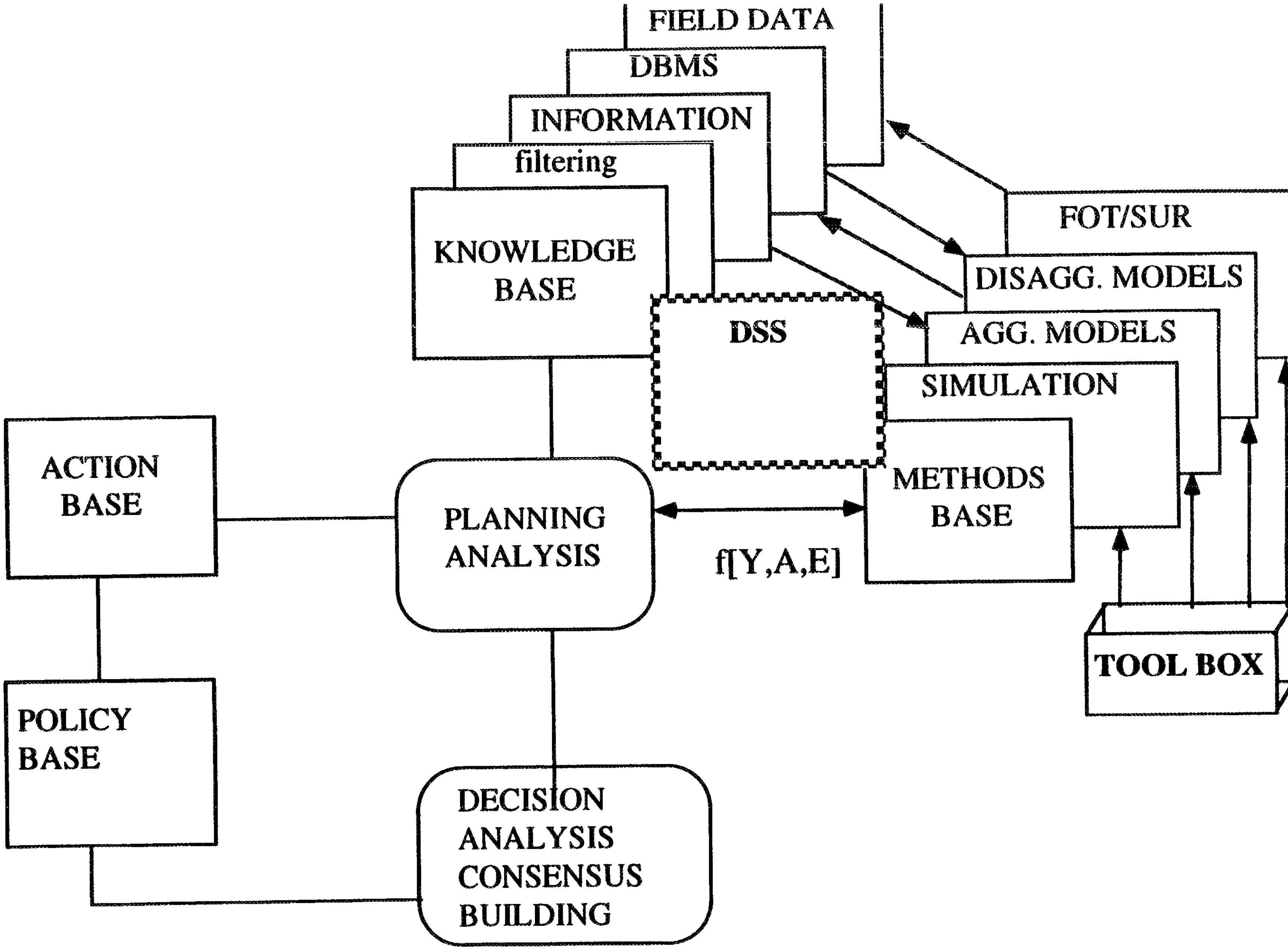


Figure 4.3 Details of the methods and tools base.

gradually become richer. The need for detailed modelling and elaborate data collection will be expected to decline.

Deliberative Planning and Analysis. At the heart of PLANiTS is an interactive deliberation among the participants in a planning activity. This deliberation is facilitated by an expert who could be a person familiar with planning and analysis and who understands and can facilitate the negotiation and adjudication that take place among the various participants. The facilitation is also assisted by an intelligent moderator based on the expert system and on computer assisted deliberation techniques. The extent to which this facilitation will be done primarily by the human expert or by the computer system is not clear yet and remains to be determined on the basis of experience with PLANiTS. In any case we would expect that the replacement of the human expert with a computer based system will be a long and slow process and probably never a total replacement. In this phase of the process participants will explore various actions, will analyze and predict measures of performance and will eventually agree on a smaller set of actions that would be considered candidates for programming.

Consensus Building and Programming. In this phase the results of the planning analysis are used in a deliberative process that is aimed at seeking consensus on programming decisions (also see Kanafani et al. 1993). This process uses an intelligent facilitator who would synthesize the results of analysis, identify areas of conflict that require resolution and point to areas of consensus that may not be obvious on the surface. Trade-offs and compromises are done in this phase. Feedback into the analysis base or to the policy base are possible and will probably be necessary as the programming deliberations continue. A number of consensus building techniques are available to assist in this process. These are discussed in more detail in Chapter 8.

Conducting Transportation Planning with PLANiTS

In this section we describe the planning process as it might be conducted within the PLANiTS environment. We use as an illustration a proposed HOV facility and associated actions. Clearly, in a real life planning situation such a proposal would be one of many being advocated by various members of a planning team. We found that the simplified example is very useful for purposes of exploring how PLANiTS might work.

The Planning Vector

The subject of analysis and deliberations in the planning process supported in PLANiTS is a *planning vector, PV.* This is a multidimensional construct which contains three sub-vectors describing the actions proposed, the criteria for their evaluation and the environment in which they are considered. The planning vector has the following form:

$$PV = (A, Y, E)$$

in which,

A an action vector

Y a vector of criteria

E an environment vector

The action vector, A, contains the elements of a proposed transportation action. These could represent a physical action, such as the construction of a facility, an operation action, such as a traffic control measure, or any combination of these. Projects may be originally proposed by individual participants in a planning process, or they may be emerging from the Policy and Goals base as mandated projects, or as opportunity projects for which funding is earmarked.

The criteria vector, Y, contains the agreed upon measures of performance that will be used in considering the proposed actions in A, the mandated constraints and planning goals that are specific to the actions in question.

The environment vector, E, contains the relevant descriptors of the environment within which the proposed actions are being considered. These descriptors reflect the specific socioeconomic and geographic characteristics of the urban area where the actions are contemplated.

Working individually or in groups, PLANiTS users will be able to interact with the policy and goals base, the action base, and the knowledge base to develop the elements of the planning vector. Throughout this process, and with the help of an intelligent facilitator, the users seek consensus on actions, measures of performance and relevant descriptions of the environment.

A Diagnostic Tour

To diagnose transportation problems in the region of interest, PLANiTS will provide a tour of the region in terms of selected measures of performance, that could include congestion, air quality, accessibility and safety. The tour is intended to inform users about questions such as the temporal patterns of congestion, the location and duration of bottlenecks, and the incidence of accidents and incidents. This diagnostic tour is conducted as a brainstorming session supported by the PLANiTS bases. This diagnosis may (re)define the problem in the users mind by increasing awareness of the problem's temporal and locational specificity, consistency across locations and future validity (by exploring projections available in the knowledge base) . The information will be critical in (re)evaluating the extent of the problem and will help establish short-term and long-term goals. During the tour, PLANiTS will be able to access the most recent and updated data base. It is conceivable that incoming real-time information from a traffic operations center might be processed and displayed to demonstrate the extent of a perceived problem. The diagnostic tour will help identify symptoms, setting the stage for exploration of feasible actions.

In addition to providing users with information, PLANiTS would have acquired knowledge about users' interest in specific measures of performance, Y, and the environment E. A summary of this information will be provided to users; then they will be asked to define the time horizon for planning and the initial formulation of actions.

Selecting the Elements of PV

The selection of elements of *PV* can be done in a variety of ways. The elements of A are often generated exogenously to begin with. Planners often have projects identified on the basis of perceived needs, or perceived problems. Often there is local consensus on certain projects that are then brought to the planning processing at a higher metropolitan or regional level. Projects are sometimes mandated by legislation requiring certain actions such as trip reduction measures. Within PLANiTS these projects are filtered through the Action Base in order to produce the A elements of the planning vector. This filtering process is conducted by searching through the action base for ways to enhance the project specifications with elements of technology, such as IVHS that may not have been considered when first defining these projects. The knowledge base is also interrogated, and using its case based reasoning elements or knowledge base expert systems would suggest articulations and modifications to the proposed actions. An important role of PLANiTS would be the capability to introduce elements of IVHS technology into the construction of action vectors. For example, an HOV project may be proposed in a particular urban corridor. The action base would invoke a search through its IVHS taxonomy to identify elements that enhance such a project. Integrating the HOV project with an ATMIS program, modifying its elements (such as persons per HOV, time of operation, entry priority, etc.) on the basis of real time traffic information. Introducing automated toll collection technologies using AVI would also be another modifier that could be suggested by the action base. The net result in this case would be an articulated A vector that defines a richer HOV plan and one that possibly more closely matches the elements of the policy and goals base. The specific descriptors of the HOV project would be given by the elements a_i of the action vector A. For example:

$$A = A(a_1, a_2, a_3, \dots)$$

where a_1 might be the length of the HOV lane

a_2 might be the number of persons required per HOV

a_3 the time period over which the HOV control would be in effect.

The elements of the criteria vector Y would be selected by a similar process of deliberation and interrogation of the knowledge base and the policy and goals base. The planners are faced with a number of objectives, constraints and criteria. The extent to which these are tradeable or otherwise subject to negotiation is open. While total consensus is not required here, indeed it may not even be possible, it is necessary for the planners to agree on the set of criteria that they wish to carry forward in the *PV*. The purpose of PLANiTS in this regard would be to help the users trim the size of the Y vector as much as possible. This is done in order to simplify the subsequent analysis needed to evaluate *PV*, and to simplify to a manageable level the amount of deliberation necessary during the decision making phase. One can easily imagine how difficult, if not impossible, the task of seeking consensus would be in a multi-criteria decision making situation if the number of criteria exceed about half a dozen. In the case of an HOV project, the planners may agree on a limited set of criteria for evaluation including average occupancy, emissions, and corridor travel time, and might decide to include equity issues but exclude safety, and so forth. The resulting criteria vector might look like this:

$$Y = Y\ (\ y_1, y_2, y_3, \ldots.)$$

where

- y_1 might be the average vehicle occupancy in the corridor
- y_2 might be the per unit emissions during given periods of time
- y_3 the travel time in the corridor for HOV users
- y_4 the travel time for non-HOV users.

PLANiTS will also assist the planners in defining the environment of the project by selecting the relevant elements of the E vector. This can be done by synthesizing the results of the diagnostic tour and by looking to the knowledge base for suggestions on what are relevant descriptors of the environment for the purposes of this particular planning vector. PLANiTS might suggest that for the HOV project under consideration the density of development, the average commute O-D trip length, and the average network transit accessibility in the corridor might be relevant. The users might agree to adopt these but to add average income in the region. The selection of environment descriptors requires a trade-off between specificity and generality. Specific descriptors would permit more thorough analysis of the planning vector, but more general descriptions would facilitate the search through the knowledge base and would permit more dependence on the expert system for analysis, thereby avoiding lengthy and data intensive analyses. The resulting environment description vector might look like this:

$$E = E(e_o, e_1, e_2, e_3, \ldots.)$$

where

e_o might be the geometry of the corridor

e_1 might be the average commute O-D trip length in the corridor

e_2 might be the corridor density of development

e_3 might be corridor transit accessibility

Analyzing the Planning Vector

With the planning vector *PV* defined, the user can now proceed to the next phase in PLANiTS. Here the planning vector, together with others that would have been generated in a similar fashion would be subjected to analysis and deliberation. The purpose of the analysis is to estimate the specific values of the elements of Y, i.e., the criteria for evaluation. In this process, it is also possible to conduct optimization and to adjust the specific values of the elements of the action vector A. This analysis and deliberation process is conducted with the help of a knowledge based expert system which interrogates the knowledge base and the methods and tools base. The system explores ways to predict the performance of the proposed actions against the agreed criteria. In doing so the system seeks to minimize the intensity of modeling and the intensity of primary data collection. By searching in the knowledge base and looking for similar planning vectors, the system would suggest answers to the user, who would consider whether to accept them or to go for more thorough analysis. We would expect that for fairly well known actions, such as HOV lanes, considerable knowledge would be available in the knowledge base. Predicting the performance of such planning vectors might be done totally on the basis of such knowledge. On the other hand if *PV* were to include some new technologies with which experience is limited, as advanced route guidance systems, then major primary information collection such as through field operational tests, may be unavoidable. The users have the option of intervening in this process and deciding on the desirable level of modeling intensity.

Seeking Consensus on Programming

By the consensus seeking and programming phase PLANiTS would have synthesized the results of the analysis and summarized the values of the criteria vectors. Areas of dominance would be identified and described, as well as situations where a trade-off is necessary. These syntheses would permit the planner, perhaps with the help of an intelligent facilitator to deliberate and seek consensus on programming actions. PLANiTS would contain, in its tools base a variety of models of multi-criteria evaluation and decision making. Calculating schemes such as Saaty's Analytical Hierarchy Process would reside here and be ready to assist the planners by synthesizing the deliberations and highlighting the important aspects of the negotiation. Considerable feedback would probably occur at this stage, as the planners go back through PLANiTS to revise certain elements of the planning vector in order to explore the impacts of different actions or policies.

There are a number of techniques for providing computer aided facilitation to this process. We explore in Chapter 8 some of these techniques with a view toward selecting an appropriate element for development within PLANiTS .

Chapter 5

THE STRATEGY AND ACTION BASE

The strategy and action base contains a set of actions to increase transportation supply, reduce demand, increase mobility or otherwise improve system performance. It would recommend a set of primary actions which have significant impacts on system performance and possible add-ons. A primary strategy could be the construction of HOV lanes and supportive actions could be:

- Construction of Park-and-Ride facilities.
- Construction of exclusive HOV ramps and flyovers.
- Enforcement facilities.
- Advanced Public Transportation Systems (APTS) offering real-time rideshare matching.
- Parking pricing and employer based programs.

The following sections develop a structure for the strategy and action base.

A Taxonomy of Actions

The way actions are combined and implemented is critical in determining their impacts. For example, the joint implementation of ATIS and ATMS technologies may provide greater benefits than the sum of their individual benefits. Further, the attributes of actions, e.g., the extent of economic (dis)incentives will determine their impacts.

Another example of mutually reinforcing actions is that of Automatic Vehicle Identification (AVI) technology used in conjunction with a congestion pricing strategy. This also points out that separating technology and non-technology actions may be unnecessarily restrictive. The feasibility of implementing technology actions along with non-technology actions should be considered where appropriate.

Table 5.1 is an "action interaction" matrix which shows which actions are mutually synergetic and which are at cross purposes. The matrix also shows *dependence* among actions. For example, field operational tests may show that Advanced Traveler Information Systems cannot be implemented without a comprehensive advanced transportation management and surveillance system. Another example of dependence among actions is that suggested by Varaiya and Shladover (1991) who argue that ATIS and ATMS should be designed to accommodate more futuristic AVCS technologies.

The impacts of actions can be measured in terms of measures of performance. Table 5.2 presents the structure for a taxonomy of actions based on their impacts. The system impacts may be general (measured in terms of congestion, air quality, safety and accessibility) or action-specific (e.g., changes in neighborhood traffic due to ATIS). The individual level impacts may be tangible from the perspective of the individual (e.g., travel time savings and increased accessibility) or intangible (e.g., increased comfort and convenience).

Certain actions may have greater institutional support than others. This area is becoming increasingly important as recent policies encourage joint ventures between public and private organizations. Thus, actions may be considered from the perspective of their implementability and organizational support.

The taxonomy matrix gives an impression that actions can be related to individual measures of performance directly. However, there are intermediate steps which must be considered in evaluating impacts. A major step involves understanding how actions may influence individual decisions. Individuals' choices include lifestyle decisions, accessibility decisions, and travel (and trip substitution) decisions. Table 5.3 presents a method to analyze the impacts of actions on individual decision making focussing on new technologies. Depending on the nature and attributes of each (technology) action, the effects may vary across these decisions. This is illustrated more clearly when the decisions are considered individually (Figure 5.1). The key point is that actions can be mapped to specific decisions. The following paragraphs provide examples which focus on new technologies:

Long-Term Lifestyle Decisions. The decisions to form families and participate in

Actions	Measures of Performance				
	System		Individual		Institutional
	General	Action-specific	Tangible	Intangible	
	Congestion Air Quality Safety Accessibility	Tech. perf. Nbd. traffic	Travel time Access	Convenience Comfort	Implementability Org. support
Demand-side actions ATIS (auto) •Pre-trip info systems •Enroute info systems TELE-TECHS •Teleworking •Teleshopping DRIVER WARN. & ASSIST •Collision warning •Obstacle detection •Smart cards (AVI) *Supply-side actions* AVCS •Lateral control •Longitudinal control ATMS •Signal control •Ramp metering •Integ. Fwy/Art					

Environment

Table 5.2 A taxonomy of actions.

Actions	Decisions																		
	Short-term travel								Short-term trip substitution				Medium-term accessibility				Long-term lifestyle		
	Mode	Destination	Departure time	Pre-trip route	Enroute diversion/return	Parking	Trip chaining	Trip frequency	Teleworking	Teleshopping	Teleconferencing	Telerecreating	Auto ownership	Residential location	Residential type	Employment location	Family formation	Labor participation	Other
DEMAND-SIDE ACTIONS																			
ATIS																			
•Auto																			
•Transit																			
ATMS																			
•Signal control																			
•Ramp metering																			
•Integ. Fwy/Art																			
DRIVER WARN. & ASSIST																			
•Collision warning																			
•Obstacle detection																			
•Smart cards (AVI)																			
TELE-TECHS.																			
•Teleworking																			
•Teleshopping																			
SUPPLY-SIDE ACTIONS																			
AVCS																			
•Lateral control																			
•Longitudinal control																			
FLEET MGT TECHS																			
•Passenger counting techs.																			
•Fare payment techs.																			
•Reservation/matching techs.																			
SPECIALIZED VEH																			
•Lean machines																			
•Electric vehicles																			

Table 5.3 Impacts of actions on decisions

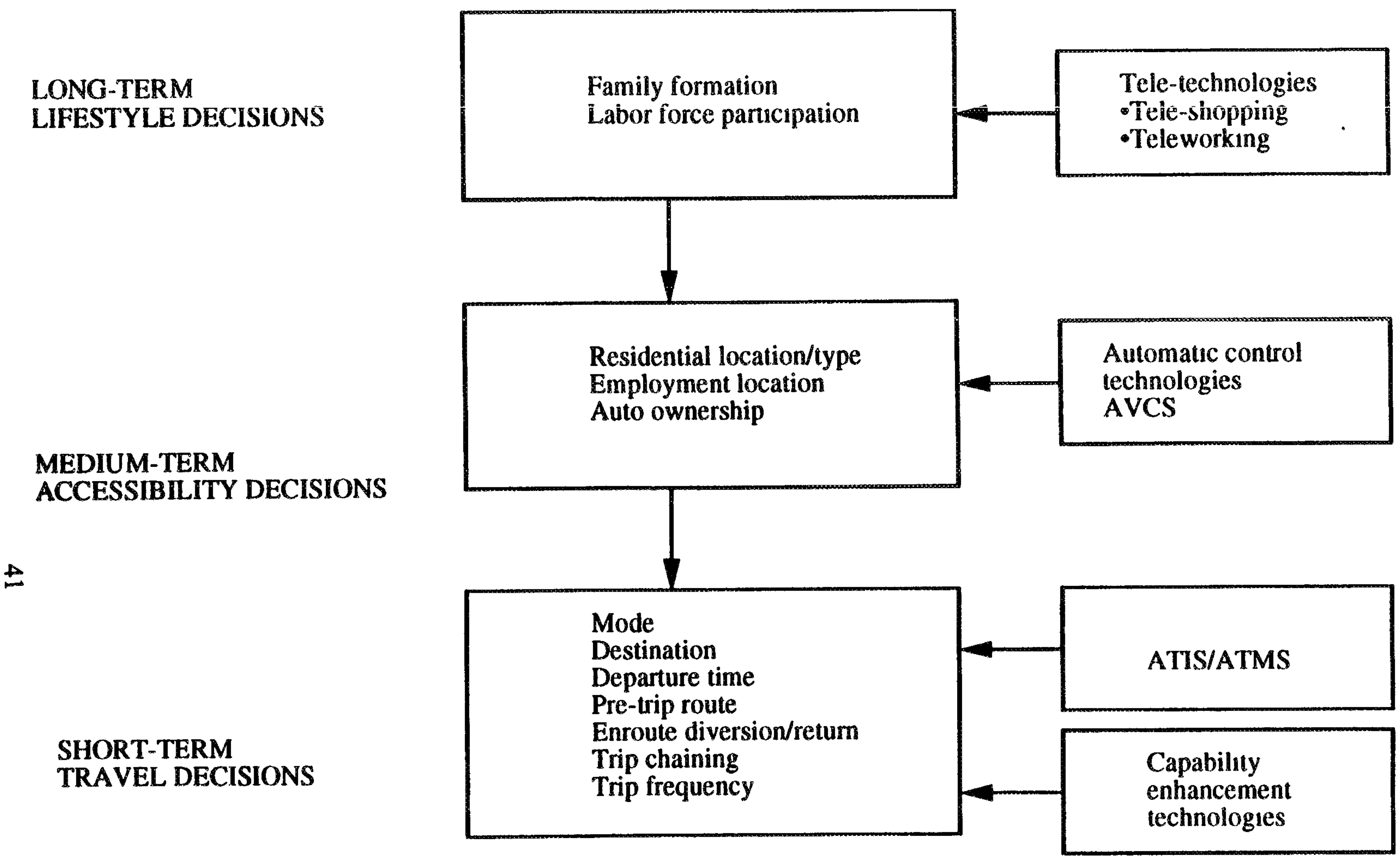


Figure 5.1 Hierarchy of various decisions and influence of technologies.

the labor force may be impacted by tele-technologies. For example, a person who previously would have stayed home to raise children may now be able to do so while participating in the labor force through tele-working Alternatively, individuals may be more likely to form families because tele-technologies allow them to work at home. Clearly, causality is hard to establish in this case.

Medium-Term Accessibility Decisions. Individuals may change their residential and work location, and automobile ownership choices due to the availability of automated highways. Specifically, AVCS may decrease the travel time between home and work significantly, allowing people to relocate further from their work places. These technologies may make automobiles even more attractive by lowering the cost of travel, possibly increasing levels of auto ownership Alternatively, new transit technologies may make travel by transit or carpool more appealing--decreasing the need for owning automobiles. Congestion pricing implemented with AVI technologies can encourage people to relocate more closely to work.

Short-Term Trip Substitution Decisions. Individuals may substitute their travel (whether or not to make a trip) by teleworking, tele-shopping, tele-conferencing and tele-recreating. Although tele-technologies may suppress demand, they may also generate travel. For example, the automobile of a person who now works at home may be used by his or her spouse or child.

Short-Term Travel Decisions. Short-term travel decisions consisting of mode, destination, pre-trip route, enroute diversion/return, departure time, parking, trip chaining and trip frequency decisions may be directly influenced by ATIS and by early versions of AVCS such as driver warning and assistance technologies.

Advanced Technologies: A Definition

New technologies form a large set of actions, therefore we distinguish between what constitutes primary actions and add-ons. New technologies can range from a simple map to automatic vehicle control. For the purpose of transportation planning, we suggest that a definition be based on whether impacts of the technology are incremental or non-incremental. Improvements such as providing a map or installing an actuated traffic signal are incremental (and can be referred to as "Improved"

Vehicle Highway Systems), whereas automated highways and advanced information systems are non-incremental improvements (and can be classified as "Intelligent" Vehicle Highway Systems). To further clarify these distinctions, necessary conditions for new technologies are as follows.

Non-incremental new technologies should provide *significant* tangible benefits to individuals, such as travel time savings. They should also provide *measurable* system level benefits upon deployment. For instance, the impact of a non-incremental technology should be measurable in terms of at least one system level evaluation criterion. The system level criteria may include (but not be restricted to) congestion, air quality, economic productivity, accessibility, safety and energy efficiency.

Non-essential features for non-incremental new technologies are:

- Whether a technology will allow and facilitate communication between various levels in the system. For example, integration of freeway and arterial operations may help in designing better strategies for diverting drivers in incident conditions.
- Whether the technology aims to develop and facilitate system level monitoring, guidance, and control. Not only does Advanced Transportation Management System enhance system control, but information disseminated through ATIS may also be used as a "soft" control when unexpected events occur.
- Whether a technology supports both activity participation and travel decisions. For example, ATIS can be designed for route guidance only, or it may support travel as well as activity participation decisions. Broader decision support is more desirable. Furthermore, the technologies may encourage trip substitution as well as support accessibility and lifestyle decisions.
- Whether a technology will substitute for some of the driving tasks through automation (enhancing capabilities of individuals while they are traveling). Specifically, AVCS technologies may assist individuals in controlling their vehicles (e.g., steering, speed) and help in guidance (e.g., overtaking). Ultimately, they may allow the complete automation of vehicle operations.

The requirements for primary actions presented here do not preclude actions which do not satisfy the criteria. In fact such actions are to be considered as add-ons to primary actions.

Chapter 6

THE DATA AND KNOWLEDGE BASE

The main elements of the data and knowledge base system are. intelligent data bases, a case base and an expert base. The data bases will have information on existing transportation facilities and operations, land-use, demographics, travel patterns and projected travel patterns and demographics. The case- and expert-bases would contain relationships between system components. The relationships can be theoretical (e.g., cost of transportation influences mode selection), empirical (e.g., analysis of data shows that the quality of information mode selection) and prescriptive (if such is the case then do this). Further, the theoretical relationships can be causal (change in A results in a change in B), a-causal (changes in A and B may be related) or functional (organization A employs individual B). The data and knowledge base will have two modules: a case-based reasoning (CBR) module and a knowledge-based expert system (KBES). These modules will form part of the transportation planning Decision Support System (Manheim and Isenberg 1986; Vlahos 1992; Rich 1983; Guariso and Werthner 1989).

Initially, knowledge from field operational tests and early experiments will be represented in the CBR module. As and when a sufficiently large body of knowledge develops, the expertise will be embedded in the knowledge-based expert system. Thus PLANiTS will allow users and computers to interact synergistically and users will have access to recent information stored in the knowledge base. The elements of the data base are discussed first, then the case-based reasoning system and the knowledge-based expert systems are discussed.

Operationalizing Relationships

Before proceeding, a method for operationalizing relationships from the literature, experts, and inferences from responses of users is needed; consider the processing of literature as example. Relationships based on state-of-the-art research regarding actions and their impacts will be synthesized. The knowledge base will integrate the results from reports and published material. Literature can be placed on a continuum of relevance for planning decisions. Acceptability of research studies may be determined through soliciting opinions of researchers and practitioners. Each study will be checked by evaluator(s) for a problem definition, clearly defined objectives and generalizability of results and inferences. The evaluators will use the following list of criteria for inclusion of relationships in the literature base.

- *Relevance of study to planning decisions.* Ideally, the information presented to users should support their planning decisions. Providing information about studies that are not relevant to transportation planning is undesirable.
- *Expected benefits.* The benefits of the study from the standpoint of what researchers, practitioners, and interested individuals will gain from the results. In addition, the contribution of the study to transportation practice and to the body of knowledge is important.
- *Potential for deriving "rules" and relationships from the study.* Whether or not the study can be used to derive IF, THEN type rules and whether the study analyzes relationships between variables influences its acceptability.
- *Normative or descriptive study.* Often studies contain descriptive and in some cases normative models. It is important to identify whether the information is descriptive or normative. Descriptive models may be more generalizable than normative models, depending on the context.
- *Level of modeling intensity.* Often there are opportunities to analyze some aspects of the problem before conducting the field experiments. Whether a study is pre-experiment analysis (e.g., new empirical/simulation models based on new data, existing models and existing data, analysis of literature) or evaluation of a Field Operational Test (FOT) determines its level of modeling intensity. Higher modeling intensity will be associated with greater acceptability in the literature base.
- *Type of study and sophistication of concepts and analysis.* Whether a study is largely qualitative or quantitative determines its type. Qualitative studies may

identify conceptual relationships. Quantitative (model-based) studies will yield relationships once they satisfy the following criteria:

- *Conceptual and methodological structure.* The relationships between system components should be explicitly conceptualized and they must be reasonable. Any simplifying assumptions should be recognized and mentioned. Further, the procedure should be logical, comprehensive and defensible. In case of field operational tests the procedure for investigation and the experimental design should be clearly defined and the reasons for selecting a particular methodology should be elaborated.
- *Simplicity.* The model should be comprehensible at a conceptual as well as mathematical level. Models may become complicated if the modeler attempts to be accurate. So there is normally a trade-off between simplicity and accuracy. In any case the analysis should result in meaningful conclusions and useful recommendations with regards to study objectives. Greater sophistication of analysis can sometimes result in more substantive conclusions. For example, the multivariate approach is distinctly superior to the examination of variables independently as it compensates for inter-dependencies among explanatory variables and allows exploration of interaction effects. Further, explicit treatment of uncertainty is likely to enhance the accuracy of analysis (but add complexity).
- *Validity.* Models are valid if they adequately represent reality. Further, it is desirable to have the ability of testing model predictions against real behavior.
- *Action sensitivity.* Action sensitive models should be able to estimate the effects of strategies in terms of performance criteria. The model should allow for explicitly evaluating the effect of changing action sensitive variables (which the user can presumably control).
- *Data Requirements.* Some models are more data intensive than others, i.e., they require more data for calibration and prediction. Data requirements influence the ability to validate model components and

outputs.

- *Originality of the study.*
- *Nature of the study.* Whether the study develops static or dynamic models is important. Often changes in behavior of a system are better modeled when considering the time dimension.
- *Specificity of study.* Studies can range from very specific to very vague. More specific studies are desirable. Further, the level of information detail can vary across studies. For example, sometimes authors leave out details needed to assess the validity of conclusions.
- *Consistency of research findings.* Whether the research findings are internally consistent as well as externally consistent (with the similar studies).
- *Timeliness of study.* Whether the study addresses the "burning" issues in the field may increase its likelihood for inclusion.

Studies become "old," with time; depending on the nature and content of studies they may age differentially. There will be a mechanism to remove cases and rules based on studies that become obsolete.

Database

The database would contain information on individual behavior, system performance and institutional behavior as well as a description of the data. The individual behavior database may consist of interviews/focus groups, cross sectional and longitudinal surveys, vehicle movement logs, and human factors data. The behavior database will allow users to obtain information on travel patterns (origins and destinations, mode choice, stated and revealed preferences regarding new technologies), accessibility decisions and lifestyle choices. The system performance data can be general (loop detector data on occupancy and volumes, safety data, energy consumption data and pollution data) or action-specific (information system performance, control system performance).

To diagnose transportation problems, system performance can be represented on a Geographic Information System (GIS)--however, this does not preclude other data representation methods. The GIS will have the spatial distribution of objects and information about them. It will be used to superimpose measures of performance such as congestion, noise and pollution. Some of these will be subdivided into categories, for example, congestion will be characterized as incident induced or recurring.

Data can be stored on flat files, in a relational database management system (RDBMS) or an object-oriented database management system (OODBMS). While each storage method has advantages in specific contexts, their usefulness and applicability will be ascertained in the second Phase of the project.

Case-Based Reasoning Module

Humans acquire, process and store useful information in their memory and later retrieve it to address new situations. They have the ability to learn from their experience and are often able to better address similar future situations. For example, having driven a roadway, a person becomes familiar with it and can anticipate the highway features often resulting in better driving performance. Case-based reasoning (CBR) uses the idea of learning from experience in the context of computers. Experiences stored in the computer memory are recalled to address new situations. CBR relies on simple logic rules, for example it can recommend concepts that did work and it can warn against things that did not work.

CBR is a relatively new paradigm in Artificial Intelligence (see proceeding of workshops on Case-based reasoning sponsored by DARPA 1988, 1989, 1992). It determines the similarity of past cases to a present situation, retrieves relevant cases from computer memory and informs the user about how similar situations were addressed and whether the solutions were successful. The advantages of CBR approach are as follows (DARPA 1989):

- Causal models of past cases can be represented to obtain insights and explanations. However, learning through comparison of the current case with an earlier one does not require a causal model. This is particularly appealing in contexts where notions of causality cannot be applied easily, e.g., in predicting second order effects. More importantly, in the relatively unexplored area of planning for new transportation technologies, where knowledge about technology performance is limited, the relaxation of this requirement is especially relevant. Initially, implementation decisions can be made by examining evidence from field operational tests. Successful field operational tests can be replicated, whereas past mistakes can be anticipated and avoided.

- In the field of transportation, there are some existing cases which can be used to "seed" a case-based system. Many more cases will become available as the results from field operational tests on new technologies begin to filter in.

An important limitation of CBR in the context of transportation planning is that no two cases are exactly similar. Judging similarity of cases is often difficult, and sometimes arbitrary, because the methods for comparing cases are not well developed (research on this topic is limited, see DARPA 1989 for a discussion of "preference heuristics"). Further, if two cases are similar enough, it is often difficult to modify the previous cases sufficiently to provide useful insights and predictions. For example, to analyze impacts of a two, three and four person per vehicle HOV lane on traffic congestion, some insight might be obtained from experience with a two person per vehicle HOV lane. However, it will be difficult to modify the previous case sufficiently to numerically predict the congestion impacts of a three or four person HOV lane.

The following sections discuss the application of CBR in PLANiTS. The objective is to explore how CBR can help in basic and advanced analysis. The specific components of a PLANiTS CBR module are presented and steps in using the system are discussed.

Case-Based Reasoning for PLANiTS

PLANiTS can use case-based reasoning during two stages. Firstly, at a basic analysis stage, for providing information regarding impacts of actions. Specifically, users' brain storming activity and action generation may be supported by informing them about the impacts of similar actions taken in the past. Further, if similar cases are not available, CBR will be used to decide whether advanced analysis are needed. Secondly, at a more advanced analysis stage, CBR will be used for comparing the concepts (relationships between variables) and data (raw and processed) for the current case with stored case(s). The parameter estimates for a current mode choice model can be compared with estimates from a retrieved model, and obvious discrepancies identified. Further, the past mode choice model can be modified to obtain additional insights (a procedure similar to model transferability analysis). The analysis will allow assessment of impacts by not only informing users about similar cases but also modifying past cases to obtain deeper insights into action consequences.

The information presented to users can be descriptive, prescriptive or both. An example of descriptive relationships is that "given certain conditions, HOV lanes often reduce traffic congestion." Example of a descriptive and prescriptive relationship is "given the similarities of travel patterns between corridors X and Y, and that HOV lanes often reduce traffic congestion, it seems reasonable to implement HOV lanes in the current situation." Further, not only the positive consequences of actions will be presented but also warnings against actions that did not produce the desired impacts or resulted in unanticipated negative consequences will be given. Suppose that experience from field operational tests of route guidance systems show that they successfully reduce congestion when there is surplus capacity on alternate routes and when alternate routes do not pass through many neighborhoods. Further, that route guidance systems sometimes congest alternate routes and cause safety problems. If in the current case, the alternate routes do pass through many neighborhoods but have significant surplus capacity, then information regarding overall success of ATIS in reducing congestion will be presented along with warnings about possible opposition from local communities and occasional congestion/safety problems.

Components of the Case-Based Reasoning Module

This section describes components of the PLANiTS CBR system. It relies heavily on the work of researchers in the CBR domain (see DARPA 1988, 1989, 1992). At the core of case-based reasoning is the nature of comparison between cases. These can be of the following types:

- Comparison of qualitative criteria and descriptions for the two cases. For example, comparison criteria can be whether or not traffic congestion is a serious problem in the region of interest, and whether or not infrastructure is available to support an action.
- Comparison of underlying relationships in the two cases. A conceptual model can have descriptive (causal, a-causal or functional, empirical) and prescriptive relationships between concepts and physical entities. Further, class hierarchies may exist between system elements. Whether or not the important relationships and structures hypothesized in the current case are also present in the retrieved case will influence similarity among cases. For example, when analyzing travelers' route choice, one may expect that it will be influenced by attributes of the travelers and alternatives. A similar retrieved case would have the same structure.
- Comparison of quantitative attributes between the two cases. The quantitative attributes can consist of raw data (e.g., design characteristics for a technology and transportation infrastructure) or processed data (descriptive statistics and parameter estimates).

The cases, collected from literature and experts, will be stored in an object-oriented "case base" because of its greater generalizability. All cases in memory will be indexed according to actions, performance measures and the environment. A **matcher** will provide a listing of similar cases by accessing them through the index. In the advanced analysis stage, a **resolver** will resolve differences between the retrieved and current case and a **chooser** will then screen the initial matches using more stringent goodness of fit criteria. If predictions are required and/or several relevant cases are retrieved, then an **analyzer** would provide predictions and compile evidence from the cases. A **reviewer** would provide "sanity checks" and veto a match or provide warnings about the (in)compatibility of the cases. The prescriptive reasoning mechanism would be responsible for making recommendations. It will rely on rules such as do not recommend actions which are "double edged swords." After an action is implemented and results on its performance (success or failure) become available, an **assimilator** will acquire and store the information for future use These components will be discussed in greater detail in a separate report.

Research Issues in Case-Based Reasoning Development

Some cases will have complex structures and sub-classes. There is a need to represent clearly the connections between components and also the various types of relationships that can exist among the components. The object-oriented approach provides a mechanism for representing such relationships and supports storage and retrieval of complex structures. Further, there is a need to combine CBR with the rule-based expert system as well as the models in the methods base. This will be done within the context of PLANiTS.

In analyzing complex transportation problems, a previous case may address part of the problem, requiring additional cases to address the remaining problem. For example, to analyze the impacts of HOV lanes on congestion, an equivalent case may be found, however, the same case may not be useful if congestion impacts of combined implementation of HOV lanes and ramp metering were needed. A structure will be developed to organize and use knowledge from different cases to address complex transportation problems.

Knowledge-Based Expert Systems Module

When faced with a problem, individuals have the ability to process information stored in their memory and *reason* with the available knowledge. Knowledge-Based Systems (KBS) mimic the memory and reasoning capabilities of human beings. In so doing, their objective is to equal and preferably surpass humans' problem solving abilities.

Knowledge-Based Expert Systems (KBES), a branch of KBS, are computer programs which use reasoning to solve problems and help users make decisions. Expert systems are being developed widely in transportation (OECD Workshop on

Knowledge-Based Expert Systems, 1990; Tung and Schneider 1987; Ritchie 1987) and have been integrated with other useful analysis techniques, e.g., Seetharam et al. (1990) have applied expert systems along with GIS to evaluate transportation policies.

KBES can consider imperfect information (e.g., when relationships between system components are not known reliably) and solve mathematically ill-defined problems. One requirement for developing expert systems is that some expertise must exist. In transportation sufficient expertise is available to "seed" the PLANiTS KBES, and more information is being generated rapidly from field operational tests and technology deployment. KBES provide a natural progression from intelligent data bases and Case-Based Reasoning systems in that only when sufficient knowledge is accumulated will it be transferred into the expert base. The knowledge will be obtained from field operational tests, selected literature and human experts. The main limitation of expert systems in the context of transportation planning is that problems are usually complex and there are seldom "experts" or studies that the participants can mutually agree upon.

The following sections discuss the application of KBES in PLANiTS. The objective is to explore how KBES can help in analysis. The specific components of a PLANiTS KBES module are presented.

Knowledge Based-Expert Systems for PLANiTS

In the context of PLANiTS, the problems are often complex due to the nature of issues involved, incomplete data bases, lack of adequate models, and the need for deliberation and negotiation. At the same time, the process of extracting domain-specific knowledge and transforming it into rules usable in KBES requires a structure. The available knowledge from literature, for example, is sometimes inaccurate, poorly structured, fragmented, and incoherent. Collecting, integrating, processing, refining, filtering, and structuring knowledge of transportation systems for representation as rules will be done in PLANiTS.

Most current KBES are rule-based, and often use empirical relationships and/or subjective knowledge acquired by human experts. Such systems do not perform adequately beyond the boundaries of their knowledge domain. The PLANiTS KBES will embody "deep" knowledge about causal, a-causal and functional relationships. Such systems, when developed will presumably perform better than systems based solely on empirical relationships. Thus, KBES in PLANiTS will have conceptual models which allow deeper reasoning when rules are insufficient to address the problem.

Once developed and validated, the KBES will form part of the knowledge system which meets the requirements of different planning agencies and will allow for rapid processing and integration of information on new technologies from field operational tests.

Components of the Knowledge-Based Expert Systems Module

An expert system requires a set of inputs, which describe the current transportation problem; the inputs are processed through an inference mechanism which has functions and operators and produces a solution/advice. This is communicated to users through a set of outputs.

The main components of KBES module are knowledge (facts, relationships and heuristics represented on a continuum of soft and hard rules), an inference mechanism and a user interface. The domain-specific knowledge is stored in the expert base where it is accessible to the inference mechanism. The expert base has a set of rules which can be augmented, changed, or deleted by system developers. The rules have antecedents, which are conditions that should be satisfied, and consequents, which are the actions to be taken when certain conditions are satisfied. The inference mechanism is a procedure for determining application of various rules stored in the expert base, and it can be forward chaining (data-driven reasoning), backward chaining (goal-driven reasoning) or both. For example, forward chaining allows matching antecedents of rules with available information. The inference mechanism develops solutions to problems using reasoning strategies, such as Bayesian inference, to analyze both user inputs and domain specific knowledge. The expert systems will be validated by comparing the answers with case studies performed by human experts. Discrepancies can be identified and removed accordingly.

KBES will be developed in an "object-oriented" environment, which allows modeling objects and their relationships. Both static and dynamic objects, e.g., creation and dissipation of an incident, can be represented. Work has commenced on developing a KBES for HOV lanes.

Research Needs for Knowledge-Based Expert Systems

In PLANiTS, the KBES module will be integrated with other decision support mechanisms, including CBR and the methods base. The key research issue is how can the methods base perform computation when needed by the KBES and vice versa. Coupling the knowledge and methods base will require work. Another important research question is how to imbed a learning mechanism for developing rules from observing user reactions.

Chapter 7

THE METHODS AND TOOLS BASE

The method base allows individuals to use existing models or develop new models. The modeling efforts are supported by a model base, a tool base and a concept base. Within the model base, existing (UTPS) planning models (trip generation, trip distribution, mode choice and route choice) and operational models (FREQ, TRANSYT) will reside. The tool base will contain an array of generic models such as regression and simulation, to support higher levels of modeling intensity. The rules required for model retrieval, model development, and model use (choice of models) as well as rules for linking sub-models, reside in a concept base. As yet it is unclear whether the concept base should be treated as part of the methods and tools base or the knowledge base. At this point we focus on its contents.

Elements of the Methods and Tools Base

Concept Base

The rules for models will be contained in the concept base; consider rules for model development as an example. The relationships between system components, expressed as rules in the concept base, can support parameter estimation. The nature and type of relationships between system components will be specified. Table 7.1 shows a structure for investigating travel decisions. These decisions may be influenced by various actions. The impacts of actions can be quantified in terms of measures of performance. In addition to actions, individuals' decisions are also influenced by the context, i.e., attributes of the alternatives and attributes of the individuals.

The relationships will be expressed as rules. The ATIS rule may say:

IF the objective is to evaluate impacts of ATIS (action) on delays (measure of performance)

AND the impacts are to be assessed on individuals' mode choice

Actions	Decisions	Measures of Performance			
		System		Individual	
		General	Action-specific	Tangible	Intangible
	Destination Time Route Mode Chaining	Congestion Air Quality Safety Accessibility	Tech. perf. Nbd. traffic	Travel time Access	Convenience Comfort
Demand-side actions ATIS (auto) •Pre-trip info systems •Enroute info systems TELE-TECHS •Teleworking •Teleshopping DRIVER WARN & ASSIST •Collision warning •Obstacle detection •Smart cards (AVI) ***Supply-side actions*** AVCS •Lateral control •Longitudinal control ATMS •Signal control •Ramp metering •Integ Fwy/Art.					

Context
• Attributes of alternatives
• Attributes of Individuals

THEN the following factors will influence route diversion: information and its attributes, and contextual factors (attributes of the alternatives and socioeconomic characteristics).

The HOV rule may state:

IF the objective is to evaluate impacts of HOV on congestion

AND the impacts are to be assessed on system performance

THEN the following factors will influence system performance: characteristics of HOV lanes (number of lanes and persons per vehicle), supporting actions (enforcement facilities, exclusive ramps and flyovers) and contextual factors (O/D patterns in the corridor)

Similarly, rules can be developed for other actions. The concept base will also have more complex rules regarding interactions between various actions.

Model Base

A structure for the model base is shown in Table 7.2. The existing models (or their sub models) will be represented in terms of their sensitivity to various actions and model outputs in terms of measure of performance. The environment of models will be described by equations and the relevance of the model to specific situations. All models will have information on their theoretical structure, validity, accuracy and data requirements.

Tool Base

The tool base will support advanced modeling and it would be used by people experienced in quantitative analysis. It will contain generic models to be applied when users feel that the knowledge base and the existing models do not adequately address their problem. Table 7.3 shows that the models could be econometric/statistical techniques (discrete choice, regression, structural equations), simulation, and artificial intelligence techniques (fuzzy sets and neural networks). These models can be written in an object-oriented language such as C++. The structure for these models is largely similar to that for the model base.

	Action Sensitivity								MOPs			
Existing Models	ATIS	ATMS	AVCS	DRIVER WARN & ASSIST	SPECIALIZED VEH	HOV LANES	RAMP METERING	SIGNAL OPTIMIZATION	CONGESTION	AIR QUALITY	SAFETY	ACCESSIBILITY
TRIP GENERATION												
TRIP DISTRIBUTION												
MODE CHOICE												
NET ASSIGNMENT												
FREEWAY SIM (FREQ)												
ARTERIAL SIM (TRANSYT)												

Environment
Equations
Relevance

Evaluation
Theory
Validity
Accuracy
Data Reqmt

Table 7.2 Structure for a model base

	Action Sensitivity								MOPs			
New Models	ATIS	ATMS	AVCS	DRIVER WARN & ASSIST	SPECIALIZED VEH	HOV LANES	RAMP METERING	SIGNAL OPTIMIZATION	CONGESTION	AIR QUALITY	SAFETY	ACCESSIBILITY
Regression												
Structural equations												
Discrete choice												
Survival models												
Time series analysis												
Neural networks												
Fuzzy sets												
Simulation												
Queueing analysis												
Linear programming												
Multiobjective programming												
Information theory												
Bayesian decision mkg												

Environment
Theory
Equations
Relevance
Accuracy
Data Reqmt

Table 7.3 Structure for the tool base

A description of the generic models will be provided along with the appropriateness of models for specific applications. For example, regression is appropriate for analyzing continuous dependent variables, whereas, discrete choice analysis is used for discrete dependent variables. Neural networks are non-parametric analysis techniques used for exploring functional relationships between inputs and outputs.

A descriptor tree will be used for finding appropriate models (Figure 7 1) The tree will help user(s) find a suitable model(s) in specific contexts by allowing a systematic search.

Various models can be combined to obtain richer insights. For example, discrete choice analysis can be used to estimate parameters of a choice model that relates route selection to system performance, information, socioeconomic and contextual factors. These parameters can then be used to assign traffic in a network. Thus, linking models can enhance the quality of analysis.

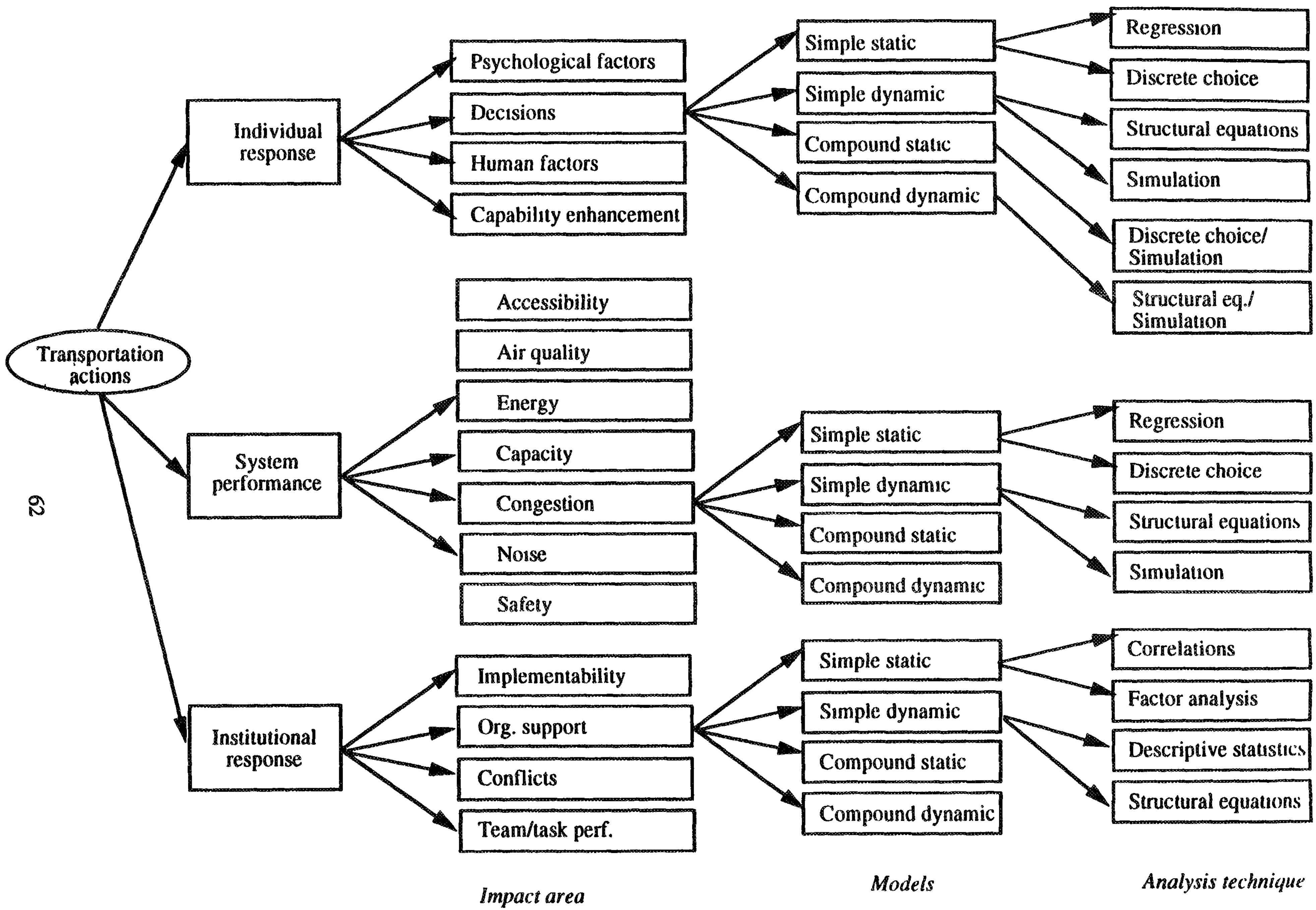
Performing Analyses with PLANiTS

A manifestation of the PLANiTS analysis environment is provided for the purpose of illustration (however, this is by no means the only one). The "basic" level of analysis intensity will be an initial filter for analyzing the consequences of actions in specific contexts. It will provide advice based on similar cases elsewhere. The "complex" level of analysis intensity will support more comprehensive modeling and data collection efforts, when warranted.

Basic Level of Analytical Intensity

Upon completing the specification of the planning vector, *PV*, the users begin to explore the level of analytical intensity required for their evaluation. PLANiTS can provide information on the effectiveness and impacts of selected actions in earlier contexts. For example, it may tell the users how well HOV lanes have worked and what the impacts of specific HOV strategies were on system performance.

One consequence of the basic level of analysis can be that the users acquire sufficient knowledge to make their decisions. Another consequence may be that users


Transportation actions
Individual response
System performance
Institutional response
Psychological factors
Decisions
Human factors
Capability enhancement
Accessibility
Air quality
Energy
Capacity
Congestion
Noise
Safety
Implementability
Org. support
Conflicts
Team/task perf.
Simple static
Simple dynamic
Compound static
Compound dynamic
Regression
Discrete choice
Structural equations
Simulation
Discrete choice/ Simulation
Structural eq./ Simulation
Correlations
Factor analysis
Descriptive statistics
Impact area
Models
Analysis technique

formulate a feasible set of actions and acquire knowledge about their impacts in other locations. They may use it as an opportunity to conduct detailed evaluation.

Complex Levels of Analytical Intensity

The decision to conduct in-depth analysis will be made through deliberation and it will likely require technical experts. However, users will be informed that greater complexity in analysis may not always lead to better or more robust conclusions. The experts can conduct in-depth evaluations at the following levels of complexity:

- Existing models with existing data
- New models with existing data
- Existing models with new data
- New models with new data.

Before beginning in-depth evaluation, the following would be specified: policies and their requirements in terms of measures of performance (and their weights), the area/region of interest, a feasible and evaluable set of actions and time frame or planning horizon.

Existing Models with Existing Data

In using existing models with existing data , the model base will guide users to the appropriate model. The existing models will have information about their action sensitivity, inputs and outputs, data requirements and methodology. This information will be used to guide the users in choosing an appropriate model.

If long-term planning is desired, then prediction of land-use patterns will be needed The PLANiTS environment could offer a choice of land-use models. It will also inform the user regarding the relevance, limitations and assumptions of the models. PLANiTS will provide information about the conceptual and methodological structure of the models as well as their validity and accuracy. If short-term (operational) planning is desired, then instead of a land-use model, prediction of factors such as accident frequency and traffic flows may be needed.

A unique feature of the model base will be the connectivity between transportation planning and operational models. For example, users may wish to run a four-step model, such as EMME2, and then use FREQ to develop ramp metering strategies for incident management. PLANiTS will develop connectivity among models where appropriate.

New Models with Existing Data

Sometimes existing models and/or data may not be suitable for analysis of new actions. For example, behavioral choice models assume perfect information; that is, individuals have knowledge of all alternatives. Clearly, such an assumption cannot be supported when evaluating the effect of information technologies. Models may have other limitations. Temporal aspects of behavior are not well understood, particularly inter- and intra-personal variability in travel behavior are not accounted for in behavioral models. Further, adequate representations of inter-relationships and constraints between the decisions of the individual and the decisions of family members are not modeled adequately.

In certain situations it may be necessary to combine behavioral and network models to obtain useful insights about impacts of actions. The following paragraphs illustrate the steps in choosing an analysis technique. The treatment of steps is rather superficial because each step draws upon a large body of knowledge.

After users decide that a new model is needed, they would specify the *analysis level*, i.e., whether impacts should be evaluated at the individual, system or institutional level (or all three levels). Then the decision regarding *analysis type* can be made. For example, it may be decided that impacts of new technologies on individual behavior should be analyzed using stated preferences (as opposed to revealed preferences). This decision can be based upon the following considerations. Stated preferences allow greater control in testing combinations of actions (stimuli) at different levels; understanding tradeoffs between variables is relatively easier; stated preferences are simpler and easy to use and efficient because the sample size can be increased by obtaining several responses from the same individual.

Users will decide whether or not to develop simple or compound models.

Situations warranting compound models may arise if the analysis must be conducted at two or more levels requiring connectivity between levels. In evaluating impacts of demand-side actions, connectivity between models of traveler behavior and transportation system performance is desirable. Another situation requiring compound models may arise when two or more measures of performance are selected for evaluation. If impacts are evaluated in terms of both traffic congestion and safety, then compound models may be needed.

Even after making the aforementioned decisions, users will have considerable flexibility in deciding on specific technique appropriate to analyze data. Although certain general principles can be followed (and PLANiTS will advise regarding appropriate level of analysis models), researchers use different techniques to address similar situations--sometimes with equal validity. In PLANiTS, users may be asked to agree on a specific technique before it is used. Technical expert(s) can give users a choice of analysis techniques. For example, stated preferences can be analyzed using conjoint analysis, trade-off analysis or discrete choice analysis. The group may choose to use more than one technique, however.

Existing Models with New Data

During analysis, users may decide to collect additional data. PLANiTS will support the experimental design of data collection.

Experiments can be placed on a continuum ranging from natural, where researchers have little or no control (of stimuli), to laboratory, where researchers have (nearly) full control. The validity and generalizabilty of laboratory experiments is difficult to determine, however. For the purpose of transportation planning, some degree of control is desirable to analyze the issues clearly.

The selection of a data collection method would depend on:

Nature of actions. For example, to analyze impacts of HOV lanes on traveler behavior, real-life situations (natural experiments with unobtrusive measurement techniques) can be used, whereas, to analyze the impacts of automatic vehicle control systems on traveler behavior, laboratory experiments may be used.

Measures of performance. The estimation of congestion requires different data compared with safety.

Environment. Certain data collection designs are more appropriate in one context compared to another.

Based upon information about actions, measures of performance, the environment, time frame, users will make decisions about the level of data analysis (individual, system, institutional) and data collection type (e.g., observational, direct communication, or both). That is, whether data will be collected by observing phenomena/individuals or through direct communication with individuals.

Human, mechanical and electronic methods can be used for data collection through observation. Further, if the observation involves humans it can be obtrusive or unobtrusive. Often unobtrusive observation is a better measure of true preferences. More recently, quasi experimental designs have been implemented to study traveler behavior (e.g., ADVANCE field operational test in Chicago). These designs allow researchers to observe (travelers) in a semi-natural setting.

The decision to select a data collection design is complex and depends on the objectives and budget considerations. Other considerations include the type of models to be calibrated or validated and criteria for experimental site selection. Knowledge regarding applicability of experimental designs in various contexts will be contained in the methods and tools base. For example, a before and after study can be recommended to design a panel survey for evaluating the effect of Advanced Transportation Management and Information Systems (ATMIS) on traveler behavior. The same research design can also be recommended for data collection on network performance, e.g., occupancies and flows, when assessing the influence of ATMIS technologies.

Chapter 8

COMPUTER AIDED DECISION SUPPORT IN PLANiTS

Throughout the transportation planning process, important decisions must be made that sometimes result in conflict amongst the participants. The PLANiTS system aims to reduce this potential for conflict, to facilitate conflict resolution, and to improve the quality of decisions. This chapter explores the feasibility and usefulness of computer support for group decision making that occurs in support of the planning and programming of transportation actions. The conceptual framework described here is structured to promote consensus building, negotiation and deliberation techniques as part of the planning process. In this chapter we explore various group support techniques and define criteria for selecting, or developing a component for PLANiTS.

Scope of PLANiTS Support

Group decision making is complex. Participants with opposing or entangling alliances, powerbrokers with formal or informal empowerment, and the conflict of local interest pitted against regional concerns all contribute to the intricacy. The mandates of state and federal legislation force many of these participants to cooperate. A widely-held expectation is that use of an electronic medium to facilitate group processes will lead to better decisions and higher productivity by more fully extracting the resources of group discussions and interactions. However, accurately articulating the logic of human decision making continues to challenge those engaged in modeling human behavior and cognition. The direction and magnitude of impact of a computer-based group decision support system on final solutions are not completely understood. For example several studies report higher levels of conflict and negative emotional expression in computer-mediated communications than in face-to-face communications (Applegate, Konsynski, Nunamaker, 1986; Siegel, Dubrovsky, Kiesler, 1986). Researchers have found that computer support may raise the level of conflicts by heightening the awareness of members' viewpoints and causing greater objectivity in reviewing proposed ideas or solutions to a problem. It is unclear whether increased conflict is a direct result of the computer mediated communication itself, or whether the support systems simply provide a mechanism that brings out existing differences among group members (Watson, DeSanctis, Poole 1988). It has been established, however, that group cohesion and interpersonal attraction diminish with greater physical distance and anonymous working conditions. The usefulness of computer-based facilitation in conflict situations is not without dispute.

Early software development focused primarily on technology issues, without sufficient attention to the complexities of group dynamics. Even the successes have consistently fallen short of expectations (Grudin, 1990). The disparity between those who would benefit from an application and those who were required to do additional work to support it is a significant cause for many system failures (Markus and Connolly, 1990). Increased use of keyboard input and greater volume of information flow can add to the level of effort required in a group meeting, thus lowering group efficiency.

The sophistication of a decision support facilitator in PLANiTS will understandably be limited by this lack of understanding. In line with the general philosophy of the overall development strategy, incorporating increasingly sophisticated tools on an incremental basis could contribute to the understanding of the influence of computer support on group processes while still producing a helpful product in the short term. Methods could eventually be designed to support a human facilitator alone, the group alone or both. A long term goal of PLANiTS would be a sophisticated facilitator that could guide participants through the process assisting in the individual decision-making, detecting possible conflict, suggesting and brokering resolution techniques. A short term goal would be to develop a small set of techniques that could aid a human facilitator and perform some of the simpler tasks.

Product Development

When compared to computer support for individual decision making, commercial applications for group decision support systems are still relatively early in the product development cycle. Computer support for group decision-making has attracted a moderate amount of academic and commercial research; however, thus far none has been specifically tailored for public sector applications, much less for transportation planning. The following briefly describes current progress in the development of computer support for group decision making.

The general term for software support of group processes is *Groupware*, which is defined to be any specialized computer aid designed for the use of collaborative work groups (Johansen 1988). Groupware encompasses three distinct concepts, group decision support systems (GDSS), computer-based systems for cooperative work (CSCW) and electronic meeting systems (EMS). The distinction between GDSS and CSCW is in the primary type of group support each was designed to provide. GDSS is an integrated computer based system that facilitates the solution of an unstructured or semi-structured task by a group that has joint responsibility for performing it (Gallupe, DeSanctis, Dickson, 1988). It typically is task oriented in that it provides a means for a group to perform and complete a task, such as reaching a decision, planning or solving problems. CSCW-based applications are more driven by communication needs. They provide a means for small groups to communicate more efficiently, enabling them, for example, to jointly create or critique a document. However, it is believed that these two classes of systems will completely overlap or converge to a single class of group support technology, a concept coined "electronic meetings." Electronic meeting systems (EMS) enhance communication channels by adding structure to meetings and completely recording groups sessions to aid productivity in subsequent sessions. EMS may also structure problems, idea generation and organization, planning, and even elicit knowledge for the construction of knowledge systems (Dennis, George, Jessup, 1988). Certainly most of these concepts are relevant to PLANiTS.

While the idea of computer support for groups was first introduced over forty years ago, it was only with the proliferation of personal computers that its application was seriously considered. Software applications with simple versions of the capabilities described above are now offered on the market. Available commercial applications include Lotus Notes, CTC VisionQuest, IBM TeamFocus, Ventana Group Matrix, SmartChoice OptionFinder and NCSA Collage. Some of the techniques offered, such as support for co-authoring, shared databases, asynchronous brain storming and electronic "blackboard," are potentially useful to support processes within transportation planning. A variety of universities are conducting research in the development of these applications, as well as the impacts that they may have on the users and the ultimate decisions. The University of Arizona has a dedicated research facility called the Plex Center where electronic meeting forums are researched (Dennis, George, Jessup, Nunamaker 1988). Xerox PARC and University of Minnesota have explored the influences of computer mediated group support in addition to developing applications (Poole, Holmes, DeSanctis 1988). A list of existing applications of both research and development and commercial, as complete as possible, is included in Appendix 2. The influence and usefulness of electronic media on group processes and decision making continues to be researched.

Applications development has focused on group processes that are related to content--processes pertaining to the production of a particular product or service (Bannon and Schmidt, 1991). Indeed, the major development focus historically has been for the specific needs of business teams. Some corporations have taken advantage of these specialized packages. Dell Computer Company, Proctor and Gamble, Marriot, Metropolitan Life Insurance Corporation, and Westinghouse are exploring the usefulness of groupware. Users of groupware in these instances are primarily executives, managers, sales persons and other "knowledge workers." Notwithstanding these examples, widespread usage of generalized applications of groupware systems even in the business community is limited.

Design Objectives

The decision-making and facilitation component of PLANiTS to support problem formulation and solution for groups will combine communication, computer, and decision support technologies. The diversities of these developing technologies offer exciting opportunities for facilitating group interactions. The following section outlines specific goals to support these functions and, where possible, suggests the type of tools that would be useful.

Consensus Building. Group cooperation and negotiation is ubiquitous throughout the planning process and often pivotal to the quality of the resultant decision. The theory underlying implementation of group decision support systems for these purposes would maintain that a GDSS should foster more even participation in situations requiring group consensus, especially from those who have slow verbal latencies (Hiltz, Turoff 1978). This then should facilitate a systematic or structured group decision and negotiation process, and promote effective conflict management. Consequently, group consensus in GDSS situations should be higher than when compared to groups that are not computer-supported (Zigurs, Poole, DeSanctis 1988).

The process of using computer-supported methods for group decision making appears to improve the level of participation, but it does not make the process of decision conclusion any easier--indeed sometimes it makes it harder. There is also evidence that the decision, when finally reached, may be of lower quality than if the 'best' decision maker in the group has acted on his or her own (Rohrbaugh 1981)--although the overall commitment to the decision could well yield better results than this would appear to indicate. Lastly, electronic support does not guarantee consensus, especially amongst players with deeply held, mutually exclusive positions.

Voting, ranking and rating schemes are some of the concepts that will be incorporated into PLANiTS. Existing research in conflict management for global peace and environmental mediation will be particularly useful (Isard, Smith 1982; Rahim 1990; Susskind, Bacow, Wheeler 1983). Primary tools for PLANiTS support, already available in commercial packages, permit yes-no, true-false, or agreement-disagreement for voting, and shuffling the order of items on a list to create a ranked ballot, or assigning numeric weights to each item. Other voting support techniques could include fixed point allocation routines or voting matrices. Voting matrices could reveal group agreement or disagreement over a range of alternatives.

Conflict mediators have found that voting often reduces consensus and that other structured techniques should be employed first to encourage compromise and negotiation (Poole, Holmes, DeSanctis, 1988). Alternative decision support technologies include decision modeling methods (such as decision trees, risk analysis forecasting methods, and multi-attribute utility functions), structured group methods (Nominal Group and Delphi techniques), and rules for directing group discussion (agenda-setting techniques, identification of conflict style) (Thomas, Kilman 1974). Capabilities such as tracing group thinking patterns over time for group and sub-group analysis would also be useful for consensus and negotiation purposes (Blake, Mouton 1964).

Balance of Power. An important opportunity for PLANiTS is to reduce the "group think" phenomena. Groups are often susceptible to "group think" where a single or small minority of participants dominate the direction of the logic, inhibit idea expression and distort subsequent decisions through member control and social pressure. Group think is considered undesirable because it may dampen the potential creativity of a group and often leads to suboptimal decision-making. It is believed (or hoped) that group decision support systems may lessen this phenomenon by permitting equal participation. A more democratic decision process should emerge by facilitating greater participation (Gallupe, DeSanctis, Dickson 1988; Janis 1972).

Conceptually, greater participation and promotion of an equal voice in transportation planning appears appealing, yet complete equality between participants is not always proper or just. In order to be credible to users of the prescribed model and even observers external to the process, PLANiTS must preserve the integrity of varying levels of power and authority within a particular transportation planning group. Throughout the spectrum of actions and decisions made during the planning process, only some will be democratically decided. Politically speaking, there are appropriate times in the planning process for "one person, one vote." At other times, a committee may consider the views of various interested parties and make their decisions. Employing a neutral mediator, be it human or computer, sometimes dilutes accountability (Burton, Dukes 1990). Informal processes that invite special interest groups to participate can confer onto them a legitimacy that is not due. Certain players have more at stake, while others may have greater authority. The PLANiTS group support procedures must promote group communication and shared knowledge, and create a decision arena that can accommodate players with differing levels of power, accountability, and authority.

Information Flows. One of the advantages of new transportation technologies such as IVHS is the availability of information. This increased access to information can overwhelm participants. Without adequate structure to integrate or synthesize various views and data, a group can easily drift. Therefore, one of the goals of PLANiTS is to reduce the process loss associated with disorganized activity, and to increase the efficiency of information processing

Electronic brain storming, electronic information sharing, and structured processes for idea commenting are examples of tools that can be used to improve the synthesis of information. Accommodating groups that are either geographically or temporally separated can reduce traditional scheduling constraints and increase access to information. Particularly useful will be communication technologies such as electronic messaging, local and wide-area networks, tele-conferencing, and store-and-forward facilities.

Summary of Goals

From reasons described earlier, it is not entirely clear that computer support of mediation and decision making will ensure many of these desired benefits. Investigation of research results from group decision support systems indicates that there is no clear agreement on the benefits of GDSSs (Poole, Holmes, DeSanctis 1988). An important requirement in the development of PLANiTS decision and negotiation support is that it should improve the resultant decision.

Specifically, a group support system implemented in PLANiTS should facilitate the decision-making and negotiation process by:

1. structuring decision making processes,
2. tempering member dominance, while accommodating differing levels of power, accountability, and authority,
3. increasing efficiency, communications and access to information, and
4. improving the quality of the resulting group decision.

A Logic for Selecting Techniques

The design of the support system should be incremental and modular: initially assisting a human mediator or facilitator with suggestions and gradually becoming more sophisticated in its support as product development improves. The logic for adopting the appropriate technique is based on temporal, *spatial, behavioral, and contextual* considerations. The domain of decisions tools can be determined from these characteristics.

Temporal and Spatial

Accessibility / proximity of group. Traditionally the planning process required the coordination of people and face to face meetings. However, communication and computer technologies can support planning processes across time and place. Groups can meet at the same time yet be physically separated (common in CSCW) or can work together in their own agencies asynchronously.

Processing Mode. The usefulness of decision techniques will also be driven by the capability of the processing mode. Whether support is provided for the facilitator only, for participants only, or for both remains to be determined. The set of support possibilities will largely depend upon the presence (or absence) of a facilitator and computer processing capabilities.

A taxonomy of support techniques may be based on these three variables (temporal, spatial and processing mode). Table 8.1 illustrates how technical sophistication and the dimensions of time and space dictate the appropriate technique for idea generation. The methods typology will vary by whether group processing is sequential or parallel and whether the methods support single or multiple group sessions. When multiple group sessions are permitted, the PLANiTS facilitator must integrate and use information across sessions and between groups. If there are subgroups or if an individual works asynchronously, certain other tools may be useful.

Table 8.1 Processing Support (for Idea Generation)

PLANiTS Support For:	Processing Mode	
	Sequential	Parallel
Facilitator only	Facilitator assists conventional generation	Facilitator assists conventional generation
Participants only (multiple workstations)	Users take turns generating ideas, displayed on public screen	Everyone enters comments at same time. Method decides order that comments will be displayed (Delphi)
Both (multiple workstations)	Each individual lists own ideas. Facilitator controls process by which they are presented to group (Nominal group technique)	Participants generate ideas simultaneously. Facilitator or PLANiTS may control process (Electronic Brainstorming)

Behavioral Consideration

Characteristics of Group. The context in which, for which, by whom and for whom the decision is being made may dictate the appropriateness of certain decision support tools. Features of the group that may influence the process include group size, individual member characteristics, coalition-related characteristics, history, cohesiveness, experience, formality or informality, ongoing or one-time, and organizational context (Dennis, George, Jessup 1988).

Contextual Consideration

Stage of the Planning Process. Appropriate decision support techniques depend upon the stage of the planning process. To identify relevant decision techniques, each step in the planning process can be roughly illustrated by describing its primary feature as judgmental, rational, political, complex, etc We recognize that all of these steps will contain some of these characteristics, to a greater or lesser degree.

Time Sensitivity. The process time required can dictate the appropriate or possible tools. If a group needs to make a decision immediately, certain tools will no longer be applicable because of the intricacy involved.

Information Available. The level of information available to each participant may vary. Incomplete data sets or uncertain forecasts will influence the possible tools to use.

Expected Outcome. "Outcome" refers, in this case, to the result of any particular decision scenario. As such, expected outcomes sometimes drive the entire planning process; they frequently drive negotiation processes. While the desirability of this practice is debatable, it is, at the very least, necessary to recognize this as the reality of politics.

Objective criteria for outcome expectation include quality of decision or outcome, participant satisfaction with the outcome and process, participant confidence in the outcomes, level of group consensus, and number of alternatives considered during the process. Commitment to outcome is also important. Some participants are committed to solving the problem, while others are committed to their particular solution. When participants hold steadfast to certain ideas, resolution of conflicts becomes increasingly difficult. Understanding this commitment assists the mediator in selecting the tools.

Policy Options. The number of options that are being considered may influence the quality of the resulting decision. A large number of complex options may limit the quality of the evaluation because of time and resource constraints. One standard would be, of course, to limit as much as possible the number of options.

Planning

Planning Objectives. The guiding principles of different players may certainly lead them to value differing objectives. Identifying the motivations and attitudes behind certain judgments is often helpful to conflict resolution.

Example of Logic Structure

Consensus building techniques such as tracing group decision patterns and displaying clusters can be used throughout the process. However, there will be certain points where significant, non-incremental decisions must be made, requiring formal negotiation, compromise or agreement between parties. To illustrate how the proposed logic structure in PLANiTS would support this more formal step, an example is shown. This example supporting formal negotiation is based on one described by Isard (Isard, Smith 1982).

Suppose PLANiTS had determined that the most relevant considerations were:

1. number of options being considered;
2. type of utility functions that the participants could use (i.e., ability of participants to judge various options);
3. concern of participants with improvement over the current state of affairs or with concession from stated positions that differ, the position of each being that which he or she considers best; and
4. ability of participants to focus on outcome or actions. If the outcome is too divisive, it may be necessary to focus only on prior actions and indirectly on the final outcome.

A matrix of these characteristics and all possible values is shown in Table 8.2.

Using Isard's illustration, if there were **few** options, if participants were able to **rank** outcomes in order of preference and to focus on **improvements**, and **outcomes**, a finite domain of techniques could be identified. PLANiTS could recommend the set of appropriate decision support techniques based upon the values in this matrix (finite, ordinal, focus on improvement, outcome-oriented). List 8.1 contains those tools that would be most practical for the scenario described.

Table 8.2 (Partial) Matrix of Characteristics

No. of Options	Utility Function	Planning Objective	Expected Outcome
Few	Rank Outcomes	Improvement	Only Actions
"	"	"	Outcomes
"	"	Concession	Only Actions
"	"	"	Outcomes
Few	Assign Relative Values	Improvement	Only Actions
"	"	"	Outcomes
"	"	Concession	Only Actions
"	"	"	Outcomes
Few	Assign Precise Values	Improvement	Only Actions
"	"	"	Outcomes
"	"	Concession	Only Actions
"	"	"	Outcomes
Many	Rank Outcomes	Improvement	Only Actions
"	"	"	Outcomes
"	"	Concession	Only Actions
"	"	"	Outcomes
Many	Assign Relative Values	Improvement	Outcomes
"	"	"	Only Actions
"	"	Concession	Outcomes
"	"	"	Only Actions
Many	Assign Precise Values	Improvement	Outcomes
"	"	"	Only Actions
"	"	Concession	Outcomes
"	"	"	Only Actions

Source: Isard, Smith (1982) p. 9

List 8.1 Recommended Tools for Example

1. Minimum total of ranks (highest rank = 1) (weighted or unweighted)
2. Minimum difference in ranks weighted or unweighted
3. Maximum total of rank improvements
4. Maximize the minimum in rank improvements
5. Minimize the difference in rank improvements
6. Maximize equal rank improvement
7. Changing actions to "if..,then..." policies
8. Maximize good-cause payment
9. Apportionment principles
10. Achievement of minimum requirements (satisficing)
11. Last-offer arbitration (with incentive to think of others)
12. Method of determining group priorities (Saaty Analytic Hierarchy Process principles)

Source: Isard, Smith (1982) p. 11

Each of these tools represents an established negotiation technique that the mediator may elect to use to seek consensus among participants.

To further assist the mediator in reducing the set of possible techniques, PLANiTS could prioritize the domain of techniques based on cost, outcome transparency and other selected criteria. PLANiTS could indicate the techniques that have a high cost (in this example, procedures 7 and 12 are expensive to operationalize); the techniques that have pre-indeterminate outcomes (techniques 8, 10 and 11); and the techniques (7 and 12) that do not require information about preferences of other participants, a situation that may occur when a workshop or meeting is not feasible.

Early in the development cycle, PLANiTS role in negotiation and conflict resolution may be to simply produce a list such as the one shown in List 8.1 and provide text describing each technique, their advantages, and their disadvantages. As PLANiTS evolves, the electronic facilitator can assume a greater role in the consensus building process and actually begin to guide the mediator. The following section explores more fully the role that PLANiTS may assume during its development.

Recommendations for Development

In this section we propose a development approach for implementing the negotiation and conflict resolution techniques. Our short term objective is to achieve an operational prototype for demonstration purposes within a year. The long term objective is to construct a fully operational PLANiTS support model. Since a significant milestone for PLANiTS is a prototype of the system, the suggestions are centered on this objective. Obviously the more detailed and complex issues, while discussed here, must be examined further and addressed more fully in later design stages.

Taxonomy of Techniques

The following describes the taxonomy of techniques, separated by major categories. Listed under each of these categories are some techniques that would be useful. The four categories of the techniques are idea generation, decision support, consensus building, and facilitation.

Idea Generation

Electronic brain storming should encourage idea generation and promote creativity. It can be supported by sequential or parallel processing. Member dominance can be tempered easily with computer supported brain storming, since it can permit anonymous participation and can structure contributions. This is a proven concept that is already implemented in many existing groupware applications. It is an obvious tool to include early in the development of PLANiTS.

Issue analyzer should consolidate key items produced from idea generator. This could be useful for many purposes. It could serve as a feedback mechanism; it could provide a forum for discussion; and it could supply a summary of the idea generation process. Eventually, the Issue analyzer could integrate external, yet relevant, information from the literature and the knowledge base. The logic required for this category of techniques is likely to be sophisticated, requiring capabilities such as word pattern recognition and a dictionary of common terms.

Topic commentor should provide a forum for participants to freely interact. Participants may enter, exchange and review information on self-selected topics. It could support solicitation of ideas and provision of additional detail in conjunction with a list of topics.

Decision Making

Voting tool should provide a variety of prioritizing methods. Examples include rank ordering and weighting, multiple choice, and Likert scales.

Alternative Evaluator should provide multi-criteria decision making support. Alternatives can be examined under flexibly weighted criteria to evaluate decision scenarios and tradeoffs. Examples include concordance-disconcordance procedures, stochastic methods, reduction methods, and fuzzy set analysis.

Non-quantitative procedures should include among others, Burton's workshop theory (interaction process for zero-sum to positive sum games), Kelmans workshop theory, Fisher's Yesable Propositions.

Consensus Building

Idea organizers should include stakeholder identification or assumption surfacing, Saaty's method of determining group priorities, questionnaire assistance, and group dictionary.

Structured resolution techniques should include conventional delphi, goals delphi or policy delphi and nominal group techniques. Other established techniques include achievement of minimum requirements (satisficing), apportionment principles; changing actions to "if...,then..," policies; maximizing good-cause payment; last offer arbitration (with incentive to think of others).

Policy formulation should support group in developing a policy objective.

Facilitation

Session director should guide the facilitator or eventually replace human facilitator responsibilities in selection of tools to be used in a session. An example of this capability would be to generate an agenda of useful tools for a given meeting. The Director could diagnose key characteristics of a situation to assist the facilitator in selecting the appropriate tool. As PLANiTS evolves, the Director will become more reliant upon an expert system and a knowledge base.

Coordinator encompasses generic collaborative task support. Tools such as group writer, group outliner, and appointment calendar could be useful to meetings. These capabilities already exist in commercial packages.

Prototype Design Approach

The most preferred techniques could be implemented in the prototype. If possible, surveying potential users regarding the tools they would be most interested in having implemented in the prototype would ensure that participants would be provided with useful assistance. Opinions could be solicited at planning workshops or from surveys.

If this method is not possible then the following approach is recommended. To maintain simplicity while ensuring usefulness, the prototype should include a single technique from each of the major functional categories of idea generation, decision making, consensus building and facilitation.

It is recommended that brain storming be the first application to develop. Electronic brain storming is an appealing and proven concept that can promote creativity of participants. It is likely that participants will find this a practical and productive tool. By providing an instrument whose usefulness is readily transparent, participants can become familiar with the potential of PLANiTS, begin adapting their work habits to using it, and may become influential in shaping the direction of succeeding versions of PLANiTS.

PLANiTS will eventually provide both qualitative and quantitative decision support. Qualitative decisions that can be converted to quantitative measures are more straightforward, have been more fully explored as software applications, and can be more easily included than pure qualitative decision support. Initially providing voting, ranking, and rating tools would be a modest and feasible goal.

Major objectives underlying consensus building are conflict avoidance, resolution or settlement. Mediation of conflict frequently requires sophisticated diagnosis and prescription of problem and procedure. Including a consensus building technique in the prototype that is simultaneously simple to implement and effective as a technique may indeed be a formidable task. However, a fundamental principle of consensus building is to facilitate communication between parties. Practically speaking, any technique that improves communications may facilitate consensus building. A well constructed electronic brain storming application may be a sufficient tool to assist a human facilitator in consensus building.

At the prototype stage, the facilitator should probably function simply as a warehouse for the available techniques, providing descriptions rather than prescriptions for a human facilitator. The PLANiTS facilitator can provide detailed descriptions of procedures that would assist the human facilitator in performing them. The logic for diagnosis of conflict situations, while a fundamental responsibility of the facilitator, is sophisticated and is probably too complex for early implementation as a part of PLANiTS. It is therefore recommended that the criteria for the logic parameters described earlier be included for use by the human facilitator, but that PLANiTS not act directly as a facilitator during the prototype stage.

Long Term Implementation Strategy

The following lays out an incremental development strategy for long term implementation of the decision and consensus support module. The key benefit from incremental, modular implementation is that portions of consensus building support can become functional relatively early in the development of PLANiTS. Accordingly, the logic to build an increasingly sophisticated support system should incorporate knowledge gained from the prototype. The basic design approach is to begin to incorporate the logic framework described in this chapter. The ultimate design objective will be to include all the of the criteria (Temporal/Spatial, Behavioral, Contextual, and Planning) in the logical structure. However, it is recommended that each of the criteria be incorporated as separate modules, with a smart facilitator that coordinates them coming on-line at a later point. The following suggests how to begin implementing the logic criteria.

A straight-forward criterion to begin incorporating is the Stage of the Planning Process described under Contextual Considerations. In Table 8.3 stages of the planning process are identified with techniques useful for the tasks encountered in each stage. This matrix of functions linked to stages should include work accomplished in prototype development, but will probably require additional development. The next refinement would be to more precisely define the techniques and their usefulness in particular situations. The salient features of each stage can be used to help identify techniques appropriate for that particular stage.

As PLANiTS becomes more sophisticated, both the repertoire of techniques within each category and the decision support functions associated with each stage of the planning process will increase. It is likely, however, that the techniques for some of the stages can be more standardized than for other stages. In particular, the Analysis of Actions stage should eventually have access to a wide-ranging and diverse set of decision support techniques, while techniques for Problem Identification and Problem Definition may remain fairly routine. Examples of specific techniques that would be useful in each stage of the planning process are shown in the last column of Table 8.3. Sometimes, the type of specific techniques recommended for the planning stage is identical to the function (i.e., the functions of idea generation are identical to the techniques recommended).

Refinement of this matrix should continue in a similar fashion, with more techniques being added as the logic for selecting the techniques becomes more sophisticated. Once this matrix is completed and the techniques have been successfully incorporated into PLANiTS, a useful guide will be available to a human mediator. Groups could possibly interact somewhat autonomously, without constant assistance of a human facilitator.

In a similar fashion, the other characteristics for Contextual Considerations, as well as Temporal/Spatial, Behavioral, and Planning criteria, can be introduced into the PLANiTS system. As described above, PLANiTS can begin to accommodate more and more specialized criteria to further refine technique selection. However, this is merely a preliminary set of criteria. Prior to implementation, it is recommended that all of the criteria and techniques that have been suggested here or deemed appropriate elsewhere be reviewed by experts. A panel of experts could be polled on the suitability of this set before it is finalized. It could be a delphi style inquiry of experts in decision support, conflict management, public policy, and of course transportation planning. This assembly of experts could not only consider and approve the set of consensus techniques that will be stored in PLANiTS, but also the logic which is associated with each technique.

Issues and Recommendations

Evolving Processing Support. The support for processing in PLANiTS across time and space will most likely occur in some kind of technology continuum. It is expected that earlier in development (i.e., the prototype stage), configuration options will be considerably more limited than later. Earlier versions of PLANiTS will support relatively simple face-to-face, real-time interactions. Issues concerning group dynamics related to the level of sophistication of the processing mode will not be as important--the assorted possibilities described earlier will not yet be relevant.

However, PLANiTS will eventually be enhanced to permit remote, asynchronous processing. Understanding or anticipating the impact or influence of these disconnected interactions will be difficult; however it is likely that this new type of processing will alter the behavior and dynamics of group situations. The degree of sophistication of communication and computer technologies, (the available processing mode) will largely determine how influential accessibility and proximity factors will be on the set of recommended tools. Exploring the impact should be essential.

Table 8.3 Categories for Planning Stages

Stage of Planning Process	Category of Techniques	Specific Techniques
Problem Identification	Idea generation (Electronic Brain storming; Issue Analyzer).	Electronic Brain Storming; Issue Analyzer.
Problem Definition	Consensus building (Idea Organizer; Policy Formulation).	Assumption Surfacing; Questionnaire Assistance; Group Dictionary; Policy Formulation.
Selection of Actions	Decision making (Voting Tool).	Minimum Total of Ranks; Minimum Difference in Ranks; Satisficing.
Analysis of Actions	Decision making (Alternative Evaluator).	Concordance-discordance Procedures; Stochastic Methods; Reduction Methods; Fuzzy Set Analysis.
Discussion of Analysis	Consensus building (Structured Resolution Techniques).	Method of Determining Group Priorities.
Selection of Action	Decision Making (Voting tools).	Maximum Total of Rank Improvements; Maximize the Minimum in Rank Improvements; Minimize the Difference in Rank Improvements; Maximize Equal Rank Improvement.

Technical sophistication of mediation support. As part of the long term development strategy, it is expected that a human facilitator will be a necessary component in mediation during a significant period of the development path. However, many functions of the electronic facilitator should emerge slowly and naturally during development. For example, the role of the facilitator in the Stages of the Planning Process was not even mentioned in the earlier text on the matter. It almost transcends the stages.

In a theoretical sense, the role of the electronic facilitator remains rather ambiguous. The logic for constructing a consensus building system will ultimately be a major part for the facilitator. But the role of the facilitator could be greater than just the logic. Recording or learning from on-going experiences could be a valuable ability of the electronic facilitator. The functions of (1) characterizing the situation and (2) diagnosing the proper mediation techniques would lend itself to an expert system to assist the human mediator and to learn from the on-going process. Developing rules for mediation support should occur simultaneously with other development.

Limitations of consensus building. Realistically, consensus building can never eliminate some of the obstacles to decision making. While community participation and public awareness are all strengths that can be useful to the successful implementation of transportation planning projects, consensus building almost always incorporates satisficing. Furthermore, while the concepts of consensus building and decision support may be universally endorsed, when these techniques should be put into action is not as widely agreed upon. One reason is that it is not always obvious that consensus or compromise serves the public interest the best. While this may be difficult to operationalize, it should be recognized that consensus or cooperative planning efforts are not always in the best interest of the public.

Value of computer support for decision making. Aside from an brief discussion of the (sometimes) inappropriateness of a completely democratic process and of the uncertainty of computer supported mediation, this chapter has almost completely subscribed to the concept of computer supported consensus building as essential to quality decision making. And for the most part it can be regarded as a positive objective to pursue. However, improved information and communication flows do not always guarantee improved decisions Any kind of conclusive judgement on the impacts and influences of computer-supported mediation is yet to occur. Subsequent PLANiTS research has the potential to increase the understanding of these impacts. It is recommended that any new capability be assessed as fully as possible as to how it may impact the decision process.

Another great uncertainty is the value of computer support for public policy decision making and for the even more narrow field of transportation planning. The expansive assortment of issues, such as huge costs, protracted planning time frame, extensive community participation, multiple objectives (mobility, economic development, job creation, etc.), set transportation planning apart from many of the traditional applications for conflict mediation, settlement or resolution. So even in the isolated cases where computer-supported mediation in other fields has been successful, the applicability to transportation is not entirely evident.

Chapter 9

SUMMARY AND CONCLUSIONS

In this research we proposed a framework for a transportation planning methodology that responds to the challenges and opportunities posed by the developments in IVHS. The important features of this methodology are as follows:

Computer Supported Integration of Planning and Analysis. The PLANiTS system represents a unique computer platform in which analysis models and planning deliberations are integrated and supported. Within this system, rapid feedback between planning and analysis permits a streamlining of the process, and transparency of methods and assumptions serves as a catalyst for consensus in programming decisions. Computer aided deliberations further simplify and strengthen the rather complex processes that have emerged in transportation planning in response to recent legislative mandates and to the ever increasing complex of rules and regulations that impact transportation system.

A knowledge Base for Transportation Planning. The wealth of information that will characterize the IVHS era can be a tremendous asset for transportation planning. We have proposed a framework for integrating and transforming the large amounts of transportation data into a knowledge base that is useful for analysis and decision making. The use of techniques of case based reasoning and knowledge based expert systems permit the use of this rich knowledge base in making inferences with the minimum amount of primary data collection.

Integrating Transportation Models. The PLANiTS environment is designed as a platform to permit the integration of a variety of models into a single unified system. These models include UTPS type prediction models, system performance models such as FREQ and TRANSYT, and models of the impacts of transportation programs on the economy and air quality.

The initial feedback from a preliminary presentation of PLANiTS was quite positive (see Appendix 3 for a summary of a seminar held in June 1993 where PLANiTS was presented and discussed). We are encouraged to proceed with the development of a prototype and some of the important components. An important aspect of this development is to look for ways in which the planning system can be made truly in tune with the political processes of planning. It is clear to us now that PLANiTS must have political support if it is to be of any value in the real world of decision making and transportation programming. With this in mind, the following research activities are under way in the second phase.

Second Phase Research Effort

The current efforts representing the second phase of this research are focused on further development of a preliminary version of PLANiTS and associated elements. The research includes the following:

1) *Development of a PLANiTS prototype.* This prototype will have a complete shell of the overall structure of the PLANiTS system that can be demonstrated on a limited scale in a desktop computer environment. The prototype will include a planning vector intended for illustrative purpose and containing perhaps two or three actions, a similar number of criteria, and environmental descriptors. We will use the prototype to test and demonstrate PLANiTS.

2) *Development of the Knowledge Base.* The knowledge base is perhaps one of the most unique features of the proposed methodology. We will develop a framework for knowledge representation in transportation planning, and then combine this with adaptations of techniques of case based reasoning and data filtering to create a

knowledge base for planning. We will select the actions programmed in the PLANiTS prototype to begin to enrich the knowledge base with real information.

3) *Integration of Models.* We will develop a platform for the integration of planning and operations models into a methods base for PLANiTS. There is currently a large amount of research activity focussing on the integration of planning and operations models. There is also a large modeling effort underway to develop models of system behavior under IVHS scenarios. We are hoping that the PLANiTS environment could become a unifying platform for such model integration activities.

4) *Decision Support Techniques.* We will continue to specify the requirements of a decision support environment for PLANiTS and select a specific system for integration into PLANiTS.

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APPENDIX 1

SUMMARY OF INTERVIEWS

COMMENTS OF INTERVIEWEES REGARDING NEW TECHNOLOGIES

Accommodating new technologies in transportation planning models

The model can be used in a "what if" mode, assuming the effects of new technologies (Farhad Mansourian, Marin CMA)

They are not sure that there is a new technology that would change how planning is done. A monorail would not change how planning is done; additional information would not change it either. Even smart highways could be modeled by increasing capacity. (Fred Vogler, Carol Williams, Marin Planning).

Modeling an automated highway might be as simple as increasing the capacity of the highway. In modeling a facility for small cars or automated cars the problem is estimating the percentage of such cars. For road pricing they could use the model to estimate cost-elasticity and then apply congestion pricing to the networks. They would need better details on how new technologies would work. (Chuck Purvis, MTC modeler).

There are so many interests to satisfy in transportation planning that is impossible to incorporate them into an analytical model. (Joel Markowitz, MTC Advanced Systems Applications)

Congestion pricing

Congestion pricing is difficult politically - it is easier to go after a few large employers with a trip reduction ordinance. We haven't gotten into market-based solutions at all. You can not do any economic incentives at the county level - people don't want to pay higher local taxes on gas or vehicles. But charging for parking is possible. (Fred Vogler, Carol Williams, Marin Planning)

Within 5 years there will probably be toll tags for automatic toll paying on the bridges in the region. Electronic license plates probably will not be required because of the privacy issue. Any new toll roads will have automatic toll collection. The private toll road in Orange County in moving forward but the East Bay toll road is not likely to happen in the near future, if ever. (Joel Markowitz, MTC Advanced Systems Applications)

The East Contra Costa toll road is probably not going to happen because it is too difficult to finance ($1 billion). (Bob McCleary, Contra Costa CMA)

AVI does not always work, the identification gets dirty and can not be read and people from out of the region do not have AVI. (Ben Chuck, Caltrans Transit Division)

Road pricing should pay local jurisdictions for taking care of accidents on the freeways. Congestion pricing is just a substitute for a gas tax. (Mike Evanhoe, Santa Clara CMA)

Advanced traveler information systems

How could it help when there are no alternate routes or modes or when cities will not allow through traffic on its streets or when one's boss will not allow flexible hours (Farhad Mansourian, Marin CMA)

Caltrans is trying to get the perfect AVI system and so it is taking a long time, and congestion pricing can not be implemented yet. (Mike Evanhoe, Santa Clara CMA)

Very small cars

People are opposed to using the railroad right-of-way for anything other than trains (in response to a question regarding using the right-of-way as a facility for Lean Machine-type cars) (Fred Vogler, Marin Planning)

These are not a good idea because we want to reduce the number of cars What about the congestion they would generate off the freeway. (Joel Markowitz, MTC Advanced Systems Applications)

Automated vehicles or small cars would be impossible on mixed use guideways because of safety/liability problems. They might work on separate guideways. (Andy Nash, Santa Clara CMA)

Automated vehicles/highways

Expensive and not likely to be funded. (Carol Williams, Marin Planning)

What about liability? What about merging? What about facilities? People would not stand for part of the road being reserved for just certain kinds of cars. It would be undemocratic. People would not want to give up control. (Joel Markowitz, MTC Advanced Systems Applications)

Automated vehicles and other new technologies are probably irrelevant at this point. There has to be a perceived need and no risk. (Bob McCleary, Contra Costa CMA)

This is not likely to reduce demand as much as telecommuting, because there is more rapid progress in information technology than in transportation technology. The former will change the way people work and the way institutions are set up. (Eugene Leon, ABAG Associate Executive Director)

The likelihood of smart highways being accepted by people is small because they want to control their own vehicles. (Fred Vogler, Marin Planning)

Automated vehicles and collision avoidance would require national standards.

(Andy Nash, Santa Clara CMA)

Using collision avoidance technology to make trucks safer is trying to solve a legislative/political issue with technology. The same effect could be achieved by limiting trucks to the right lane only and certain hours. (Mike Evanhoe, Santa Clara CMA)

When the government is operating the vehicle, there is a new liability issue. Liability is probably the biggest issue. But there is also a problem making the transition to a new system. You can't build a facility if only a few people will use it, but no one will use the new technology if there are no facilities for it. There is a danger in deploying a technology prematurely and having it not work right. (Tom Clausen, Concord Transportation Manager)

Perhaps the pathway to an automated system is incremental automation. The most expensive component, the vehicle control is already partially developed (cruise control, anti-lock brakes, power steering). One could add lateral control (the magnetic pins in the roads are not very expensive), collision avoidance, and so forth. Over the course of time, most people would have cars with some automated features. The traffic operations systems are being developed. We could just keep adding automated features to the fleet and the road until there were sufficient vehicles to develop fully automated lanes. (Tony Hitchcock, PATH)

Alternative fuels

Although Caltrans is already involved in this, the air quality board is where it belongs. PG&E is promoting natural gas vehicles. (Andy Nash, Santa Clara CMA)

Near-term technologies

MTC's Advanced Systems Applications Division was created in 1991 to take advantage of opportunities offered by ISTEA. It is an implementation organization and does not do research and development. It is currently promoting a pavement management system, an emergency call box system, automatic fare collection, centralized transit information via telephone, a traveler information system, and transportation control measures, such as optimal signal timing. (Joel Markowitz, MTC Advanced Systems Applications)

Traffic operations system

Caltrans is currently developing a system of loops, TV cameras, and computers that will gather and process traffic information. (Joel Markowitz, MTC Advanced Systems Applications)

Caltrans is putting in a $10 million TOS system in Santa Clara County, which was probably chosen because it has the most advanced highway system in the Bay Area. The county would rather have that money for other projects. (Andy Nash, Santa Clara County)

The City of San Jose is developing its own traveler information system for its arterials. They will interlink all of their downtown traffic signals. They already have 200 on the system and eventually will have 1000. (Andy Nash, Santa Clara CMA)

New technologies and the economic climate

The current economic climate is not good for new technology or any new projects. People are busy hanging onto what they have. They perceive things as a zero sum game. There is a sense of scarcity, which makes it tougher to do anything. People who want to fight against change have become a much stronger force. (Bob McCleary, Contra Costa CMA)

Political acceptability of new technologies

Willing to consider new technologies but not optimistic that they will succeed politically. (Farhad Mansourian, Marin CMA)

There is an ideology that we shouldn't be making things easier for cars. (Carol Williams, Marin Planning)

The acceptability of new technologies is strictly political and is not based on cost-effectiveness. Politics are about how people want to live their lives and they favor cheap gas, driving alone, and driving anywhere. (Fred Vogler, Marin Planning)

Equity is always the achilles heel of efficiency. (Gene Bardach, UC Public Policy)

We need to get the current system in order before initiating new technologies. For example, Caltrans is installing TOS throughout Santa Clara County, even on roads that will be severely congested. Motorists will not be impressed with signs that say "Road congested" or "Have a Nice Day" where the freeway is congested. The timing is wrong. Everything will be automated eventually, but new technologies should be introduced at the appropriate time. (Mike Evanhoe, Santa Clara CMA)

Introducing new technology

It is important to show that the technology will work, through use of demonstration projects. A new technology might be adopted if it has been demonstrated to solve a problem that people perceive they have. It is also more attractive if some other level of government is paying. There is no incentive for a local government to adopt a new technology on its own; there are too many other places to spend money and they are not willing to take any financial risks. Technology must be sensitive to local impacts and must respect the desire not to lose local control. The State could take a more aggressive stance on new technology, such as advocated in the Katz bill. A separate agency, not Caltrans, should be responsible for technology diffusion.

(Bob McCleary, Contra Costa CMA)

If there is money for new technology, it will happen. Local governments are busy with day to day concerns and are reluctant to get into something expensive and controversial. They do not want to be the guinea pig and they need someone to share the risk. This might be the state or federal government. The State is probably easier for technology diffusion because the federal government is too far removed. You can not stop implementation of a new technology at the county line, maybe a state-regional-county structure is needed, so as to involve all of the players. Caltrans could perform this function; a consulting firm would not be as good because they would not have a stake in making it work. To introduce a new technology, first build a case for it--show its effects on employment, its cost, and why it is a good idea. If there is a political person who is interested in it, make sure that he/she gets information about it. The initial champion of a new technology need not be a political person, but ultimately a political champion is needed. (Brigid Hynes-Cherin, San Francisco CMP)

It would be good to have a state agency, within Caltrans, do the evaluation of new technologies, but the RTPAs should do the diffusion because they know the local situation and the players. For example, once the benefits of some of the technologies had been assessed, MTC would meet with the local staff people to get their ideas about how and where new technologies should be tried. It is not too early to begin thinking about this--local transportation planners and decision-makers have heard about new technologies but are not very knowledgeable about how they would work. They have concerns about the effects of AVIS in diverting freeway traffic on to local streets and they think that automated vehicles are too far off or too expensive to be worth thinking about now. (Chris Brittle, MTC Planning)

A new technology needs a government sponsor. You start with the concept, then convince a transit operator or city to try it. This is the role of the MTC Advanced Systems Application Division. If it works, others try it and it is funded through the regular process. Ad hoc groups would probably be the way to move into new technologies. The CMAs might be the prime movers, MTC would link up with those who would be promoting the new technology, and the partnership would come into play. (Hank Dittmar, MTC Legislation and Finance)

People are very resistant to change. To succeed, you need a champion with a clear vision and clear mission. But first, you need to determine if there is going to be a market. Demonstration projects are a very good idea in order to discover the weak spots of the technology. The champion could be an organization. The idea could originate in a county. New technologies could be franchised with a private company. If you give local people the right legal tools and the right incentives, they can be quite creative, especially if they are chasing money. (Dennis Fay, Alameda CMP)

The most important thing is to identify new technologies as options when corridor studies are done. The technologies need not necessarily be feasible right now. An institutional champion will be needed to make sure that new technologies are given adequate consideration. It should be a coalition of academics, industry, and governments. (Therese McMillan, MTC Planning)

The CMAs can bring people in and build a constructive base so that they can implement new technologies. This is already happening with signal optimization and ramp metering. (Mike Evanhoe, Santa Clara CMA)

The best way to introduce new technologies is to get local traffic engineers to want to do it. For example, the engineers in San Jose are really excited about the automated traffic light system they are installing. Every city in Santa Clara County has a traffic engineer, and they like to get together to talk about new things. (Andy Nash, Santa Clara CMA) When you try to initiate things at the state and federal level, things may not be very realistic. (Mike Evanhoe, Santa Clara CMP).

The cities may not have a role in new technologies such as a traveler information system. They will do signal optimization and ramp metering, as long as local people are not disadvantaged by through traffic. In evaluating a new technology, one would look at the experience elsewhere and examine the data and than take it to the city council if it looked promising. The biggest problem would be introducing something brand new. (Tom Clausen, Concord Transportation Manager)

ITE, East Bay Traffic Engineers, and ITS might be the best way to get the information out on new technologies. Most transportation engineers in cities the size of Concord are well educated and keep in touch with new technologies. Caltrans could promote new technologies initially. (Tom Clausen, Concord Transportation Manager)

Key questions in implementing technology

1) Who is involved, 2) what to do institutionally, and 3) how to make decisions. (Brigid Hynes-Cherin, San Francisco CMA)

FINDINGS

Modeling Planners view modeling as the typical 4 step process. They would accommodate new technologies in the model by adjusting capacity and making assumptions regarding the share of the market that would utilize new technologies. They are not thinking of changing the model structure itself. How to model new technologies is not an important issue to them.

Political Feasibility The important issue is political feasibility. Some people take this as given, others expect to be able to shape it through education of staff and politicians. How people view it does not seems to be related to their position or constituency, but rather to their own attitudes toward the technologies, which may be shaped by their knowledge of the technologies.

Attitudes Toward New Technologies Four of the nine non-MTC planners felt that new technologies were not relevant, because they were too expensive, did not address a perceived problem, or were not yet available. The Caltrans planner held much the same view, espousing life-style change as the solution to congestion. However, CMA managers from Alameda County and San Francisco, Dennis Fay and Brigid Hynes-Cherin, saw promise in new technologies and are attempting to educate their CMAs about the potential of new technologies. The Associate Executive Director of ABAG was very supportive of telecommuting.
Of the five MTC planners interviewed, only the long range planner, Therese McMillan, was enthusiastic about new technologies and plans to take action to promote them (by including them in the long-range plan). The Advanced Systems Applications planner, whose job is to promote demonstrated new technologies, was actually hostile to automated vehicles and very small vehicles. The other three MTC planners were interested in new technologies but are not taking the initiative to educate the local planners with whom they work.

Changing Attitudes There are opportunities to work with the people who are interested in new technologies to educate and change the attitudes of the less enthusiastic. The CMA managers association, which Dennis Fay helped organize, and the MTC partnership, for which Therese McMillan is staff person, are both good forums for discussing new technologies. In addition to changing attitudes, such discussions could provide the people who are developing the technologies with useful feedback.

Implementing New Technology New technologies relating only to vehicles will require no public involvement, other than meeting product and safety standards.

Their deployment may be motivated by the need to comply with regulations, such as CAFE standards or clean air regulation.

Technologies that require public operation or that involve public facilities are a different matter. A demonstration will be needed to show that the technology will work. A need (market) for the technology must also be shown. A champion will be needed to promote the adoption of the technology, acquire funding, and achieve implementation--this could be an individual or an organization. State or federal funding will be necessary to reduce risk and to motivate local governments to try new technologies. Most CMA managers thought that a state agency should take the lead in evaluating and promoting technologies. They were split as to whether it should be part of Caltrans. Implementation will require cooperation between this agency and local and regional agencies as well as with the industry developing the technology.

Hitchcock's notion of incremental movement to an automated system is very interesting. It eliminates many of the problems that people note about automated systems, that they would be only for the affluent, that you can't get enough vehicles automated facilities until there are enough automated vehicles, which no one would buy unless there were automated facilities. This suggests that we might try some vision building with city and county traffic engineers, that is, looking at an end state and mapping a path to get there.

APPENDIX 2

DESCRIPTIONS OF INFORMATION TECHNOLOGY TO SUPPORT GROUP DECISION MAKING

GIBIS: NCR Human Interface Technology Center, University of Texas at Austin and MCC (Microelectronics and Computer Technology Corporation). GIBIS, "Graphical Issue Based Information System", is a hypertext tool for exploratory policy discussion. SUN workstation-based tool, it is not clear when application is not graphic based, if SUNs are necessary. DECAID "Decision Aid for Groups" (Proceedings of the Conference on Computer Supported Cooperative Work 1988. p 140).

PLEXSYS: University of Arizona. A GDSS operating since 1985 at the PlexCenter (conference facility which includes 24 interactive IBM PS/2 workstations). Written in turbo Pascal and uses IBM PCNetwork.

SAMM (Software Aided Meeting Management): University of Minnesota. 1988. A nonspecialized, multi-purpose model designed to facilitate group consensus. Embodies a widely-used decision procedure, Dewey's Reflective Thinking Model along with conventional ranking, rating and voting procedures. Written in C and operates in UNIX on an NCR Tower Computer system. started in 1986.

CALTEAS (Computer Aided Landuse Transport Environment Analysis System): University of Tokyo. Multi-level GIS based database and expert system developed on Sun workstations. 1990.

VIRTUAL NOTEBOOK: Baylor College of Medicine. Technologically extended analog to ordinary notebook to help members of a biomedical group coordinate efforts and share information and improve group functions. Uses Sun Workstations, Unix, Sunview tools and hypertext system (Proceedings of the Conference on Computer Supported Cooperative Work 1988. p 39)

OBJECT LENS: MIT. Information Lens is a prototype electronic mail system (circa 1987) which employs smart semi-structured messaging. Allows unsophisticated computer users to create their own cooperative work applications using a set of simple, but powerful building blocks. SIBYL: manages qualitative aspects of decision making (1990). RTCAL supports meeting scheduling by building a shared workspace of information from participants on-line calendars. RTCAL/IOLC is somewhat analogous to Colab. Austin project also considered similar (Computer Supported Cooperative Work, p 397). Implemented in Interlisp-D on Xerox 1100 series workstations connected by Ethernet (Proceedings of the Conference on Computer Supported Cooperative Work 1988. p 115).

COSMOS. Development of language/action perspective as part of larger project, in particular computer-based message systems and computer mediated communications. (Proceedings of the Conference on Computer Supported Cooperative Work 1988.)

COORDINATOR. An electronic communication system explicitly designed to embody a model of human cooperative activity on IBM XT/Ats. Action Technologies (Stanford Univ) (Proceedings of the Conference on Computer Supported Cooperative Work 1988. p 189; Computer Supported Cooperative Work, p 623).

AUGMENT. Tymshare, Inc. Text processing system for multi-user network environment. Originally developed at SRI International under sponsorship of NASA, DARPA and RADC. System evolved on time-shared mainframes and packet switched network environment (Computer Supported Cooperative Work, p 107).

COLAB. XEROX PARC. Experimental electronic meeting room support. Focuses on face-to-face support. BOARDNOTER imitates the functionality of a chalkboard. COGNOTER guides brain storming and support idea development processes--it is used to prepare presentations collectively. Think-tank, Freestyle and NoteCards are similar programs. ARGNOTER is a tool for considering and evaluating alternative proposals. It has three components: proposing, arguing and evaluating. Considered similar to SIBYL, (1987) and SYNVIEW (1986). NOTECARDS a hypertext environment. Software built on Xerox Lisp Machines connected by Ethernet and written in Loops (a language similar to Smalltalk). (CSCW 88, p 216) (Computer Supported Cooperative Work, p 335)

QUILT. Collaborative document production. Bell Communications Research. Uses Orion database system in X Windows and Xt toolkit.
Claremont Graduate School.

Commercial Packages:

NOTES: Lotus Corp. A generic groupware application that permits replications of databases, support for distributed servers and disconnected users, E-mail and integrated development tools. Runs in Windows on OS/2 workstations and servers. The Notes Application Programming Interface (API) allows programmers to develop specialized applications in C, as well as to import and export data from custom systems. Price: $495/user (may have 15 percent academic discount).

COLLAGE: National Center for Supercomputing Applications (NCSA). Runs on system 7 Mackintosh computers with Ethernet. Considered the next generation of scientific data analysis tool, provides image display and analysis, color table editing, and spreadsheet display of floating point numbers. on network, provides capability to distribute data analysis and visualization functions. This functionality is being implemented in tools on X Windows and PC-compatible platforms.

VISIONQUEST: Collaborative Technologies Corp. Austin, TX. Runs on network of

DOS-based Pcs and LANs. Also supports VisionQuest for Notes. Price: $27,500 (university research agreement: $250). (25 users)

GroupSystems V: Ventana Corp. Tucson AZ run by J. Nunamaker who ran the research and development at U of AZ. Price: $34,900.

TEAMFOCUS: IBM. Is same as the licensed version of GroupSystems. Price: $50,000.

OPTION FINDER: a portable audience response system that permits sophisticated polling of groups. Permits anonymous voting; has four question formats (nominal scale, discrete scale, likert scale, paired comparison); displays results (bar chart or x-y axis plotting); supports brain storming. Can be used for conflict management, issue surfacing. Option Technologies Inc., Mendota Heights, Minn. Supports and projection system that connects to a VGA port on a DOS based PC. Price: $11,800-15,561.

SMARTCHOICE: SmartChoice Technologies, Hoboken NJ. Unix based.

APPENDIX 3

SUMMARY OF PLANNING SEMINAR

A seminar was held on June 16, 1993 to present the PLANiTS concept to transportation planners and academics. The general opinion expressed at the conference was that the PLANiTS methodology could be useful to both planners and citizens' groups. Just providing a "memory" of what has already been learned would be very useful.

Although seminar participants liked the knowledge base and the fact that PLANiTS would help them to do more and better analysis, it was the participatory nature of the process that attracted the most comment. A representative from the Sierra Club was particularly positive about this.

Public Participation and Inter-agency Cooperation There would be widespread access to PLANiTS for individuals and interest groups. Uses could access the data base and study the process. They could look at the tradeoffs, such as between the environment and congestion. PLANiTS would allow a dialogue about the information so that people could see who said what. A citizens' group could add its measures of performance and assumptions to the data base or even add a competing data base, although there would be limits on what could be entered into the system. Unlike the current process, which is based on models, mandated processes and "sound practice", PLANiTS would provide a means to debate and criticize the process. It would support awareness of the problems and issues, generation of alternatives, analysis and evaluation. The system would sharpen insights rather than provide answers. It would allow users to explore alternatives. This is important because participants were virtually unanimous in their belief that it is impossible to construct an analytical process that is value neutral. PLANiTS has the potential to improve the quality of debate and the working of politics, but it will not eliminate politics. Therefore, we need to attend to the importance of argumentation. There is no right answer, but instead a diversity of answers.

Several people noted that information does not solve all problems and can create problems; it will not guarantee consensus and in fact will make people more aware of their differences. But it was generally agreed that consensus was not required; instead, reaching resolution should be the goal of the process. It was noted that people may agree on ends without agreeing on assumptions.

A high level of access to information has other risks. It could confuse users. It also could make agencies more vulnerable to criticism. It was recognized that agencies would not want their analysis to be scrutinized by the public until they had confirmed that it was sensible and correct.

The mutually reinforcing nature of advocacy and analysis was discussed. Information can sway the opinions of advocates. On the other hand, advocates are needed to provide the political power to act on the basis of good analysis.
The following questions were raised regarding the participatory, decision-making aspect of PLANiTS:

- How do individuals and groups that are interested in only a small part of the process participate--for example, neighborhood interests with self interests?

- How does PLANiTS avoid information overload for the hardware and users of the system?

- What would be the policy regarding the type or timing of information made available for public review and use?

- How is resolution reached?

Creativity One participant warned of the danger of locking the status quo into PLANiTS and thus locking out creative, new ideas. Others countered that the openness of the system and the ability to carry on a dialogue should provide both the motivation and ability to introduce new ideas and methods. They noted that creativity can be sparked by intense confrontation, funding constraints, and failure. However, to spark creativity, the failures must be recognized as such.

Quality Control, Error, and Uncertainty One academic participant pointed out the need for quality control. There has not been much peer review of what is currently "known" about transportation. PLANiTS should have a peer review process, and the process should be transparent. Another noted that transportation agencies are increasingly having to defend themselves against lawsuits. When this happens they need a means of certifying the models they use. It was noted that there are varying degrees of accuracy in models and the data input to the models. People are unaware of the extent of this error. It would be an enormous step if we had a system that could let users know the extent of error and uncertainty. We need to involve the public in debates about the quality of the data.

PLANiTS Scope There was interest in providing tools for determining mode choice for freight as well as for personal transportation. Intercity transportation might also be included. PLANiTS should address land use and economic impacts and utilize the work on GIS systems for planning. It should include information on funding sources--where and how to get money for projects.

Funding and Implementation It is importance to have a clear long-term client or clients in order to fund the system. Large computerized systems, such as Lexis, have a clear client. It was noted that whoever funds PLANiTS may control access to the system.

An obvious arena for applying PLANiTS is MTC's preparation of the TIP, 7-Year Plan and 20-Year Plan.