Application of Decision Analysis to Intelligent Transportation System Societal Issues

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16. Abstract

A demonstration of the use of decision analysis to address societal and institutional issues in an Intelligent Transportation System-based paratransit implementation was performed. A decision analysis technique called Multi-Organization Decision Analysis (MODA) was developed, and it is based on the Decision Risk Analysis process used widely in the private sector. Its objective is to facilitate consensus among the disparate public and private sector stakeholders in a decision process. The stakeholders are represented on a decision-making team, and they are supported by a team of analysts. MODA meetings are aided by facilitators. The process includes the development of a shared vision statement framing the problem, developing alternative solutions, analyzing the alternatives, and reaching a decision. Progression to the next step of the process does not occur until consensus is reached on the present step.

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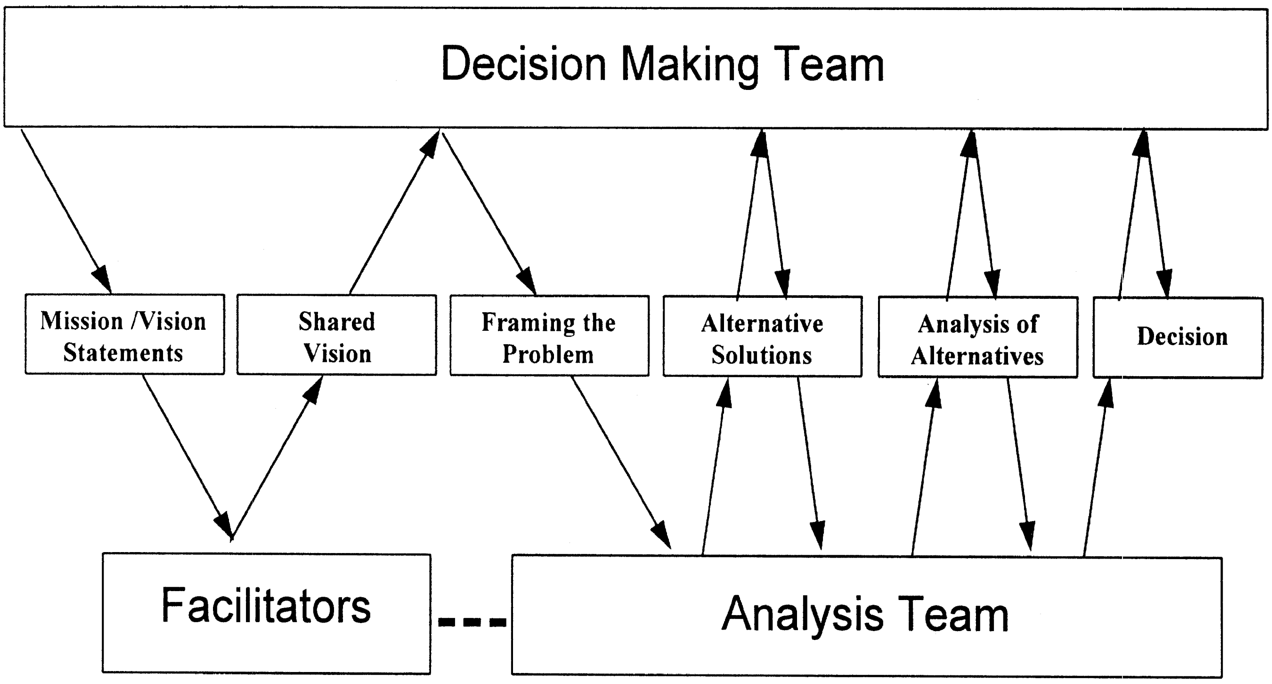
EXECUTIVE SUMMARY

Societal and institutional issues are pivotal concerns in the implementation of Intelligent Transportation Systems (ITS). If not considered to the satisfaction of affected parties, they can inhibit the implementation process. If considered carefully, the technology can enhance the personal lives and business opportunities of a community. A major factor inhibiting the careful consideration of societal and institutional issues in ITS implementations has been the lack of application of methods to address these issues in a structured way.

Because societal and institutional issues are so important, it was decided to demonstrate the use of a decision analysis method to bring them into the process of deciding on an ITS implementation. The technology chosen was ITS-based paratransit service at the community level. The specific decision was whether an individual community should upgrade the paratransit services already provided by a regional transit authority to include ITS technology such as vehicle location and route scheduling. The hypothetical community in which this decision was to be made was based on a typical community in Southeast Michigan.

A decision support method called Decision Risk Analysis is widely used in the private sector. This method was modified to include representatives of several organizations from the public and private sectors. The new method is called Multi-Organization Decision Analysis (MODA). A schematic of MODA is shown in the figure. Its objective is to facilitate consensus among the disparate public and private sector stakeholders in a decision process. The stakeholders are represented on a decision-making team, and they are supported by a team of analysts. MODA meetings are aided by facilitators. The process includes the development of a shared vision statement, framing the problem, developing alternative solutions, analyzing the alternatives, and reaching a decision. Progression to the next step of the process does not occur until consensus is reached on the present step.



Because a hypothetical community was used in the demonstration of MODA, it was not possible to get actual stakeholders to participate in the process. However, people who actually represented a community government, a regional transit authority, the handicapped community, the elderly community, and a road commission participated in the process. They were joined by two additional people who were very familiar with the functioning of a commercial shopping mall and the state department of transportation. Together, these people comprised the Decision-Making Team. The Analysis Team was composed of six analysts from the University of Michigan project team. Facilitation of meetings was also done by project team members.

Consensus was reached by the Decision-Making Team after two meetings. While there was a considerable amount of disagreement concerning the LOS to be offered and the cost of providing it, the key to common ground was provided by one member of the Decision-Making Team and processed by the Analysis Team. In order to analyze the alternatives suggested by the Decision-Making Team, the Analysis Team developed spread-sheet-based algorithms including all the variables of interest to the Decision-Making team such as LOS, connectivity to neighboring communities, net present value of the necessary investment, cost of the service, and so on. To reach consensus, it was necessary that tradeoffs be made by the participants.

Through this demonstration, it was found that MODA is a viable tool to use in bringing societal and institutional issues into the ITS implementation planning process. MODA is applicable to a variety of ITS technologies, geographic locations, and institutional and jurisdictional constituencies.

I. INTRODUCTION

This document is the final report of a project entitled "Application of Decision Analysis to Intelligent Transportation System (ITS) Societal Issues," funded by the Transportation Research Board Intelligent Transportation System IDEA Program and conducted by the University of Michigan Transportation Research Institute. Its duration is from March 1996 to March 1997. The research project team includes: Barbara C. Richardson, Ph.D., Research Scientist, University of Michigan Transportation Research Institute, Project Director; Walter A. Albers, Ph.D., President, Albers Systems, Inc., Consultant; Lidia P. Kostyniuk, Ph.D., Adjunct Associate Research Scientist, University of Michigan Transportation Research Institute; Michelle A. Barnes, B.S.E., M.P.A., Senior Research Associate, University of Michigan Transportation Research Institute; Daniel A. Rodriguez, B.S., M.S., Ph.D. student in Urban, Technological and Environmental Planning, University of Michigan; and Owen W. Ward, undergraduate student in Mechanical Engineering and Economics, University of Michigan.

The importance of addressing societal issues in intelligent transportation system (ITS) implementation is explained by examining the role of transportation in society. Transportation plays a pivotal role in society by providing access to nearly all of a person's non-home-based activities and virtually all goods and services. Most of us do not use transportation for the sake of transportation itself, but rather to gain access to our jobs, schooling, medical care, shopping, recreation, and so on. This access is needed by almost every member of society. In planning for new transportation systems, it continues to be important to consider not only the views of those with the financial resources to pay for new transportation systems services, but also the views of all those who might benefit from their implementation. This study is focused on demonstrating a way to enable these different views to be heard and included in the planning process for ITS. The product developed during this study is entitled Multi-Organization Decision Analysis (MODA), a structured process that accommodates these different views and is applied in a variety of multi-organization decision contexts.

Section I of this report provides information on the reasons to seek new ways of addressing societal issues in making decisions on Intelligent Transportation Systems and states the objective and method of the project. Section II reviews a decision support method called decision risk analysis. Section III presents the development of the MODA Process. Section IV identifies the decision problem and describes its setting. Section V summarizes the process and presents the results of applying the decision-making process. Section VI presents a project summary. Section VII presents the conclusions. Section VIII presents recommendations of the project. Several appendices follow.

A. BACKGROUND

The transportation-planning process generally involves identifying the problem, developing alternative solutions, analyzing the options, and choosing the best alternative. It is complicated by the difficulty of identifying what "best" means, since different stakeholders in the system have different definitions. Private sector providers of transportation technology need to make a profit to remain in business, while the public sector is charged with the responsibility of maximizing public welfare. Wealthier consumers desire ever-increasing levels of comfort, convenience, and safety. The less affluent need basic transportation in order to participate as productive members of society. In short, each individual person or organization has his, her, or its own needs.

The traditional transportation-planning process accommodates the disparate views of stakeholders by a variety of means including public hearings and information sessions. (See, for example, U.S. Department of Transportation 1996.) These meetings serve to address economic issues, access to activities, neighborhood vitality, safety issues, community noise, availability and convenience of the transportation system, as well as equity issues associated with the distribution of the costs and benefits of the system. Unless societal issues such as these are adequately addressed, there is a risk of incurring great societal costs. However, there is no clearly defined process to bring the information gleaned from such meetings into the planning process in a structured way. Demonstration of such a structured process is the essence of this project.

B. OBJECTIVE AND METHOD

The goal of this project is to demonstrate the applicability of decision analysis in bringing societal and institutional issues into the ITS planning process so as to increase the potential for public/customer acceptance of ITS, reduce or eliminate potential institutional problems, and meet societal transportation needs. The project consists of two stages.

The objectives of stage one of the project were to:

- Identify applications of public and private decision analysis throughout the United States.
- Develop the decision analysis process that will be used in stage two.
- Identify a suitable ITS-related decision to demonstrate the decision analysis process.

The objective of stage two of the project was to:

- Demonstrate the new decision analysis process in an ITS implementation decision.

To meet the objectives of stage one, the method of the study included literature searches for decision-analysis methods and applications and for vendors of decision-analysis services; meetings with key people to gain insight to develop a new decision model and to identify a decision problem; and development of the new model. The stage two objective was met through the establishment of surrogate decision-making and Analysis Teams, which were key elements of the decision process. Meetings were conducted, analyses performed, and ultimately a decision pertaining to an ITS implementation was reached.

II. THE DECISION RISK ANALYSIS PROCESS

The ultimate objective of any decision support approach is to assist decision units in reaching a choice of action in an uncertain environment. Many approaches and tools have been developed to achieve this end and have been applied successfully in recent times. Among these are the analytical hierarchy process (Saaty 1980), gaming (Duke 1977; Stein 1981), multiattribute utility analysis (Keeney and Raiffa 1976), conjoint analysis (Green and Rao 1969, 1971; Luce and Tuckey 1964), and decision risk analysis (Barabba and Zaltman 1991).

The research project team examined these tools and methodologies and selected the decision risk analysis (DRA) approach as having the most potential for a successful application in the multi-organization setting, which includes public sector organizations, that is characteristic of ITS implementation decisions. The reasons for the choice of DRA are that it provides an efficient structure for bringing in the diverse opinions of a variety of decision makers and its multiattribute nature allows any attribute of concern to be considered. Furthermore, DRA's flexibility and adaptability allow the use of any analytical methods that are appropriate, including all those listed above. It is, in effect, a hybrid process that adapts to the particular problem, and yet remains robust. The following section describes the decision risk analysis process and gives examples of its applications.

Appendix A contains descriptions of some of the other available decision-support tools and methodologies. Appendix B contains lists of vendors of decision support software and consulting services.

A. DESCRIPTION

DRA is a decision support method that brings together representatives of all stakeholders in the decision of concern through a series of structured dialogues that build on the diversity of opinions. The DRA process as described by Barabba and Zaltman (1991) evolved from the early work of Keeney and Raiffa (1976), Howard and Matheson (1983), and Oppenheimer (1984). It includes a Decision Review Board, which consists of the major stakeholders in the process who have decision responsibility, a Core Study Team of technical people who are knowledgeable about technical information and analytic methods, and a facilitator. The facilitator is a neutral third party, typically an outside consultant who ensures that the procedures are followed. (See appendix B for a list of consultants who provide such services.) Typically, the Core Study Team is made up of analysts from the staffs of each member of the Analysis Team, thereby ensuring balance in the analyses. The DRA process consists of four steps: (1) framing the problem, (2) specifying alternatives, (3) performing analysis, and (4) making a decision. Throughout the DRA process, buy-in or consensus of the Decision Review Board is required before moving on to the next step. Figure II-1 shows the steps of the DRA process and the interactions between the Decision Review Board and the Core Study Team.

The decision dialogue process (DDP) is a derivative of DRA that shares DRA's basic structure but uses more innovative and creative techniques in obtaining the consensus among the members of the Decision Review Board. The unifying vision approach, described by Kusnic and Owen (1992) is an example of one such consensus-building method. It brings together the frames or world visions of each of the decision makers resulting in a broadening of the visions of the decision group and increasing the likelihood that the recommendations coming out of the overall process will be implemented.

B. APPLICATIONS OF DECISION RISK ANALYSIS

A literature search for applications of DRA in the private sector revealed that there was a multitude of DRA-related applications in the 1980s and early 1990s. However, it also became clear that there were many other applications of DRA that were mentioned in the literature, but without sufficient detail to replicate. Most likely, there are countless applications not reported at all. The reason is undoubtedly that many of the applications of DRA in the private sector focus on a proprietary decisions which, if revealed publicly, would jeopardize the decision maker's competitive position.

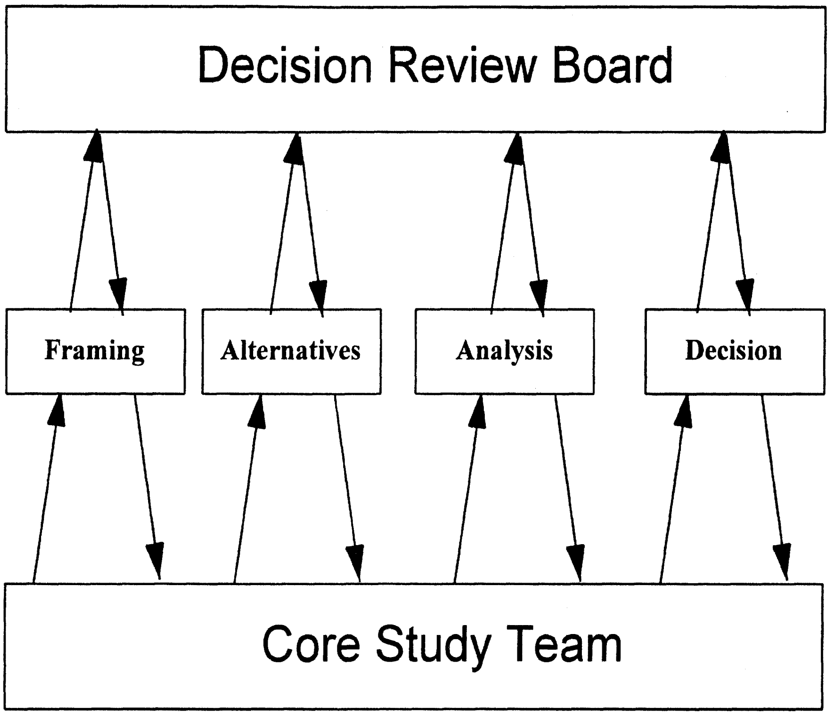


FIGURE II-1 Decision Risk Analysis Process

Electric utilities have made substantial use of DRA-related techniques for the analysis of a wide variety of problems, particularly those regarding decisions about health, economic, and environmental risks. Balson et al. (1992) discuss several applications of DRA techniques to decisions about the management of these risks. One example is the case of large boilers used in electricity generation. The large boilers that are used to make steam, which in turn is used in the electricity-generating process, periodically need to be cleaned. The cleaning material along with the boiler residue must subsequently be disposed of and may contain concentrations of some substances that could render these materials and residues hazardous. One application of DRA was made to this problem that at the time was unique: It sought to minimize the health and environmental costs of the future generation of hazardous waste. After considering a number of permutations and combinations of possible cleaning agents, prerinse states, treatment and disposal methods, and cleaning frequencies, the decision board chose a strategy that clearly would minimize future health and environmental costs while simultaneously saving the utility $119,000 over a twenty-year period.

Du Pont Corporation has made extensive use of DRA methodologies with enough success that it has adapted and incorporated DRA as an ongoing business process. Some would say that Du Pont has institutionalized DRA. They use it to help business teams develop creative strategy alternatives, evaluate these alternatives rigorously, and select those with the greatest expected stakeholder value (Krumm and Rolle 1992). One successful application within Du Pont has been described as a decision to adapt a new strategic plan for one of their principal business units. The problem was framed around the criterion of maximizing net present value (NPV), and a number of alternative strategies were generated through the use of influence diagrams along with other analytical tools. Ultimately, the decision board concluded that a differentiated product strategy would add much more to NPV than the then existing strategy. The new plan was implemented, and the business unit enjoyed immediate success.

Another company that has adopted DRA to the point of institutionalization is General Motors Corporation (GM). Not only has DRA been employed in over forty different decision environments at GM, but has also evolved into a much more efficient and effective procedure through refinements and modifications that were suggested by GM's earlier experiences. An excellent description of the GM experience with DRA is presented by Kusnic and Owen (1992). Additional material appears in Barabba (1995) and Barabba and Zaltman (1991). It appears from a review of the literature that GM is most likely the most advanced in extensive application of DRA to private sector decision making.

As part of the investigation of DRA applications, the research project team met with Nicholas Pudar of the Decision Support Center/Methods unit at General Motors. He shared with the research project team GM's experience with the application of the "framing" step of the process to a decision problem in the Presidential Advisory Committee on Personal Motor Vehicle Greenhouse Gas Reduction (U.S. Government Printing Office 1995). The objective was to prevent increases in the greenhouse gas emissions from automobiles. The various stakeholders included both environmental groups and automobile manufacturers. All had relatively inflexible positions, but the DRA process enabled them to frame the decision problem in a way that was acceptable to all parties.

Some pre-1990 applications of DRA-related techniques are reported by Howard and Matheson (1983) and Keeney and Raiffa (1976). They include the development of long-range strategies for private corporations, the decisions on selecting a site for and licensing of nuclear power facilities, and the selection of a strategy for developing the major airport facilities of the Mexico City metropolitan area.

Although the literature search did reveal a large number of private sector applications, the results of the search were disappointing from one aspect: It is rare that any detail is presented on the actual procedure carried out or on data analysis requirements. This is due to the proprietary nature of this material. Thus, there is little real guidance to be found in the literature on how to functionally carry out a DRA process.

III. MULTI-ORGANIZATION DECISION PROCESS

As noted in the previous section, DRA was chosen by the research project team to bring societal issues into the decision process associated with ITS implementation.

As research efforts progressed on the project, it became clear that while members of a private sector company have individual views of the world and represent different positions within their organizations, they usually have a common vision of selling a product to make a profit. In the public sector, this is not the case. As individuals from different organizations (e.g., metropolitan planning organizations, city government, road commissions, hospitals, schools, etc.) gather, it is evident that each organization has its own mission or goal. In addition, the public sector has different time and budget constraints than the private sector. Given these differences between the public and private sectors, the project team decided to modify the basic DRA process to include the development of and consensus on a shared vision prior to initiating the framing of the problem.

The modified DRA process, called Multi-Organization Decision Analysis (MODA) was developed and is illustrated in figure III-1. The development of a shared vision is particularly valuable within the public sector or multi-organization context because it captures the missions or visions of the various decision makers. It was recognized that it is unlikely that public sector organizations have resources to spend the time needed to accommodate extensive discussion and deliberation during the development of a shared vision. Therefore, in MODA a shared vision statement is prepared by the facilitators prior to the first meeting of the Decision-Making Team. This shared vision is crafted from the mission or vision statements of all the organizations and interest groups participating in the decision. It is intended to represent the positions of all stakeholders and to eliminate a time-consuming stage of dialogue.

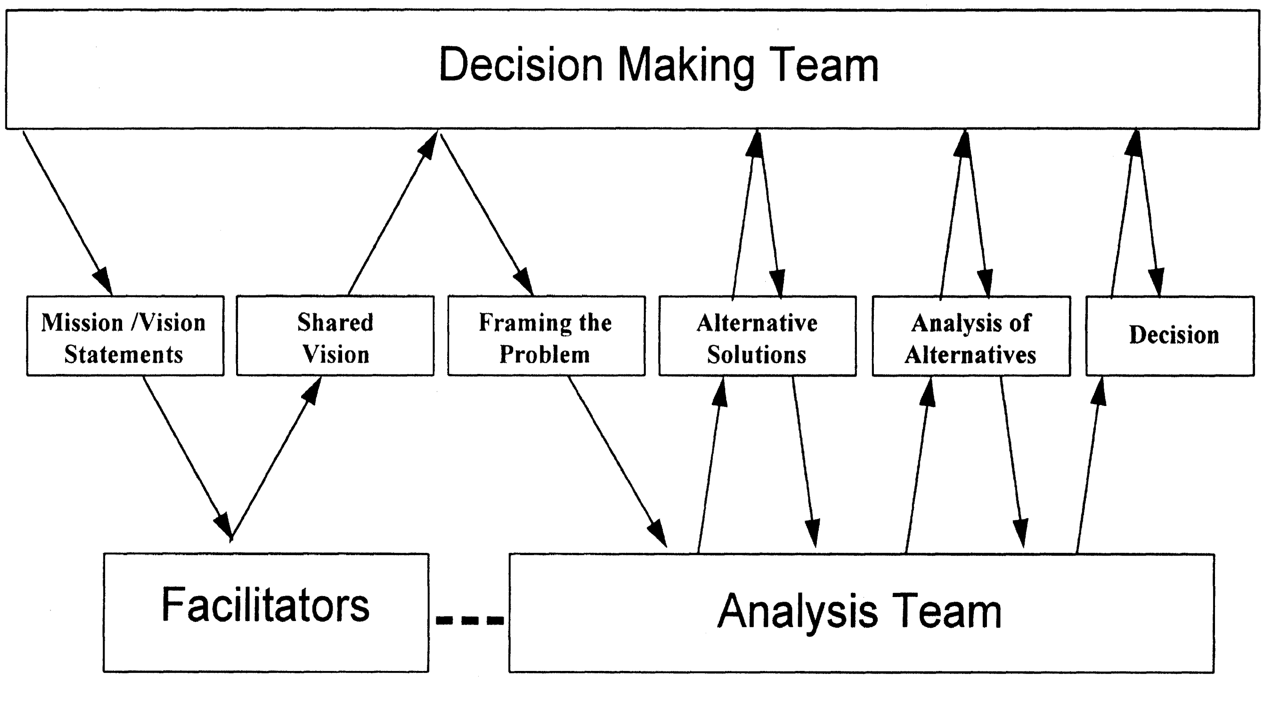


FIGURE III-1 Multi-Organization Decision Analysis (MODA)

As with the DRA process, the MODA process includes a Decision-Making Team, an Analysis Team, and one or more facilitators. The role of the facilitators, made more interesting because of the disparate organizations of the participants, includes helping the Decision-Making Team reach consensus on its shared vision and the final decision, keeping the process on track, and instructing the participants in the method of the process.

The Decision-Making Team must agree on a shared vision, which will probably be a modification of the initial shared vision prepared by the facilitators. After the shared vision is agreed upon, the problem is framed, solutions are generated and analyzed, and a decision is reached. Consensus by the Decision-Making Team is required at each step of the process.

In MODA, representatives of the various stakeholder groups that have decision-making authority or that have authority to participate in the decision-making process are included in the Decision-Making Team. It is likely that no two ITS implementation decision-making processes will be exactly the same. Different localities, organizations, agencies, and governments will require different processes. Different levels of decisions will be made. Knowing that the group designated as the Decision-Making Team may not always have the final say in a decision, the research project team nevertheless has so named the group to recognize that often it will be the decision-making body.

The Analysis Team consists of analysts who have technical expertise to carry out the necessary analyses. As in the original DRA process, it is desirable to have a one-to-one organizational correspondence between members of the Decision-Making Team and members of the Analysis Team. This correspondence increases the likelihood that there will be a balance in the representation of the various views in the analysis process.

IV. THE DECISION, THE CHARACTERIZATION OF A SURROGATE COMMUNITY, AND THE DECISION-MAKING TEAM

For the purposes of this research demonstration of MODA, surrogates were used for the decision problem, the local community, and the decision-maker representatives. In all cases, the surrogates closely replicated the actual counterparts for which they were chosen.

A. IDENTIFICATION OF THE INITIAL DECISION PROBLEM

To identify a decision for demonstration of the application of the MODA process, the research project team met with individuals from several agencies and organizations from the southeast Michigan area. The goal was to identify an actual local level decision involving societal issues in the application of ITS technologies. It was decided to address a decision within the MOTORCITI (Motor City Intelligent Transportation Infrastructure) concept. MOTORCITI is a construct for the integration of all the data needs of advanced traveler information systems (ATIS) in the southeast Michigan area.

The first meeting to identify the decision issue was with Robert Ervin, head of the Engineering Research Division at the University of Michigan Transportation Research Institute and author of the original MOTORCITI concept. Mr. Ervin explained that while the ATIS industry is primarily private, the MOTORCITI concept recognizes that traffic data are currently gathered and maintained within the public sector. MOTORCITI calls for interjurisdictional and public/private partnerships to support an information infrastructure to gather and distribute real-time traffic data throughout southeast Michigan. These partnerships would make data available to both public and private parties interested in the development and application of traffic responsive ITS products and services. This was envisioned by the ITS community in southeast Michigan as the Information Exchange System, with the intention of providing pooled transportation data to distribute travel information for both the public sector and third party information service providers (Welke 1996).

Research project staff met with James Barbaresso and Beatta Lamparski of the ITS Faster and Safer Transportation Through Traffic Routing and Advanced Controls (FAST-TRAC) project, for the Road Commission for Oakland County (RCOC). Ms. Lamparski, the assistant director of FAST-TRAC, provided background information on the regional transit provider's desire to shift the responsibility of paratransit service to local communities. James Barbaresso, former FAST-TRAC director, now the director of ITS programs at Rockwell International, provided information on RCOC's role in the development of the MOTORCITI concept in southeast Michigan.

Jonathan Levine of the Urban Planning Department at the University of Michigan explained his work on evaluating ITS components of SMART (Suburban Mobility Authority for Regional Transportation), the regional transit provider, to the research project team. He provided information on the same issue as outlined by Ms. Lamparski: whether SMART should or should not devolve its paratransit service from a regional (tri-county) service to a disaggregated set of community-based services. Professor Levine suggested that SMART might do the scheduling, dispatching, and vehicle location using ITS technology or be the technological "glue" for the individual communities that would know their transportation needs better than SMART. He noted that the two major issues relating to the transfer of paratransit services would be barriers to interjurisdictional service and political jurisdictions not wanting to support transportation costs for nonresident riders. Richard Wallace, a Ph.D. student in Urban Planning at The University of Michigan, provided further insight on these issues.

The research project team also spoke with Joan Weidner, a planner with Southeast Michigan Council of Governments (SEMCOG). Ms. Weidner provided insights into the issue of SMART devolving paratransit services from the metropolitan planning organization view and into the details related to the ITS technologies that SMART is planning to use if chosen to coordinate services for local communities.

The research project team also met with staff from the Ann Arbor Transportation Authority (AATA). AATA director, Gregory Cook, and members of his staff, William Hiller and Christopher White, provided valuable ITS data and insights into the jurisdictional and institutional barriers encountered when providing transit among multiple communities and coordinating service with other transit providers.

Discussions with these individuals provided a basis for selecting a decision problem. Furthermore, while the research project team explored possible scenarios for the application of the MODA process, SMART informed its constituent communities that it no longer wanted to continue offering multicounty ITS-based paratransit service. Each community was thus left with several choices such as taking over the operational component of a local community-based paratransit system with SMART providing scheduling and routing services, facilitating the development of the entire ITS paratransit system for that community with SMART completely running it, or not having any community-based involvement in the provision of the service. Given these issues, the research project team developed the following as the initial decision problem for application of the MODA process:

Should an individual community seek to upgrade the SMART-provided paratransit services to include the application of ITS technologies?

This project decision problem generally characterizes the questions facing the communities in the SMART service area and falls within the purview of the study. Making such a decision requires the participation of stakeholders from both the public and private sectors and falls within the definition of the MOTORCITI concept regarding inter-jurisdictional issues and the infrastructure necessary to provide real-time traffic data for an intelligent transportation system deployment. Provision of ITS-based paratransit includes a range of equity and accessibility issues, especially for the elderly and handicapped. ITS technologies that may be employed in paratransit operations include traffic management systems, route guidance, and vehicle location devices.

B. CHARACTERIZATION OF A SURROGATE COMMUNITY

With the MODA process developed and the initial decision problem identified, the research project team was ready to identify and apply the process to a specific community.

Most of the ITS activity within southeast Michigan is in Oakland County, and the research project team intended to select a community from that county for the MODA exercise. However, the socioeconomic characteristics of the communities in Oakland County are relatively homogenous; transit service is relatively poor; and transit ridership is low. Communities in Wayne County (another portion of the southeast Michigan region) have greater diversity of socioeconomic characteristics, greater transit ridership, but no ITS activity. Therefore, it was decided to create a hypothetical community called Decision City with the more diverse socioeconomic characteristics of the communities in Wayne County and with the ITS activities of Oakland County. Decision City was created to also exhibit the policies, politics, funding sources, budget, and transit operations of communities in southeast Michigan.

Specific descriptors for Decision City such as population characteristics, income and age distributions, as well as the physical and spatial characteristics are based on those from Taylor, Michigan (Taylor 1996). The road system, the bus routes, and the bus ridership information are also based on those of Taylor, Michigan. The transit operation and costs (with and without ITS enhancement) are based on those of the AATA of Ann Arbor, Michigan, another nearby community. These data were supplemented with information about Taylor, Michigan obtained from the U.S. Bureau of the Census (Campbell 1994).

Decision City is a city of 70,000 residents, six high schools, two assisted living/retirement facilities, a hospital, and a large commercial mall. It is bounded to the north and southeast by interstate highways and is accessible from the surrounding communities by transit and paratransit provided by the regional transit authority.

Decision City background information and data can be found in appendix C and include the following:

- Population, households, and jobs (1990-2020)
- Population by age distribution (1980, 1990)
- Population forecast by age and racial origin (2000, 2020)
- Land use (1990)
- Number of city road miles
- Bus ridership by fixed route
- Paratransit ridership

Figure IV-1 is a schematic representation of a map of Decision City showing its major roads and features.

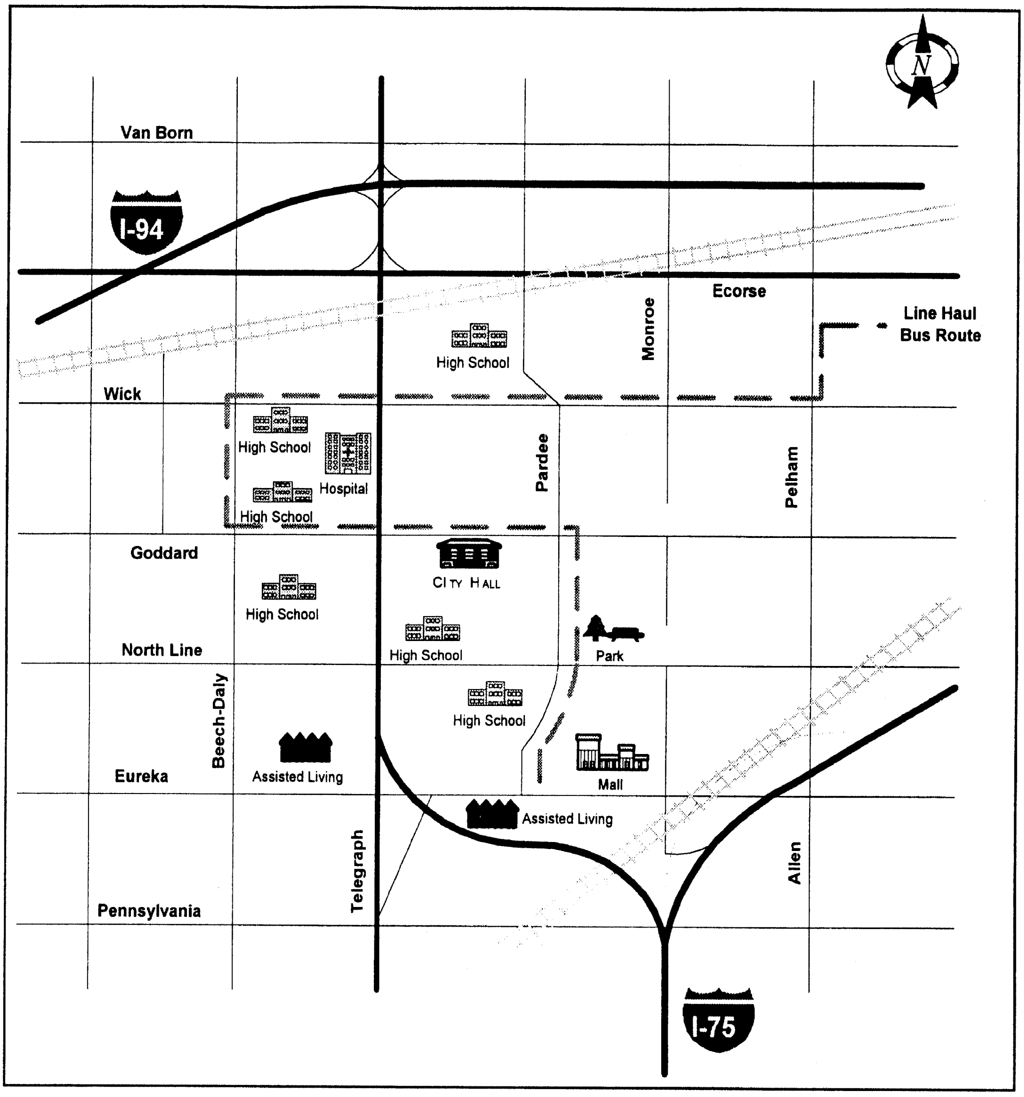


FIGURE IV-1 Schematic of Decision City

C. SELECTION OF THE DECISION-MAKING TEAM

The next step in the MODA application was the selection of those organizations and special interest groups that should be represented in the decision-making process. The following were identified as relevant stakeholders that should be on the Decision-Making Team:

- Decision City - city manager/city political representative
- Regional transit authority
- Handicapped community
- Elderly community
- Commercial mall
- Neighboring road commission
- State department of transportation

Individuals were invited to play these roles in the MODA process. Because a hypothetical community was used as the location of the decision problem, it was not possible to use actual representatives of the stakeholder groups for that community on the Decision-Making Team. Instead, people who actually represented a city government organization, a regional transportation authority, the handicapped community, the elderly community, and a road commission from nearby communities participated as surrogate representatives. They were joined by two other people who were knowledgeable about the operations of a commercial shopping mall and the state department of transportation. Research project team members acted as the Analysis Team.

Once the composition of the Decision-Making and Analysis Teams was determined, the research project team was ready to demonstrate the MODA process.

V. THE MODA DEMONSTRATION

This section provides a summary and the results of the MODA process demonstration. The meetings of the Decision-Making Team were held at the University of Michigan Transportation Research Institute on October 18 and 29, 1996. The two Decision-Making Team working sessions lasted four and three hours, respectively, and the Analysis Team met separately for two three-hour meetings. In addition, members of the Analysis Team spent many hours outside the team meetings completing the analysis. A background packet including descriptions of the project and the MODA process as well as the information on the participant's role were provided to each Decision-Making Team member prior to the meetings and is included as appendix D. In addition, background information on Decision City (from appendix C) was enclosed.

A. FIRST MEETING OF THE DECISION-MAKING TEAM

The first meeting was attended by the seven members of the Decision-Making Team and the entire Analysis Team. The objectives of this meeting were to reach consensus on a shared vision, frame the decision problem, and identify the interrelationships among the variables affecting the decision. Each meeting objective was presented, and the related discussion was moderated by the MODA facilitator.

1. Shared Vision

Members of the Decision-Making Team were provided with a draft version of a shared vision statement prior to the meeting. This version had been developed by the research project team and was drawn from the mission (or vision) statements for all the participating organizations. The draft shared vision statement for the Decision-Making Team read:

> *To ensure the provision of effective and efficient transportation service to nondrivers that will enable their access to fundamental life activities and enhance their quality of life.*

Discussion over the content of the shared vision was intense. During the discussion, the Decision-Making Team requested that the wording more precisely describe the scope of responsibility and character of paratransit services. For example, the representatives from Decision City and the Transit Authority requested that the phrase "cost effective" be added. Advocates for the elderly and handicapped wanted wording which described paratransit services as safe, reliable, and efficient while considering the differentiated needs of various user groups. Consensus on the final form of the shared vision was reached in approximately one hour. The final form of the shared vision statement was:

> *To ensure the provision of transportation service that is cost effective, safe, reliable, and efficient to eligible nondrivers with consideration of differentiated needs of various user groups.*

2. Decision Problem Statement

Upon completion of the shared vision statement, the facilitator led the Decision-Making Team through the framing of the decision problem. The initial decision problem was provided to the decision makers in a background information packet and read as follows:

> *Should Decision City seek to upgrade the paratransit services provided by the regional transit agency to include the application of ITS technologies?*

The primary input from the Decision-Making Team was that the decision problem should focus on the improvement of paratransit services for the handicapped and elderly. The role of ITS technologies in improving these services was ancillary to the overall goal. Only the additional costs associated with the application of ITS technologies was agreed to have an impact on how *much* of an improvement in services may be possible. The initial decision problem was revised by the Decision-Making Team to read:

Does Decision City want to apply ITS technologies to paratransit service?

3. Framing the Problem

Following the restatement of the decision problem, the Decision-Making Team was requested to frame or scope out the decision problem. The process of framing the problem was led by the facilitator who solicited from the decision makers as much information as possible about the decision, its inputs and impacts, and the interrelationships among these. This information was recorded and displayed in a structured manner on a blackboard by a member of the Analysis Team.

Decision-Making Team members began framing the decision in terms of LOS. The road commission representative defined LOS within the context of roadway capacity and traffic flow. The representative for the handicapped defined LOS as a function of the wait time for paratransit services. Several definitions of LOS were offered during a lengthy and controversial discussion, and the group agreed that the uncertainty surrounding wait time for paratransit services would represent an overall measure for discussing and assessing LOS. This measure is referred to as "wait time" throughout this report.

A lengthy discussion was started by the handicapped representative's demand that current paratransit services be upgraded to have zero wait time. This demand brought rebuttal from the Decision City and transit agency representatives. Both put this LOS demand in context of the overall municipal budget and its responsibility to the balance of the community and other transit riders' needs. The handicapped representative was not swayed initially and countered with arguments that the handicapped deserved better service than the rest of the community because of their limitations and for other reasons. The Decision City representative reminded the group that all members of the community are expected to have some wait time and pointed out that driver travel studies incorporate wait time at traffic signals and the time it takes to park. The transit agency representative noted that the costs of providing the LOS requested by the handicapped representative were disproportionate relative to the number of eligible riders when compared to the entire population served. It was clear that some tradeoff would be required.

Another key component of discussion concerned the additional support needed to offer connectivity to other communities beyond the city limits. Connectivity was defined as the feature of providing paratransit for trips which have either an origin or destination within the boundaries of Decision City, but not both. This component was of particular interest to the commercial mall representative. The commercial mall is located near the Decision City limits. Therefore, the mall representative wanted to capture customers who are near the mall, yet beyond the city limits. The option of offering connectivity was agreed to be a policy input, while the costs associated with upgrading the paratransit services were recognized as cost inputs. The group agreed that the output of the decision problem would be characterized by the various levels of service as defined by user needs.

The framing discussion took about two hours. This included developing the diagram of the key factors related to the decision shown in figure V-1. This figure is typical of such initial diagrams where the inputs, outputs, and their interrelationships appear disjointed and unrelated to one another. However, this brainstorming procedure is crucial as it provides the balance of the process with the interrelationships, expectations, and resources seen by the decision makers as relevant to the decision.

The decision makers took a brief break following the generation of figure V-1 on the blackboard. Upon reconvening, the facilitator requested that the decision makers review figure V-2, which was developed by the Analysis Team during the break by simply categorizing the inputs in an organized fashion and identifing the common links. The decision makers agreed to this representation.

The first MODA session closed with consensus on the shared vision statement, the decision problem statement, and the framing of the decision problem. The Analysis Team was charged with defining and costing several decision alternatives for presentation at the next MODA session.

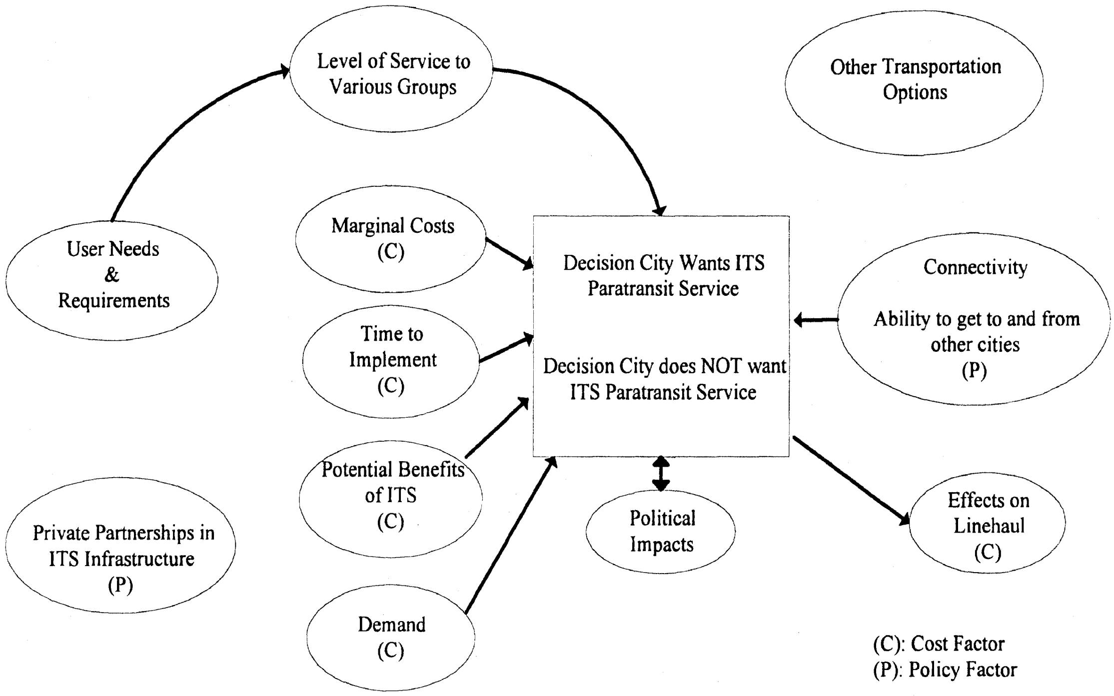


FIGURE V-1 Initial Identification of Key Factors Related to Decisions

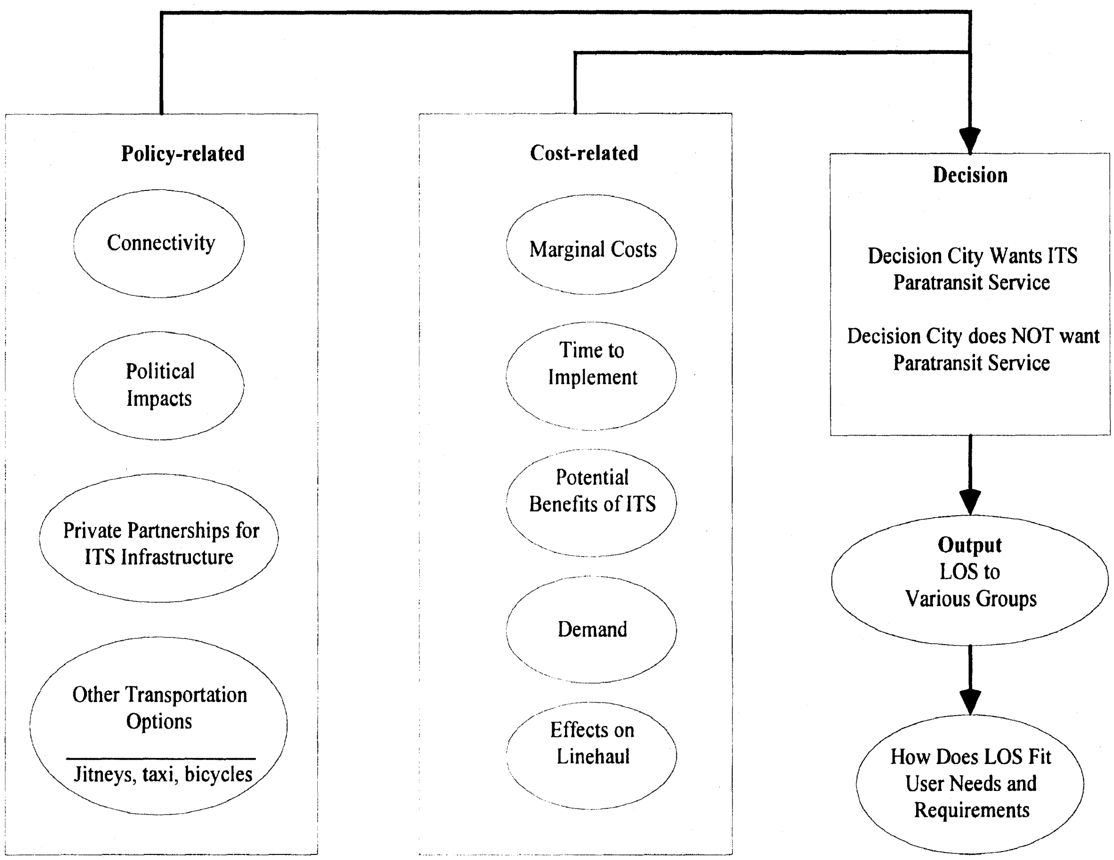


FIGURE V-2 Reorganization of Key Factors Related to Decisions

B. FIRST MEETING OF THE ANALYSIS TEAM

Following the first MODA session, all members of the Analysis Team met at the Transportation Research Institute on October 23rd. For this demonstration project, the Analysis Team members jointly represented the views of all the agencies and organizations involved in the decision. This streamlined the process, yet ensured that all views of the affected agencies and organizations were reflected in a balanced way in the analysis.

The Analysis Team started by analyzing the diagram of the key factors in figure V-2 generated in the first MODA session. Based on the diagram, the Analysis Team chose to develop an influence diagram (Clemen 1996) to translate the information shown in figure V-2 into a quantifiable depiction of the decision problem. The influence diagram method was selected because it structures the elements of the decision problem into a logical framework and contributes to clarifying a set of decision alternatives.

The identification of key factors clearly reflected the decision makers' desire to improve the paratransit users' LOS. Therefore, the LOS was described as the primary indicator for analysis of the decision alternatives. The Analysis Team also noted that there was a direct or linear relationship between the inputs and the decision, thus allowing the team to use a linear model in a spreadsheet program to quantify the inputs. Had the policy and cost categories been shown as interrelated, the relationship would have been nonlinear, which would have complicated the analytical task significantly.

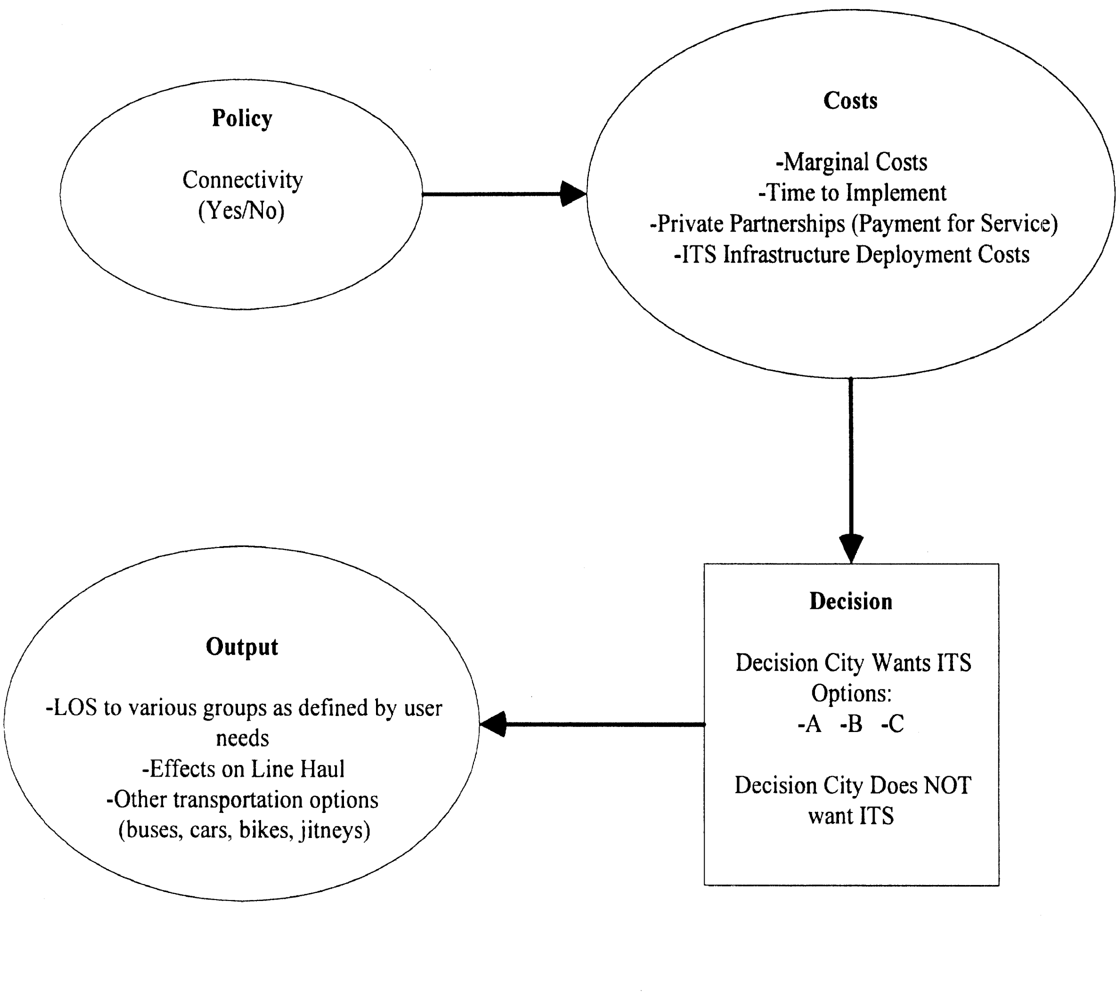


FIGURE V-3 Initial Influence Diagram

The Analysis Team developed the influence diagram shown in figure V-3. This influence diagram further delineated the major relationships among the inputs and their respective categories. A significant modification made in developing the influence diagram was to define connectivity as a policy input instead of a contributing input to cost. A policy decision for (or against) connectivity would directly affect whether or not Decision City will upgrade paratransit services to include ITS applications. However, another and more detailed iteration was required to determine the specific data needs and to define a set of decision alternatives.

Two Analysis Team members were assigned to complete the final version of the diagram, gather and/or develop data, and complete the final calculations for decision alternatives. They defined three levels of paratransit service based on four attributes important to the decision makers. Table V-1 lists these attributes and gives their definitions and values for the three levels of service. They then generated the final influence diagram utilizing the different levels of service. This captured the decision makers' concern with the paratransit upgrade and, at the same time, made the analysis more tractable.

TABLE V-1 LOS for Paratransit Service in Decision City MODA Application

LOS Attribute	Measured by	LOS A	LOS B	LOS C
Uncertainty of Pick-up Time	Maximum Waiting Time Beyond Scheduled Pick-up Time	15 min	30 min	60 min
Scheduling Ease	Reservation Advance Time for Trip: Within City Limits Beyond City Limits	No Adv. Time 24 hr	24 hr 48 hr	24 hr 72 hr
Breadth of Standing Order Policy	Who and for what trips can make standing-order reservations	All paratransit eligible riders for paid work Accredited school Health care	Wheelchair bound for paid work Accredited school Health care	Wheelchair bound for paid work
Wheelchair Accessibility	Percentage of paratransit fleet equipped with wheelchair accessible lifts	100%	75%	50 %

The final influence diagram, shown in figure V-4, was drawn to resemble arrangements used in other influence diagram applications (e.g., Clemen 1996). Such rearrangement facilitated modeling the decision in terms of the effects on various levels of service and their associated costs. Other operating information needed for the analysis was also included in the Cost/Indicators Box.

With these final modifications, the influence diagram then modeled the relationship between the cost and four level-of-service variables while accounting for the changes in these variables with the deployment of ITS technologies. The resulting influence diagram allowed the Analysis Team to directly address the major issue identified by the Decision-Making Team: upgrading paratransit's service level. Further, the model incorporated both the financial concerns of Decision City and the transit agency as well as the costs to upgrade paratransit services as requested by the handicapped and elderly representatives.

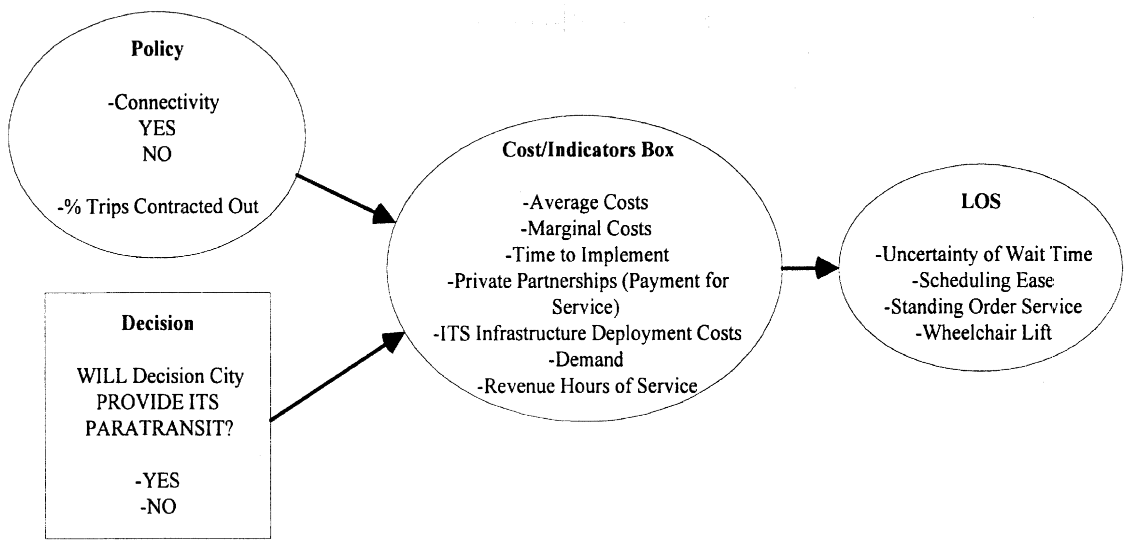


FIGURE V-4 Final Influence Diagram

Using the final influence diagram, the analysis of the decision could be disaggregated into two related components: (1) estimating changes in operating costs with ITS deployment and (2) allowing for part or all of the operating cost changes to translate into changes in the LOS variables. The first component assumes no change in LOS or other policy variables such as the amount of private participation to ensure connectivity beyond the city limits or percentage of trips provided through transit-agency-contracted cab companies. The second component assumes that operating costs and the LOS are positively correlated. Consequently, part or all of the operating costs changes would be translated into a corresponding change in the LOS. A decrease in operating costs due to ITS deployment would be reflected as an improvement in the LOS. Conversely, an increase in operating costs would be evidenced in a cutback in the four LOS variables defined above.

Other data used in the analysis included size of paratransit fleet, percentage of paratransit trips contracted out, average cost per trip, travel time reduction, anticipated increase in fleet efficiency with ITS applications, cost per vehicle for ITS, cost per service mile and hour, cost per trip by LOS, and overall demand. These were organized in a spreadsheet used to quantify the relationships portrayed in the influence diagram. The layout of the spreadsheet resembled the structure of the diagram and is shown in appendix E. The spreadsheet includes policy, cost, and LOS boxes containing inputs and calculations necessary for the analysis as defined by the influence diagram. Since the effects of deploying ITS and possibly changing the LOS accrue over a span of time, they were discounted to their present dollar value and also included in the spreadsheet.

The present paratransit operation in Decision City, or the *status quo* alternative, provides a LOS of C, which is where the present costs, revenues, and present demand were assigned. Thus, LOS C served as a basis from which the costs, revenues, and benefits for the other alternatives were determined.

The Analysis Team made a series of judicious assumptions in the modeling of the problem. These assumptions simplified reality somewhat but narrowed the scope enough for the problem to be addressed by the analysts in a reasonable time period. The assumptions relate to the demand for paratransit in Decision City, the costs of paratransit operation, and the effects of ITS on the paratransit service and operation.

It was assumed that demand for paratransit is simply the number of trips per year per eligible rider, and the elasticity of demand for paratransit with respect to the LOS is zero. In other words, there will be no additional trips on the paratransit system of Decision City even if the LOS improves over that of the present operation. This assumption was based on evidence in the transportation literature (e.g., Lago et al. 1981) that the elasticity of demand for passenger transportation is less than one. This suggests that the changes in LOS, calculated in this analysis, may be an upper bound to the real changes in LOS. Furthermore, given that the operational and cost variations due to ITS enhancement are small relative to the scale and cost of the paratransit service, the estimates provided for the changes in LOS are adequate for this analysis.

It was also assumed that there is no pent-up demand for paratransit services in Decision City with the present (*status quo*) operation and service. An increase in the productivity of the paratransit operation, which will result from ITS enhancement, will not increase demand.

It was assumed that the average cost of the paratransit operation per revenue hour is constant for a given LOS.

The calls for paratransit services in Decision City have periodic peaking characteristics, similar to those in other communities. The transit system handles this by contracting with taxi companies to serve peak hour trips that do not require wheelchair lifts. It was assumed that in the *status quo* paratransit service, the marginal costs of the operation are equal to the average costs of a private taxicab operator providing the paratransit service.

It was assumed that any ITS enhancements would be implemented only in the public vehicles. The private operators (taxicabs) contracted to provide peak-hour service would experience only negligible benefits from ITS enhancement in the public vehicles.

In this analysis, the benefits to Decision City paratransit from ITS deployment would be quantified as a decrease in operating cost resulting from an increase in efficiency of fleet use. Other possible benefits, such as driver security, community patrolling, and trip time reductions would not be considered. Therefore, the estimated ITS benefits are most likely a lower bound to the true ITS benefits.

The capital cost of the overall ITS infrastructure was not included in the costs of this analysis. However, the capital costs of the equipment needed on the paratransit vehicles to make use of the ITS services were included.

The results of the analysis were summarized for the second MODA session. The summary table shown in table V-2 was prepared, distributed, and explained to the decision makers. This table concisely displays the substantive analytical results relative to the various decision alternatives suggested in the first MODA session. The table focuses on connectivity, aggregate travel time reduction per year, LOS, and the discounted benefits (costs) due to deploying ITS and changing the LOS. Operating cost and ITS deployment-cost figures are also included, as the city and the operator would be interested in how these costs varied according to the LOS. The tables with the entire spreadsheet layout prepared as backup for the data in table V-2 are included in appendix E.

TABLE V-2 Analysis Results

	STATUS QUO	**Connectivity = YES**			**Connectivity = N0**		
		LOS A	LOS B	LOS C	LOS A	LOS B	LOS C
Travel Time Saved (hours p. year)	n.a.	8722	8722	8722	8722	8722	8722
LOS (See Table V-1)		LOS A	LOS B	LOS C	LOS A	LOS B	LOS C
Present Value of Benefits (Costs) of ITS Investment and Changes in Level of Service	n.a.	($3,892,012)	$ 420,095	$ 867,488	($3,892,012)	$ 420,095	$ 867,488
Total Operating Cost	$ 711,360	$ 851,961	$ 636,355	$ 613,986	$ 851,961	$ 636,355	$ 613,986
Total ITS Deployment Cost	$ 0	$ 480,000	$ 480,000	$ 480,000	$ 480,000	$ 480,000	$ 480,000
Private Partnerships for Expanded Service	$ 30,000	$ 30,000	$ 30,000	$ 30,000	$ 0	$ 0	$ 0

Note: Discount rate r = 0.05 over an infinite period

C. SECOND MEETING OF THE DECISION-MAKING TEAM

The second session of the MODA Decision-Making Team was facilitated by two research team members. The facilitators started by asking the decision makers to choose whether they wanted to support connectivity of paratransit services. After limited discussion, the decision makers agreed that connectivity was important for the community. Estimates of revenue to the mall from potential paratransist users from neighboring communities were quickly generated by Analysis Team members at the request of the mall operator. The commercial mall representative then agreed to continue contributing financially, therefore ensuring the connectivity of paratransit service with the surrounding communities. The ease of reaching consensus on connectivity may suggest that the MODA process facilitates reaching a decision beyond initial goals.

With consensus on connectivity, the balance of the discussion involved the costs and the corresponding LOS for applying ITS technologies to upgrade paratransit service. The conversation focused on the proposed levels of service A and B. LOS A has a 15-minute wait time and a present value cost of over $3.3 million. LOS B has a 30-minute wait time and a present value benefit of about $1 million. Discussion revealed that even the wait time of 15 minutes was unacceptably long to the representative of the handicapped population. He suggested there be no wait time for paratransit service for the handicapped. The Decision City representative countered that the driving public have wait times which can be much longer, and that that the community could not afford, financially or politically, to provide a 15-minute wait time. After intense discussion, it appeared that an impasse had been reached.

The representative of Decision City suggested that the wait time for paratransit services be established so that the net present value of the paratransit service would be zero. This would be acceptable to the city, being neither a gain nor a loss to it. This would result in a LOS with a wait time between 15 and 30 minutes. In order to determine what the new wait time would be, the Analysis Team did an eyeball sketch on the black board, estimating the approximate wait time to be 19 minutes if the net present value of the service were zero. This estimate was named A′ and is illustrated in figure V-5. All members of the Decision-Making Team agreed, given the entire set of community constraints, that 19 minutes would be a reasonable wait time for paratransit service. Recognizing that 19 minutes was a rough estimate, they agreed that the actual wait time to be calculated (subsequent to the meeting) would be acceptable to them, and they would not need to reconvene to discuss it again. The wait time was calculated to be 22 minutes and is also shown in figure V-5.

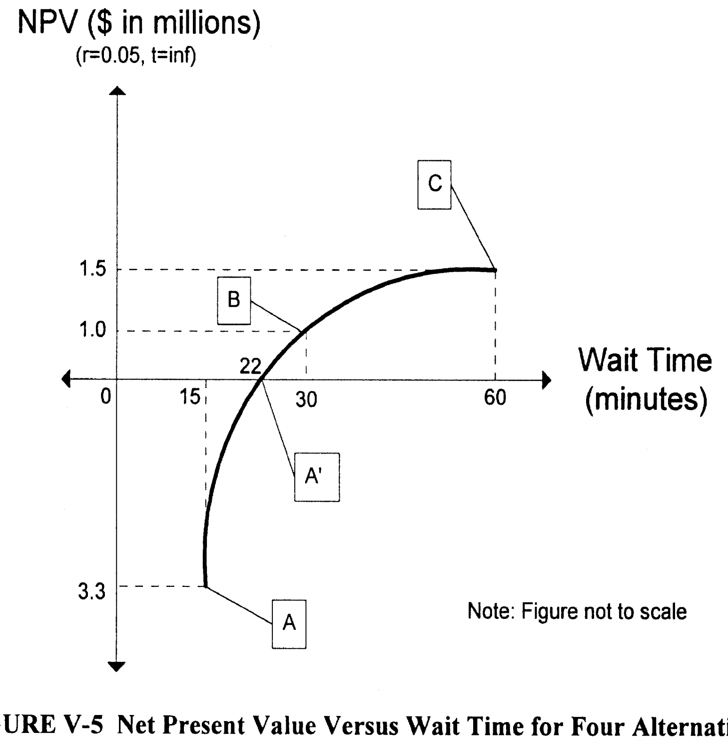


FIGURE V-5 Net Present Value Versus Wait Time for Four Alternatives

Following the discussion of the calculations of net present values and wait time, there was a brief discussion of the appropriate discounting period. It was suggested that a time period shorter than infinity might be better, but all agreed that a long time period was appropriate for this analysis. Clearly, different discounting periods would yield different results.

The difference between the original LOS A wait time of 15 minutes and LOS A′ was acceptable to all decision makers. The results of this calculation brought all parties together, and they agreed to upgrade paratransit to a LOS referred to as A′.

Consensus on the decision alternative listed below was reached:

> *To provide upgraded paratransit services through the implementation of ITS technologies in order to achieve a wait time between 15 and 30 minutes, at no additional cost to the transit agency.*

The decision makers agreed that no further meetings were necessary and instructed the facilitator and Analysis Team members to complete the additional calculations and provide the final results in writing. These results are summarized in table V-3. The decision makers also agreed to complete a MODA process evaluation for the project.

TABLE V-3 Final Results, Level of Service A' With Connectivity

Travel Time Saved (hours p. year)	8723
LOS Uncertainty of Wait Time	LOS A' 22
Present Value of Benefits (Costs) of ITS Investment and Changes in Level of Service	$0
Total Operating Cost	$669,742
Total ITS Deployment Cost	$480,000
Private Partnerships for Expanded Service	$30,000

Note: Discount rate r = 0.05 over an infinite period

D. SECOND MEETING OF THE ANALYSIS TEAM

The Analysis Team met to discuss and complete the assignments generated in the second session of the MODA process. Using a present value of zero for the ITS investment cost to the operator, LOS A′ was calculated. These results fell within the parameters agreed to by the decision makers and were then summarized and distributed to the Decision-Making Team.

E. EVALUATION OF THE MODA PROCESS BY THE DECISION-MAKING TEAM

All members of the Decision-Making Team were asked to complete a questionnaire of twelve questions which sought to establish whether the participants thought the process would help decision making among several different stakeholders and to capture views, criticisms, and opinions about the MODA process. The questionnaire is shown in appendix F. Participants were queried on what they would change about the process and how and where public input could be inserted into the process. The questionnaire also asked if the process was affected by the use of surrogate decision makers. Responses were obtained from six of the eight participants. Five of the six respondents who returned evaluations were present for both sessions, and one respondent was present for the second session only. The two participants who declined to return an evaluation were present during only the first session. In fact, one participant was present for only the first half of the first session, having been called away due to an emergency.

The evaluation consisted of a set of twelve open-ended questions. The responses to each question are summarized below.

1. Did you enjoy participating in the Intelligent Transportation System decision analysis project?

All respondents indicated that they enjoyed participating. Several reported that it was interesting, fun, and that the interactions within the group were enjoyable.

2. Did you learn anything from your participation? Please explain.

All responses were affirmative and indicated that the participants learned about the environments of the other members of the Decision-Making Team. For example, two respondents noted that they learned much about paratransit operations; one reported that she learned about the views and levels of service desired by the handicapped; and another respondent indicated that he learned about the local transportation planning agency and about the mechanisms by which the state funds local transit. Still another participant reported learning about the complexity of adapting public policies to the specialized needs of different groups.

3. What surprises were there for you?

Most participants indicated some level of surprise. The format and efficiency of the process itself surprised two of the respondents. One respondent reported that he was surprised by the level of knowledge about transportation issues and competence shown by the public administrators in the group. Another respondent reported being surprised by the inherent incomparability of the decision inputs in transportation issues.

4. Did you have enough information to participate at your level of comfort? What would have made it better?

Most respondents indicated that they would have liked more information. The representative of the city wanted to know the city's budget and current expenditures. The representative of the handicapped wanted to know more about the basic costs of operating a public transit system, expressed as cost per mile or cost per trip, for different types of vehicles, as well as information about demand by groups at different levels of service. The representative of the mall wanted to know more about the operation of the public transit system. The representative of the state noted that he was not familiar with the many mechanisms by which the state funds local transit and could have used this information.

5. Did any part of the process make you feel pressured or uncomfortable? Please explain.

Most respondents stated that they did not feel pressured or uncomfortable. However, one respondent felt hurried to agree on a mission statement. He noted that the facilitators were, in essence, trying to either override or mute the conflict over values among participants by forcing an agreement on a shared vision at the start of the decision process. He stated that he would have preferred to have the conflict openly acknowledged at the start, and then recognize that every group could not get all that it, or its spokesperson, desired. In short, he was interested in building a community of people who are willing to share rather than a consensus among people who do not know what they are sharing.

6. What could the research project team have done to make the process better?

All respondents had suggestions on how to improve the process. The suggestions include:

- The MODA process would be better if the real decision makers were involved rather than surrogates.
- The relationship between the materials provided before the first meeting and the determination of the decision to be reached could be presented more clearly.
- The methodology for group decision making could be presented more clearly.
- The data analysis should be more like the real world, and the data should be unquestionable in accuracy. It took some time for the Decision-Making Team to accept the analysis and move on.

- Start with the idea of tradeoffs. A few examples of the tradeoffs in the level of benefits for one group versus the costs of providing service would have been useful. Those costs, given the shortage of resources available to any specific community, are automatically equivalent to a denial of benefits to another group within that same community.
- Once the decision is framed, the facilitators could determine if all the invited participants are really necessary. For example, the role of the road commission was not important, once it was determined that the current agreements between the road commission and the city would not be affected. Also, if two groups have similar goals and views they could share a representative.

7. Do you feel applying the MODA process helped the Decision-Making Team reach consensus? If yes, please list specifically how the MODA process assisted as compared to other decision-making processes in which you have participated.

All but one respondent indicated that the MODA process helped the Decision-Making Team reach consensus by providing a structure that kept the decision makers focused and on track.

8. Where/how (if at all) do you think the results of a public hearing could enter the MODA process?

Two of the respondents felt that a public hearing would be useful at the beginning of the process when the problem is being framed. Three indicated that a public hearing just before the final decision is to be made would provide the decision makers with additional useful input on public opinion. Another respondent indicated that public hearings would add little because the spokespersons for various groups are intemperate in their demands and, frequently, in their language.

9. Do you feel the use of surrogate participants accurately represented the real world?

Generally, the respondents agreed that the surrogates represented their real-world counterparts at least somewhat accurately. The comments ranged from "close enough for a research project," to "about 80 to 90 percent accurate," to "yes, because the choices of the surrogates were good."

10. Do you think actual organizational representatives have access to their own staff who could complete the analysis for the Decision-Making Team?

Two respondents indicated that large cities or agencies would have the resources and staff to do the analyses, but that smaller cities, agencies and organizations probably would not. One respondent felt that no city or agency or private organization would divert its resources for this exercise. However, all three of these respondents indicated that an independent third party or a consultant would be acceptable for this purpose.

11. If the project had substantially more resources, how many more hours do you feel would have been needed to more fully explore the decision presented to the team?

Most respondents felt that the process needs more time. One asserted that this MODA application felt "hurried," and another stated that at least one more session was needed to "digest the information and to request more information and clarification." Another respondent stated that several weeks to a month or possibly even a year would be needed.

12. Do you feel the MODA process assisted in making disparate views, particularly societal issues, a more integral part of the decision-making inputs?

Four respondents indicated that the MODA process did indeed assist in making disparate views, particularly societal ones, an integral part of the decision-making inputs. Two respondents reported that they were not sure.

Comments from the respondents who answered in the affirmative are:

- Yes, but the end result is highly determined by the style and intention of those facilitating the process.
- Yes, without a question—you need to get all those involved or affected involved early in the process.

- Yes, the structure allows and ensures that all affected organizations are heard and included in the process.
- Yes, but not as much as possible or as much as needed. I feel that it is necessary to get the values of interest groups expressed as comparative priorities early in the decision process.

Summary of Decision-Making Team's Evaluation

The evaluations of the MODA exercise by members of the Decision-Making Team were generally positive. The group reported that the interactions were enjoyable and educational and that mutual respect among the members developed as the process continued. Representatives of the handicapped and the elderly reported being surprised by the level of competence and knowledge shown by the team members from public sector agencies.

Comments from the team members indicate that the initial materials they received before the first MODA session left them somewhat confused about the methodology, the nature of the decision, and Decision City. All Decision-Making Team members reported they could perform better in their roles if they had more information on some of the details of Decision City (for example, what is the City's budget, what is the demand for paratransit in Decision City as a function of LOS).

While one member of the Decision-Making Team indicated that the MODA exercise would have been better if real decision makers were involved rather than surrogates, most of the other Decision-Making Team members reported that, overall, the surrogates represented their "real-world" counterparts credibly.

It was evident from the responses to and comments on the evaluation questions that initial skepticism of some of the team members toward the MODA process diminished considerably by the end of the exercise. All but one of the team members agreed that it was the structure of MODA process that kept them focused and enabled them to come to a consensus in such a short time frame which would, however, be difficult to achieve in an actual application of MODA.

VI. PROJECT SUMMARY

A. OVERVIEW

The project, "Application of Decision Analysis to Intelligent Transportation System Societal Issues" was based on the observation that a decision-support process called Decision risk analysis was being used successfully in the private sector to aid in the decision process regarding product development and corporate strategy. It was recognized that the nature of the process allows for the integration of public and private sector demands in creating public policy. The project team hypothesized that the process, or a variant thereof, would be useful in addressing the disparate views of participants in the decision process regarding the implementation of an ITS technology where societal and institutional issues were pivotal.

The application of a decision-making method, previously used in the private sector, required further research on the process. A review of the decision analysis literature was performed, and contacts with people in the field were made. Research into a current ITS decision being faced in Michigan was conducted. Based on the findings, the Decision risk analysis process used in the private sector was modified to account for the inclusion of several organizations in the decision process and the presence of both the public and private sectors. The result was a process allowing the inclusion of diverse views that are fed into the development of alternative solutions and the reaching of group consensus on a decision. The process was named Multi-Organization Decision Analysis or MODA. The steps of the process include the development of a shared vision statement by the group, framing of the decision problem, the generation of alternative solutions, the analysis of potential solutions, and making a decision.

In addition to developing a new decision analysis support tool, MODA, an applicable decision problem was identified. The problem revolved around the needs of local communities in southeast Michigan regarding the provision of ITS-based paratransit in their communities. For the purposes of this demonstration project, the decision options were modified slightly, characteristics of a hypothetical city (based on an actual city in the southeast Michigan area) were developed, and individuals were selected to participate in the study. The individuals were not actual representatives of the organizations in the decision area, but each was either employed in organizations similar to the one they represented in the project or had other relevant experience. In addition, several were very familiar with the concept of ITS and the many requirements regarding implementation of transportation systems.

Included in the MODA process are a Decision-Making Team, an Analysis Team, and facilitators. Throughout the process, there are extensive interactions among these groups. The Decision-Making Team in this project comprised representatives of all those organizations that the research project team thought would be most likely to be involved in the decision process either as actual decision makers or as those who desire to influence the decision. These included surrogate representatives of a regional transit authority, the state department of transportation, the city, the elderly, the handicapped, the regional shopping mall, and the county road commission. The Analysis Team was a group of analytically skilled individuals from the research project team.

Facilitation was done by members of the research project team. During the meetings of the Decision-Making Team, there was intense discussion and much disagreement and expression of disparate views on topics ranging from the shared vision statement to the budget available for implementing ITS. Through the discussion and suggestions of the members of the Decision-Making Team, with input from the Analysis Team, the group was able to fashion from widely different choices one solution that they agreed upon.

B. OBSERVATIONS AND LESSONS LEARNED

This section summarizes the observations made and lessons learned by the project staff during the MODA exercise.

The Decision-Making Team displayed a diversity of personal characteristics and styles. Some members of the Decision-Making Team were outspoken, whereas others were cautious and reserved. These characteristics became evident in the dynamics of group interactions as the Decision-Making Team members presented their views, opinions, and objections towards various outcomes. As expected, diversity of personal styles and dynamics of the group were readily accommodated by the MODA process. MODA's structure allowed all members of the Decision-Making Team to be recognized and to bring their perspectives of the problem to the process. The MODA structure also gave each member of Decision-Making Team opportunities to identify the factors they felt were important and to present their views of the relationships among these factors.

Research project staff, serving as the Analysis Team, believe that they were very responsive to the concerns raised by the Decision-Making Team at the initial session of the MODA exercise and accommodated these concerns, as defined in the influence diagrams. However, the data available played a very important role in determining the nature of the relationships among variables. The quantitative data analysis embodied issues that were pivotal to the decision-making process. The focus of the Decision-Making Team on the quantitative analysis performed is a reflection of the relevance of the quantitative analysis and the biases that may be introduced in the process. This highlights the importance of (1) having an Analysis Team that represents, in the best way possible, the multiple interests of the Decision-Making Team and (2) adequate data availability.

Societal issues drove the decision-making process in this application of the MODA process. Figure V-1, Initial Identification of Key Factors Related to the Decision, captured the Decision-Making Team's concerns about societal issues. The LOS experienced by the users of the paratransit system, as defined by the group, and the costs related to providing such service were the main societal issues considered in the decision-making process. These are representative of the larger societal issues of equity and access.

Connectivity (with other communities) of paratransit service was never an issue of disagreement in the decision. The decision was structured with two options on the policy of connectivity and several options on ITS-enhanced service. The Decision-Making Team chose the policy of connectivity and dismissed the policy of no connectivity immediately, with no discussion or interactions, and proceeded to the aspects of an ITS enhanced service. Connectivity of paratransit service is, in effect, a societal and institutional issue. The behavior of the Decision-Making Team in this case shows how inherent societal and institutional issues are in this ITS decision. Further, the speedy resolution of the connectivity issue may be an example of how the MODA process can generate additional information and narrow the uncertainties to an extent that other decisions outside the primary one are easier to make.

The needs of elderly and handicapped people were indistinguishable throughout this exercise. This can be a result of the nature of the decision (i.e., in deploying ITS for paratransit services, the goals of the handicapped and the elderly may coincide in demanding better levels of service). Another explanation of the similarity of needs between the two groups can arise from individual characteristics of Decision-Making Team members representing the groups.

The interaction among public sector stakeholders was much more significant than the interaction between public and private groups. As noted above, societal issues drove most of the process. Therefore, the high level of interaction among public sector agents did not come as a surprise, as societal issues tend to be discussed in the public domain.

In contrast to the previous observation, the private sector assumed a less active role, which was constrained by the information gathered about the benefits accruing to it. The private sector role in the exercise was embodied by the mall operator who provided funds to the paratransit operator in return for extended service area coverage. If data suggest that the extended paratransit service area coverage yields benefits to the mall that are equal to or exceed the mall payment to the operator, as was the case for Decision City, then the payment is worthwhile. Hence, public-private interaction became a minor issue in this case, and the decision about the mall payment was easily agreed upon. The exercise did not address concerns related to connectivity and area coverage that have jurisdictional components that pertain to the public sector.

Interpersonal relationships during the decision team sessions were quite amicable and allowed for the MODA process to work in an accelerated time scale. However, it should be noted that the Decision-Making Team members had no prior exposure to each other before assuming their roles in this exercise. In an actual situation, many members of the Decision-Making Team might well be known to each other, and coalitions and rivalries among the members could already be in place. These relationships were not captured by this exercise. It was quite clear that the level of friendliness and spirit of cooperation observed in the Decision-Making Team in this application of MODA would not generally be present, and more sessions would be necessary to reach closure in an actual application.

C. USE OF SURROGATES

In this demonstration of the MODA process a hypothetical community was used to represent the community in which the ITS decision with societal implications was to be made. The Decision-Making Team was made up of surrogates representing the real decision makers. Even the decision itself was not an actual decision facing communities in the southeast Michigan region, but a modification of a decision that may face these communities in the near future.

Decision City was modeled after a real community in southeast Michigan. The ITS-enhanced paratransit operation and costs were also based on actual experience of a transit system in southeast Michigan. Although the community was a surrogate, it closely resembled actual communities in its population, facilities, policies, and budgets.

The members of the Decision-Making Team were volunteers either from organizations in other communities similar to the ones they represented in the MODA exercise or had much experience with them. The most realistic surrogates on this team were those with the most experience with their organizations. From the perspective of the research project team and also by their own self-report, the surrogate Decision-Making Team was quite credible in their performance in the MODA exercise.

It can be concluded that the use of surrogates as the Decision-Making Team does not detract from the applicability of the findings of this MODA exercise to other situations.

VII. CONCLUSIONS

Several conclusions can be drawn from this study and are presented below.

A. MODA WAS SUCCESSFULLY ESTABLISHED AND DEMONSTRATED

The primary objective of this project was to demonstrate the use of a decision support tool in the decision process attendant to the implementation of an ITS technology. This objective was met by modifying for use in the multi-organization decision arena the decision risk analysis process commonly used in the private sector; calling together a group of able and willing volunteers to participate in the process; and conducting the process to demonstrate the reaching of consensus on a decision pertaining to the LOS and the cost of an ITS-based community paratransit system. MODA was successfully established and demonstrated.

B. THERE WILL BE MANY SIMILARITIES IN OTHER APPLICATIONS

On the basis of the experimental procedure and its results, it would be reasonable to expect no significant differences in applications to other decisions and/or problem-solving objectives for transportation-related issues. One exception to this could be an instance where much less quantitative material may be available than that available for the particular decisions involved in the experimental system addressed in this project. In that case, greater use of probabilities, as estimated through various methodologies, might be necessary.

In this demonstration project, the societal issue was the provision of improved transportation for the elderly and handicapped, while the ITS-related transportation decision focused on implementing ITS technology in a public sector paratransit service. It would not be expected that an application of MODA to the societal issue of equity (fair distribution of benefits), where the decision involves the implementation of ITS technology, for example, in automatic electronic toll collection, would present any great differences from the application demonstrated herein. What would be different would be the skills and backgrounds of the participants, but the procedural and systemic structure would be unaltered.

C. MODA IS APPLICABLE TO DECISIONS RELATED TO A VARIETY OF ITS TECHNOLOGIES

The ITS technology that was addressed in this study is the set of technologies that can be used to improve paratransit service, namely, those for routing, scheduling, and vehicle location. From the vantage points of the participants in the process, there was little concern expressed about the technology. Rather, the participants were concerned about the LOS of the paratransit to the community, including wait time, travel time, the connectivity of the service with adjoining towns, and the costs of the system to the users, government, private sector organizations, and transportation providers.

The specific technology that would be used in reaching a solution that all members of the Decision-Making Team could support was apparently unimportant. With this experience, it is the observation of the research project team that the specific technology to be addressed in a particular ITS implementation could be of almost any type. The benefit of the MODA process is that it allows many different views to be handled in achieving a common goal.

D. MODA IS GENERALIZABLE TO A VARIETY OF LOCATIONS AND INSTITUTIONAL AND JURISDICTIONAL CONSTITUENCIES

The generalization of the systemic process described in this report is of itself a generalization of the original decision risk analysis procedures that have gone before. The reason that these procedures are easily generalizable stems from the fact that they are "flexible structures" designed to be robust and malleable under application. Because the procedures are constructed more like a set of guidelines to be molded to the situation than like an unalterable recipe that is rigid and fixed in its quantitative description, these decision-aiding and problem-solving processes lend themselves to applications of almost unlimited variety.

The process used in this study is based on modifications of earlier versions. In particular, the shared vision, the compressed time scale, the hypothetical location, the decision problem, and the surrogate team are some of these modifications. The process itself is flexible and lends itself to be generalized to suit the circumstances of the decision at hand.

VIII. APPLICATIONS AND FUTURE RESEARCH

A. APPLICATIONS

The MODA process is a decision-making aid that was developed as part of this research project. It evolved from a series of earlier decision-making aids that have been used in a variety of public and private sector contexts. The intent in its development is to allow its use in a wide variety of circumstances. These circumstances could span the entire range of multi-organization decision making, including those relating to transportation generally and ITS specifically. Within the ITS context, there are many potential applications.

Much of ITS implementation is dependent upon interactions of the public and private sectors. Examples include anything that requires public infrastructure, vehicles, technology, information, or service along with private versions of any of these. Indeed, it is harder to think of ITS that do not include extensive public-private sector or multi-organization interaction or decision making. Not only is a process such as MODA useful in making decisions involving institutional issues, but, more importantly, in those that have a societal component.

Many ITS applications involve the consideration of societal issues. These include, for example, safety, noise, economic equity, and accessibility of the system. By having a process that incorporates the opportunity for people to introduce their disparate views into the process, the likelihood of minimizing objections to ITS implementations is decreased, and the opportunity to yield benefits to society is increased.

Since the MODA process is characterized by robustness, flexibility, and ease of accommodations of diverse views, it is not unreasonable to expect that its application to other aspects of ITS technology implementation and societal issues in transportation would prove beneficial. One of the key societal issues in the implementation of almost any ITS-related technology is that of "equity," that is, "who benefits and who pays?" Because issues of equity invariably involve tradeoffs, which are often between highly polarized sides of the issue, the MODA process could be particularly applicable.

Another area of potential application is in "standard setting." The evolution of ITS has been impaired by the extremely difficult process of generating standards that simultaneously satisfy the needs of the public and private providers of transportation. The results of this project suggest that the MODA process could find substantial application in the standard-setting process, particularly at the point where the data collection and evaluation has been completed and a decision must be made.

And finally, it is recommended that the MODA process be applied at the point of deciding where and how to fund ITS implementation at the regional and local levels. Such funding concerns have often dominated these kind of "make-or-break" decisions and quite frequently involve societal issues. The accommodative nature of the MODA process can assure an even-handed and balanced approach to the required problem solving and decision making.

B. FUTURE RESEARCH

This project has shown that there is great value to be gained from using a structured decision support process to address societal issues in making a decision about an ITS implementation. This success leads to the conclusion that further research in this area is warranted and, indeed, will be most useful in developing a tool for addressing societal issues in the decision process.

Specific issues that deserve research attention include ways of identifying the participants in the process, coming quickly from a general description of the decision issue to an agreed-upon framing of the problem, and the best ways of moving from the framing of the problem to the identification of analytical methods of comparing alternatives.

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APPENDICES

APPENDIX A: OVERVIEW OF DECISION SUPPORT METHODS

There is a multitude of decision support techniques available to users today. This appendix describes several of such techniques reviewed as part of this research project.

Decision Analysis Using Gaming Simulations

Description

Gaming is a decision-making method that attempts to replicate the real environment in which a decision is to be reached and where players assume the roles of decision makers. The players may be the real decision makers or surrogates taking their roles. They are assumed to be rational, and individually through their choices of preferred outcomes, to be maximizing their expected utilities. The elements of the game include goals, objectives, constraints, and consequences. The outcomes of a game are framed and formalized by the rules of that game. The rules prescribe the relationships among the players, the sets of information available to the players, the sets of choices from which the players may select, and an element of chance. Within the set of rules developed for each game is a fixed set of outcomes from which the players select. With these formal relationships among the players established, players move through a sequence of choices until an ultimate outcome for that sequence is achieved. The results, which are unique to each game and session of play, can be characterized by listing one or more alternatives, actions, methods, goals/objectives, etc., which were the result of player interaction within the simulated gaming environment. The outcomes/decisions derived through the gaming process are then made available for client implementation or subsequent action (Duke 1977; Luce, and Raiffa 1989; and Stein 1981).

Advantages

The development of a game forces the authors to bring clarity of thought about the critical elements in a particular decision environment that goes beyond abstraction. The development of the game demands concreteness and articulation of theory and of the conditions under which gaming relationships hold. Once developed, the game can be tested and experimented with and can serve as a flexible yet comprehensive tool for the exploration of alternative decisions.

Applications

METRO-APEX is a game simulation developed for the Tri-County Regional Planning Commission of Lansing, Michigan. It was intended to familiarize various commissioners with the dynamics of their region relating to housing and home finance funding.

In December 1995, the ITS Deployment exercise at the University of Michigan used gaming as a method to assist ITS stakeholders and interest groups to formulate a shared vision of potential ITS deployment. Objectives of the exercise were to determine stakeholder deployment priorities and to develop a preliminary ITS experimental deployment plan for southeast Michigan.

Limitations

Games are expensive in terms of time and resources. The development of the gaming simulation tools requires staff, facilities, and time, specifically to learn to operate the game, to test and run the game, and to complete the postgame discussion and analysis. Gaming typically draws from client staff and/or several organizations. Thus, scheduling and assuring that the game runs properly are essential.

Decision Analysis Using Multiattribute Utility Functions

Description

The use of multiattribute utility functions is intended to enter the decision process at the point where the decision makers have already decided on the identification and bounding of the problem and have generated a set of alternative actions to be evaluated. This technique formalizes the preference or value side of the problem and prescribes a procedure for systematically identifying and structuring objectives, making value tradeoffs, and balancing various risks (Keeney and Raiffa 1976).

The basic axiom which constitutes the grounds for this technique is as follows:

If an appropriate utility function is assigned to each possible consequence, and the expected utility of each alternative is calculated, then the best course of action is the alternative with the highest expected utility. The utility of each alternative is a function of the utility of each attribute measuring the performance of that alternative. If $U_i(X)$ is a utility function of the attribute X_i and $k_1, k_2, \ldots k_r$ are some scaling constants, then the alternative described by attributes $X_1, X_2, \ldots X_n$, has the following general n-dimensional utility function:

$$U(X_1, X_2, \ldots X_n) = f(U_i(X_i), \ldots U_n(X_n), k_1, k_2, \ldots k_r)$$

The functional form depends on the nature of perceived interdependencies among preferences for the attributes. A unidimensional utility function $U_i(X_i)$ reflects the decision makers' preferences of a single attribute i over the range of its possible values, conditional on other attributes having fixed values. The functional form of the unidimensional utility function also reflects the risk proneness or averseness of the decision makers toward that attribute. The scaling or tradeoff constants measure the probability with which the decision makers are willing to trade off their preferences among the attributes. Uncertainty in the value of the attributes can be incorporated by developing a probability density function for each attribute and integrating the product of its utility function and the probability density function over the range of its values to produce an expected utility, which can be used in the evaluation process.

In practice, there is considerable interplay between objective identification and attribute selection, and the process is often iterative. An analyst assists the decision makers in that process and works with them to develop the unidimensional utility functions, assess the interdependencies among the attributes, and determine the values at which they are willing to trade off attributes. Throughout the process, the analyst goes through numerous consistency checks and allows the decision makers to adjust their preferences. The result of this process is a multiattribute utility function which incorporates the objectives and preferences of the decision makers. The utility of each alternative being evaluated can be calculated, and ranges of attribute values can be used for sensitivity analysis.

Applications

Multiattribute utility functions have been used by the New York City Fire Department. The work was carried out for the New York City Fire Department and the Rand Institute by Ralph Keeney in the early 1970s. The concepts and results of utility theory were used to quantify the experience of New York City Fire Department officials and to use this information for evaluating Fire Department policies (Keeney 1973).

An analysis was performed for the government of Mexico by Richard deNeufville, Howard Raiffa, and Ralph Keeney in 1971 to address the location of the airport (or airports) for Mexico City, the operational policy defining the services to be performed, where these services were to be located, and the timing for development of different airport facilities (deNeufville and Keeney 1973). The work helped the government of Mexico identify the disagreements on the airport issues and to recognize the different attributes of the dynamic issues.

Benefits

This method provides a prescriptive and systematic approach to identifying objectives and preferences while forcing decision makers to think hard about various value tradeoffs and their attitudes toward risky choices.

Limitations

The theory on which the approach is based actually applies to a single decision maker. Therefore, the decision makers are treated as a unit, and consensus about all the aspects of the utility function needs to be reached for the procedure to work.

This is a time-consuming process that relies on the skills of the analyst to go through the process with decision makers. The computational requirements can be quite heavy.

Conjoint Analysis Process

Description

Conjoint analysis as a tool for addressing the multiattribute decision making problem was first developed by Green and Rao (1969, 1971) and others in the early 1970s. The mathematical basis for conjoint analysis was set forth by Luce and Tuckey as early as 1964 (Luce and Tuckey 1964). It is particularly suited to multiattribute preference-measurement problems characteristic of many marketing research problems where there are many subjects making decisions regarding the purchase of goods in a marketplace, each of which has multiple attributes. Applications found in the literature frequently focus on the analysis of data to guide the construction of a probabilistic choice model such as those for consumer choice modeling. In any case, it is often possible to employ conjoint analysis in the analysis of paired-comparison data collected from subjects in many areas of study outside the traditional market research applications.

Conjoint analysis is particularly useful when one has collected a set of subjective comparisons across a set of attributes of a multiattribute preference decision where the number of decision makers is large (in the sense of a large statistical sample size). The large sampling of data supports a more accurate and reliable measurement of the key conjoint parameters and leads to more confidence in the analytical results (in the sense of "statistical significance").

Applications

There exists a large range of applications including the building of product position maps, the construction of consumer choice models, and probabilistic forecasting of market behavior that can be found in the market research literature. Applications in the transportation research field include multimodal choice studies and some aspects of road pricing.

Benefits

The process provides a means to analyze aggregate level, nonexperimental data where the number of observations is large. It plays an important role in decision problems where the number of decision-makers is relatively large.

Limitations

Conjoint analysis is highly sensitive to the quality of data. Data requirements are large and expensive to collect. The method relies on statistical methodology, and thus does not reveal any cause-effect relationships.

The Analytic Hierarchy Process

Description

The analytic hierarchy process (AHP) was developed by Saaty (1980) and his collaborators as a method for establishing priorities in multicriteria decision making contexts. The AHP requires that the problem be decomposable into a hierarchical model and structured so as to capture its basic elements. Hierarchical decomposition involves setting up levels, where each level contains a set of elements. The elements are grouped in such a way that those of a lower level directly influence the elements in the immediately higher level. These in turn must influence elements in the next level and so on up to the goal of the hierarchy. The objective is to derive a set of quantitative weights in the last level, which reflect as best as possible, their relative impact on the goal of the hierarchy. One way to accomplish this is to compare, in pairs, elements in each level, with respect to those elements in an immediately higher level. Thus, pair comparison data are usually collected and applied as a quantitative data set.

In group decision making or problem solving, it is often possible to model the problem in a hierarchically decomposed form through the application of influence diagram techniques (Clemen 1996). The advantage of setting up a problem in a hierarchical structure is that it helps an analyst focus attention on each part of the problem separately.

The AHP is particularly useful when subjective data are the only available source of information for making judgments about alternatives and criteria. It is useful not only in decision making and problem solving processes, but also can be applied to any activity in which qualitative information must be given quantitative structure for purposes of rank ordering or prioritizing.

Applications

Many applications appear in the market research literature related to consumer choice models (e.g., automobile purchase decisions). Several applications are found in cost-benefit and cost-effectiveness analyses, plant site selection decisions, transportation planning, and elsewhere.

Benefits

The approach provides a systematic way to formulate and carry out a decision-making process where the prominent sources of information are qualitative and/or uncertain.

Limitations

AHP is strongly dependent on the quality of the data that can be collected or are already available. It requires very special attention to data consistency. Too much inconsistency will render the AHP process useless. (An inconsistency, for example, is when A is preferred to B, and B is preferred to C, but C is preferred to A.)

APPENDIX B: DECISION SUPPORT CONSULTING SERVICES AND SOFTWARE VENDORS

Decision Support Consulting Services

SDC Strategic Decisions Group
2440 Sand Hill Road
Menlo Park, CA 94025

Applied Decision Analysis, Inc.
2710 Sand Hill Road
Menlo Park, CA 94025

Decision Education Center
2440 Sand Hill Road
Menlo Park, CA 94025

Decision Focus, Incorporated
650 Castro Street
Mountain View, CA 94041

Knowledge Industries
350 Cambridge Avenue
Palo Alto, CA 94306

Microsoft Research Decision Theory Group
1 Microsoft Way
Redmond, WA 98053

Lumina Decision Systems
350 Cambridge Avenue, Ste. 390
Palo Alto, CA 94306

Palo Alto Laboratory of Rockwell
Rockwell Science Center
Palo Alto, CA 94301

Decision Analysis Software and Vendors

Software - Logical Decisions for Windows
Developer/Vendor: Logical Decisions
1014 Wood Lily Drive, Golden, CO 80401

Software - Criterium Decision Plus
Developer/Vendor: InfoHarvest, Inc.,
infoharv@infoharvest.com

Software - DATA
Developer/Vendor: TreeAge Software, Inc.,
info@treeage.com

Software: DEMOS (DEcision MOdeling System, soon to be called Analytica)
Developor/Vendor: Luminal Decision Systems
(415) 327-4944

Software: DPL (Decision Programming Language)
Developer/Vendor: Applied Decision Analysis, Inc.,
(415) 926-9252

Software: Ergo
Developer/Vendor: Noetic Systems, Inc.,
info.@noeticsystems.com

Software: Expert Choice
Developer/Vendor: Expert Choice, Inc.,
Webmaster@expertchoice.com

Software: Hugin
Developer/Vendor: Hugin ExpertA/S, info@hugin.dk

Software: Logical Decisions
Developer/Vendor: Logical Decisions,
1-800-35-LOGIC

Software: NeticaApplication
Developer/Vendor: Norsys Software Corp.,
boerlage@norsys.com

Software: @RISK
Developer/Vendor: Palisades Corporation,
(800) 432-7475

Software: Crystal Ball
Developer/Vendor: Decisioning, Inc.,
(800) 289-2550

Software: Expression Tree
Developer/Vendor: Prof. C. Kirwood,
Arizona State University, (602) 965-6534

Software: Supertree/Sensitivity
Developer/Vendor: Strategic Decisions Group SDG,
(415) 854-9000

Software: Baron 2.0
Developer/Vendor: KC Associates, kchang@gmu.edu

Software: DX Solution Series
Developer/Vendor: KnowledgeIndustries,Inc.,
ki@kic.com

Software: Strategist
Developer/Vendor: Prevision,
dambrosi@prevision.com

Software: TreePlan
Developer/Vendor: Decision Support Services,
(415) 673-6217

Software: Which and Why for Windows
Developer/Vendor: Arlington Software Corp.,
http://www.arlingsoft.com

Software: Decide Right for Windows
Developer/Vendor: Avantos Performance Systems,
http://www.avantos.com

Software: BAYES
Developer/Vendor: Russel Almond, almond@acm.org,
CMU Artificial Intelligence Library

Software: BELIEF 1.2
Developer/Vendor: Russel Almond, almond@acm.org,
CMU Artificial Intelligence Library

Software: IDEAL
Developer/Vendor: Rockwell International Science Center, ideal-request@rpal.rockwell.com

Software: MacEvidence
Developer/Vendor: Prakash P. Shenoy,
pshenoy@ukans.edu
University of Kansas, School of Business
Summerfield Hall
Lawrence, Kansas 66045-2003

Software: Microsoft Bayes Networks (MSBN)
Developer/Vendor: Microsft Decision Theory Group,
dtg-msbn@microsoft.com

Software: Pulcinella
Developer/Vendor: Alessandro Saffiotti,
asaffio@ulb.ac.be,
Universite Libre de Bruxelles

APPENDIX C: DECISION CITY BACKGROUND

Decision City is a hypothetical city whose characteristics will serve as a basis for the application of decision analysis in transportation planning. The included information is based on data collected from the small Detroit suburb of Taylor, Michigan. The population of 70,000 is composed primarily of middle class families. The retail and service industries employ a majority of the strong working class in the city. Bounded to the north by Interstate-94 and to the southeast by Interstate-75, the city is fairly accessible to the surrounding Southeast Michigan area including Detroit Metro Airport nearby to the west.

One hospital is located in Taylor, Michigan (Heritage Hospital) whose capacity is 241 beds. There are two assisted living/retirement facilities in Taylor. The Maplewood Senior Citizen Center is a recreation center with a senior citizen wing which has up to three hundred visits and day and includes 3000 persons registered. The South Haven Manor is a living facility with 138 units. All further information that was used to evaluate Decision City has been collected from the SEMCOG, SMART, the City of Taylor, and the U.S. Bureau of Census. A population forecast by age and racial origin is included, which was based on extrapolated data from projected population distributions in Michigan of specific age and race classifications and total population forecast data for Taylor for a corresponding year.

TABLE C1 Population, Households, and Jobs (1990-2020)

	1990	2000	2010	2020	Change: Number	1990-2020 percent
Total Population	70811	66803	63023	61322	-9489	-13.4%
Total Households	24843	25111	25184	25736	893	3.6%
Households with children	10857	8903	6846	5947	-4910	-45.2%
Households without children	13986	16208	18338	19789	5803	41.5%
Persons per household	2.8	2.6	2.5	2.4	-0.5	-16.7%
Total jobs	29383	33289	35268	35206	5823	19.8%

TABLE C2 Population by Age Distribution (1980, 1990)

Age	1980	1990
Median age	25.9	30.7
Percent school age	25.3%	19.5%

TABLE C3 Population Forecast by Age and Racial Origin (2000, 2020)

Age	Racial Origin	2000	2020
0-19	White	15532	12439
	Black	3888	4343
	Indian, Eskimo, Aleut	144	112
	Asian, Pacific Island	438	674
	Hispanic	821	1146
	Total	20823	18715
20-64	White	31940	26858
	Black	5620	6217
	Indian, Eskimo, Aleut	253	236
	Asian, Pacific Island	705	1117
	Hispanic	1006	1489
	Total	39525	35917
65+	White	7290	7919
	Black	897	1188
	Indian, Eskimo, Aleut	27	47
	Asian, Pacific Island	68	177
	Hispanic	110	201
	Total	8392	9532

TABLE C4 Income (1980, 1990)

Income	1980	1990
Per capita income, median (in dollars)	12313	12955
Household income, median (in dollars)	37509	32659

TABLE C5 Household Income (1990)

Income Range	Percentage
Less than $20,000	28.20%
$20,000 - $39,999	33.42%
$40,000 - $59,999	22.51%
$60,000 - $99,999	14.10%
$100,000 and over	1.78%

TABLE C6 Industrial Employment Regional Development Forecast
(persons employed per industrial class 1990, 1995)

Industrial Class	1990	1995
Agriculture and Natural Resources	360	288
Manufacturing	3628	4315
Transportation, Communication, Utilities	2076	2191
Wholesale Trade	2178	2020
Retail Trade	9987	10954
Finance, Insurance, Real Estate	1679	1576
Services	8860	9261
Public Administration	615	715
Total Jobs	29383	31320

TABLE C7 Non-Industrial Employment Regional Development Forecast
(persons employed per land use class 1990, 1995)

Land Use Class	1990	1995
Office	8328	8766
Commercial	11359	12329
Industrial	2623	2913
Institutional	3971	4009
Transportation, Communication, Utilities	1534	1533
Residential	1568	1770
Total Jobs	29383	31320

TABLE C8 Land Use (1990)

	Acres	Percent
Single Family Residential	6202	41.0%
Multiple Family Residential	535	3.5%
Commercial and Office	938	6.2%
Institutional	637	4.2%
Industrial	1202	8.0%
Transportation, Communications, Utilities	655	4.3%
Cultivated Land	715	4.7%
Woodlands, shrub, grassland, wetlands	3994	26.4%
Barren, extractive	231	1.5%

TABLE C9 Number of Road Miles

	Miles
Major roads	34.27
Local roads	155.43

The SMART system provides bus service to Taylor, Michigan. Route 150, which begins at the local mall, travels through the downtown and continues to serve neighboring communities. The attached ridership data is for one way along Route 150.

TABLE C10 Ridership Data for SMART Route 150 Through Taylor, Michigan

Stop Location	Route Start Time														Location Totals
	5:16 AM	5:52 AM	6:12 AM	6:37 AM	6:56 AM	7:25 AM	7:41 AM	8:24 AM	9:11 AM	1:50 PM	3:04 PM	4:26 PM	5:31 PM	6:31 PM	
Meijer Thrifty Acres & Bus Station	X	X	X	X	X	X	X	X	X	X	X	1/0/1	X	X	1/0/1
Southland Center & Transit Center	X	X	1/0/1	X	X	X	1/0/1	1/0/1	1/0/1	3/0/3	2/0/2	5/0/6	1/0/1	1/0/1	15/0/16
Pardee & Northline	X	X	X	X	X	X	1/0/2	X	X	X	X	X	X	X	1/0/17
Pardee & Brest	X	X	X	4/0/4	X	X	X	X	X	X	X	X	X	X	4/0/21
Goddard & Pardee	X	X	1/0/2	X	X	X	X	X	X	X	X	X	X	X	1/0/22
Goddard & Birch	X	X	X	X	X	X	1/0/3	X	X	X	X	X	X	X	1/0/23
Goddard & Telegraph	3/0/3	X	1/0/3	1/0/5	X	X	X	X	X	1/0/4	X	0/3/3	0/1/0	0/1/0	6/5/24
Goddard & Westlake	X	X	1/0/4	X	X	X	X	X	X	X	X	X	X	X	1/0/25
Beech Daly & Goddard	X	X	X	X	X	2/0/2	0/1/2	2/0/3	X	X	X	X	X	X	3/1/27
Beech Daly & Madden	X	X	X	1/0/6	X	X	X	X	X	X	X	X	X	X	1/0/28
Beech Daly & Haig	X	X	X	X	X	X	X	X	2/0/3	X	X	X	X	X	2/0/30
Wick & Beech Daly	2/0/5	X	1/0/5	X	X	X	X	X	X	X	X	X	X	X	3/0/33
Wick & Burr	X	X	1/1/5	X	X	X	X	X	X	X	X	X	X	X	1/1/33
Wick & Telegraph	X	X	X	X	1/0/1	X	X	X	X	X	X	1/1/3	X	X	2/1/34
Wick & Pine	X	X	1/0/6	X	X	X	X	X	X	X	X	X	X	X	1/0/35
Wick & Elm	X	X	X	X	X	X	1/0/3	X	X	X	X	X	X	X	1/0/36
Wick & Mueller	X	X	X	X	X	X	X	1/0/4	1/0/4	X	X	X	X	X	1/0/37
Wick & Pardee	1/0/6	3/0/3	2/0/8	3/0/9	8/0/9	7/0/9	3/0/6	X	X	1/0/5	X	X	X	X	28/0/65
Wick & Dudley	X	X	X	X	X	X	1/0/7	X	X	X	X	X	X	X	1/0/66
Wick & Mortenview	X	X	1/0/9	X	X	X	1/0/8	X	X	X	X	X	X	X	2/0/68
Wick & Pickwick	X	X	X	X	X	X	X	X	X	1/0/6	X	X	X	X	1/0/69
Pelham & Wick	1/0/7	X	X	X	X	X	1/0/9	X	X	X	X	X	1/0/1	X	3/0/72
Champaign & Pelham	X	X	X	2/0/11	X	X	2/0/11	X	X	0/1/5	X	2/0/5	0/1/0	X	7/2/77
Totals by Time	7/0	3/0	10/1	11/0	9/0	9/0	12/1	4/0	4/0	6/1	2/0	9/4	2/2	1/1	87/10

-- data collected from "Linehaul Bus Planning, Fiscal Year 1992 Ridership Data, Boardings/ Deboardings by Trip" for SMART Wayne/Oakland Routes

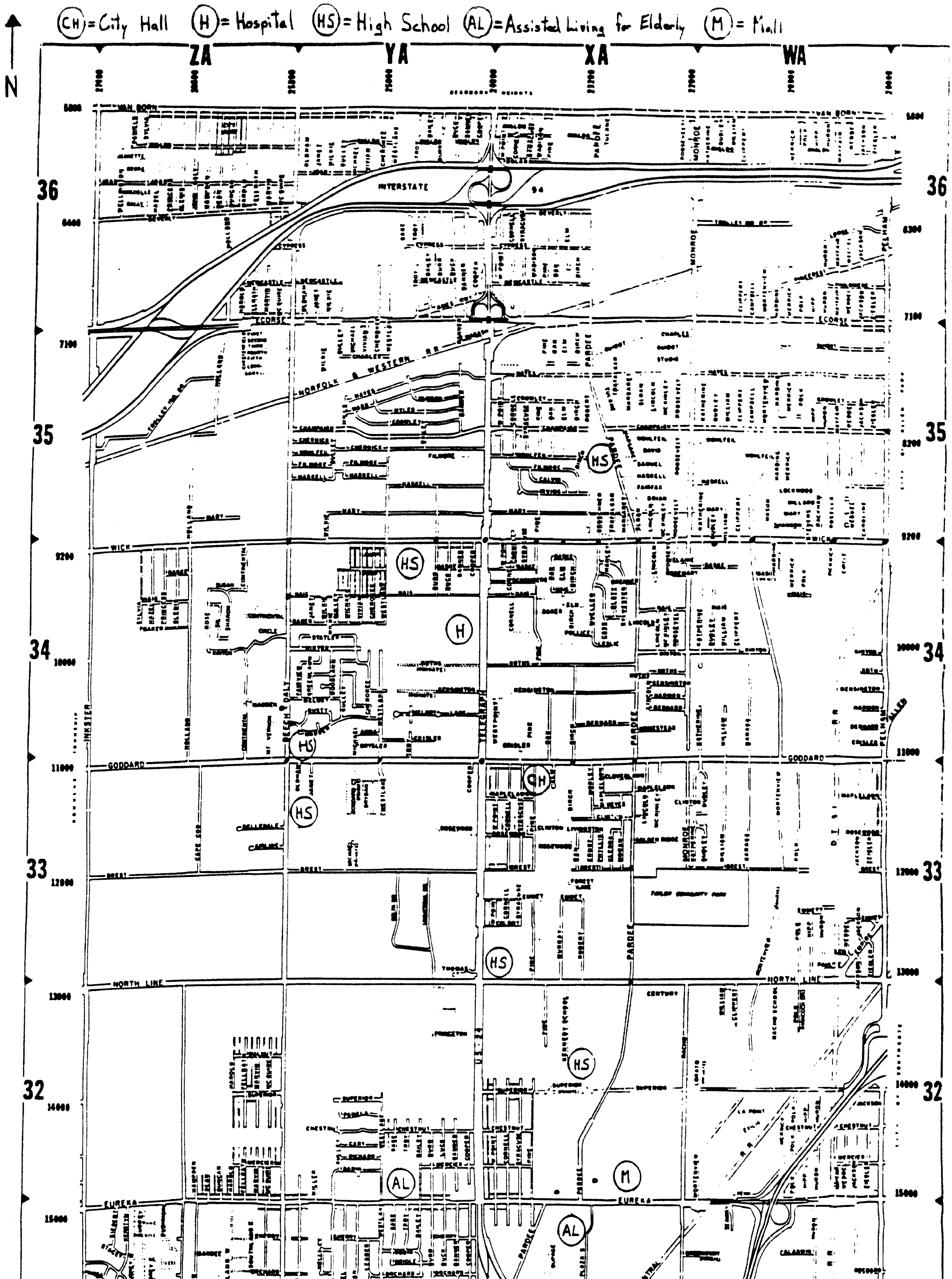
-- cell format: 3/1/7 means that three people boarded and one person got off at the corresponding stop. The last number indicates the number of people remaining on the bus after the stop.

-- 88.6% of all riders boarding Route 150 in Decision City commute to another city on the route.

TABLE C11 Paratransit Ridership Data

Monthly (June '93 & '94)	FY 94/95	FY 93/94	% Change
Weekdays	9,910	9,492	4.4
Saturdays	0	0	n/a
Sundays	0	0	n/a
Yearly ('93 & '94)	FY 94/95	FY 93/94	% Change
Weekdays	114,072	116,828	-2.4
Saturdays	51	0	n/a
Sundays	0	0	n/a

(CH) = City Hall (H) = Hospital (HS) = High School (AL) = Assisted Living for Elderly (M) = Mall



Source: City of Taylor; Allied Printing Trades Council, 1995

Taylor, Michigan

APPENDIX D: DECISION-MAKING TEAM PACKETS

PROJECT DESCRIPTION

Application of Decision Analysis to ITS Societal Issues

Barbara Richardson, Ph.D.
University of Michigan
Transportation Research Institute

IDEA Product for ITS

The Multi-Organization Decision Analysis (MODA) process is an overall decision analysis process applicable in the multiple organization environment which includes organizations from both the public and private sectors. Decisions about intelligent transportation sytem (ITS) deployment, services, and pricing will typically be made by such groups. The MODA process offers an efficient yet comprehensive procedure for reaching decisions, allows for the inclusion of societal issues in the decision process, and recognizes the resource and time constraints of the public and private sectors.

Concept and Innovation

The innovation of this project is two-fold: (1) application of a decision analysis tool that is almost exclusively used in single-organizational private sector decisions to multiorganization public and private sector decisions in the field of ITS, and (2) modification of that decision analysis tool to be more suitable for the intended application.

MODA is based on the concepts of decision analysis originally developed in the mid-1970s and modified in the 1980s and 1990s into the decision risk analysis (DRA) process and the decision dialogue process (DDP). Successful applications have been numerous in the private sector but very limited in the public or multiorganization arenas. The DRA/DDP processes bring together representatives of all stakeholders in the decision of concern through a series of structured dialogues that build on the diversity of opinion. The components include a Decision Review Board, which consists of the major stakeholders in the process who have decision responsibility, and a Core Study Team of technical experts who are knowledgeable about technical information and analytic methods. The DRA/DDP process consists of four steps: framing the problem, specifying alternatives, performing analysis, and making a decision. Throughout the process, buy-in or consensus of the Decision Review Board is required before moving on to the next step.

The greatest hurdle in the application of this decision analysis procedure to multiorganization decision making is the lack of a common vision shared by all parties. While many different positions can be represented internally within a single private business organization, there is typically a common vision (i.e., that of selling a product to make a profit). In the public sector or in multi-organization entities, this is not the case. Public organizations have diverse missions. In addition, the public sector has different time and budget constraints on decisions than does the private sector. For the decision process to work in a multiorganization public/private environment, consensus needs to be achieved on a vision of the assembled group before addressing the decision at hand. Given these differences the MODA process was developed.

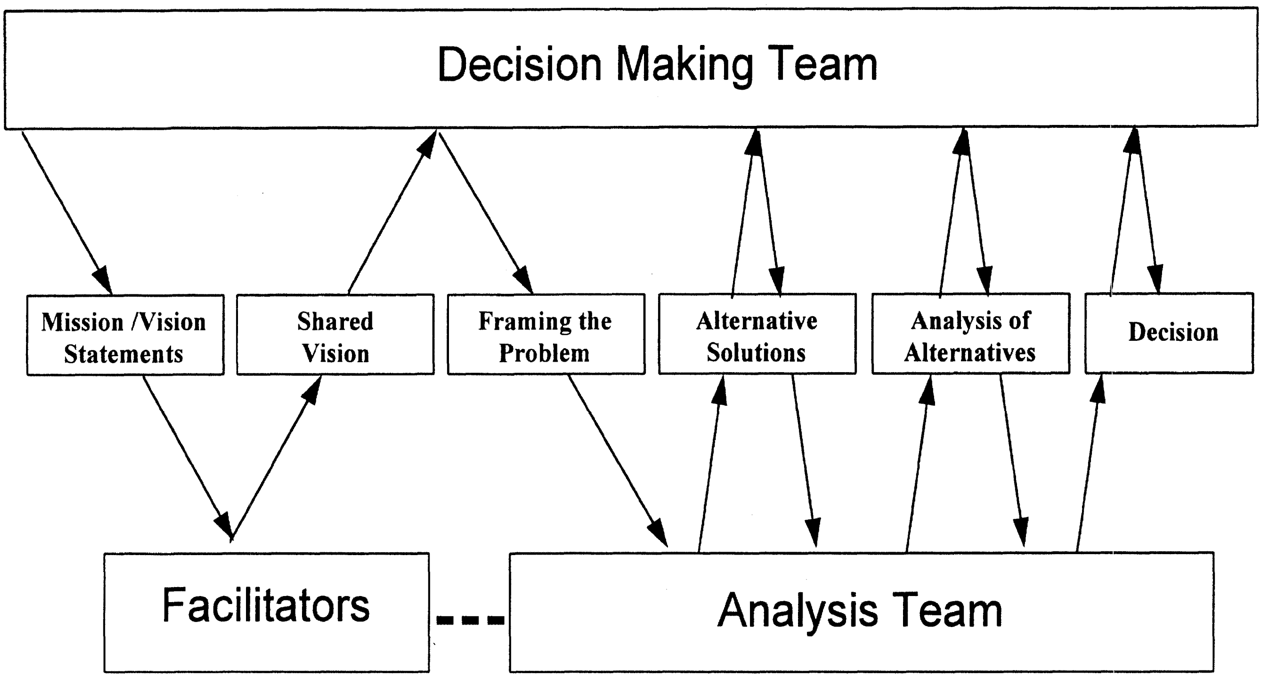


FIGURE 1 Multi-Organization Decision Analysis (MODA)

Figure 1 shows the components of the MODA process. MODA facilitators (neutral outside parties) prepare a shared vision statement based on the mission and vision statements of the stakeholders in the decision. Once the shared vision is accepted by the Decision-Making Team, the steps of problem framing, solution generation, analysis, and decision can be undertaken. Consensus of the Decision-Making Team must be reached at each step before proceeding to the next. The innovative attribute of the MODA process is the crafting of the visions and missions of the various stakeholders into a shared vision. This is anticipated to allow the productive infusion of societal issues into the decision-making process in a multi-organization environment.

Project Results

A current local issue involving ITS provisions for paratransit services was selected for the first application of the MODA process. The regional transit agency recently informed its constituent communities that it would no longer offer multi-county ITS-based paratransit system. Each community then had the choice of taking over the operational component of a local community-based paratransit system with the regional transit agency providing scheduling and routing services, facilitating the development of the entire ITS paratransit system for that community with the regional transit agency completely running it, or not having any community-based involvement in the provision of the service. The decision is thus community-based, requires the participation of many stakeholders within the public and private sectors, and involves interjurisdictional issues and the infrastructure providing real-time traffic data for an intelligent transportation system deployment.

Road to Implementation

The plan for implementation of the MODA process must wait for the completion of the first demonstration described above. After this exercise is completed, MODA will be modified, if necessary, and offered to the ITS community as a tool for reaching implementable decisions in an efficient way.

Decision City Representative

Statement of Shared Vision of the Decision-Making Team

To ensure the provision of effective and efficient transportation service to nondrivers that will enable their access to fundamental life activities and enhance their quality of life.

Decision City Mission Statement

Decision City strives to provide the highest quality of life for its citizens through an accountable local government which encourages and relies on the involvement of the community.

Decision-Team Member Role

To represent the agency such that the decision agreed upon by the Decision-Making Team is in keeping with the agency's mission and within authority granted to that agency.

APPENDIX E: SPREADSHEET DETAILS FOR INFLUENCE DIAGRAM

POLICY	
Connectivity Y/N	Y
PERCENT paratransit Transit Auth.	0.5
ITS FLEET UTIL. IMPROVEMENT	0.33

DECISION CITY ANALYSIS -With Connectivity-

COSTS BOX	Status Quo	LOS A	LOS B	LOS C
Av. Cost (per pax trip)	6.24	7.30	5.41	5.21
Marginal Cost	6.95	7.33	6.25	6.95
Time to Implement (yrs).	0	1	1	1
Pvte. partnersh. pmt/yr	30,000.00	30,000.00	30,000.00	30,000.00
$/reg. eleg. user	107.14	107.14	107.14	107.14
Extended Area Regtd Users	280.00	280.00	280.00	280.00
TOTAL Registered Users	2,300.00	2,300.00	2,300.00	2,300.00
Trips/rgstrd user (AATA)	49.57	49.57	49.57	49.57
$ per pax trip	2.16	2.16	2.16	2.16
ITS Deployment Costs (p. vehicle)	0.00	20,000.00	20,000.00	20,000.00
Demand pax trips (yr)	114,000.00	114,000.00	114,000.00	114,000.00
Dem growth (not from LOS)		0		
Farebox revenue	126,516.49	126,516.49	126,516.49	126,516.49
OTHER COST FIGURES				
Cost/Rev Hour	22.90	32.07	23.76	22.90
TOTAL Oper. Costs	711,360.00	831,960.60	616,355.25	593,985.60
Revenue Hrs.	31,063.76	25,938.24	25,938.24	25,938.24
Trips/hr	3.67	4.40	4.40	4.40
TA Trips/vehicle/yr	5700			
Cab Trips/veh/yr	2375			
DISCOUNTING	Status Quo	LOS A	LOS B	LOS C
# TA vehicles	10	10	10	10
# cabs/contracted service	24	24	24	24
TOT ITS Maint. Costs	0	20000	20000	20000
r (discounting rate)		0.05	0.05	0.05
t (length of benefits)		1000	1000	1000
PV (WITHOUT VEH. COST)		-3,292,012	1,020,095	1,467,488
0	Vehicles			
Cost p. vehicle	100,000	0	0	0
	NPV	-3,292,012	1,020,095	1,467,488

LEVEL OF SERVICE	Status Quo	LOS A	LOS B	LOS C
WT	1	0.25	0.5	1
Scheduling Ease	(24,72)	(0,24)	(24,48)	(24,72)
User Friendly Fleet (% ADA)	50%	100%	75%	50%
Aggregate Pax Travel Time Savings (hours/year)	n.a.	8722	8722	8722
Standing Order Service	See Table V-1			

WT=Window Arrival Time beyond scheduled time (hrs)

Sched. Ease= Advanced Scheduling Requirements (incity, outcity)

DECISION CITY ANALYSIS -Without Connectivity-

POLICY	
Connectivity Y/N	N
PERCENT paratransit Transit Auth.	0.5
ITS FLEET UTIL. IMPROVEMENT	0.33

COSTS BOX	Status Quo	LOS A	LOS B	LOS C
Av. Cost (per pax trip)	6.24	7.30	5.41	5.21
Marginal Cost	6.95	7.33	6.25	6.95
Time to Implement (yrs).	0	1	1	1
Pvte. partnersh. pmt/yr	30,000.00	0.00	0.00	0.00
$/reg. eleg. user	SQ IS Conn	0.00	0.00	0.00
Extended Area Regtd Users	280.00	0.00	0.00	0.00
TOTAL Registered Users	2,300.00	2,020.00	2,020.00	2,020.00
Trips/rgstrd user (AATA)	SQ IS Conn	N.A	N.A	N.A
$ per pax trip	SQ IS Conn	0.00	0.00	0.00
ITS Deployment Costs (p. vehicle)	0.00	20,000.00	20,000.00	20,000.00
Demand pax trips (yr)	114,000.00	114,000.00	114,000.00	114,000.00
Dem growth (not from LOS)		0		
Farebox revenue	126,516.49	126,516.49	126,516.49	126,516.49
OTHER COST FIGURES				
Cost/Rev Hour	22.90	32.07	23.76	22.90
TOTAL Oper. Costs	711,360.00	831,960.60	616,355.25	593,985.60
Revenue Hrs.	31,063.76	25,938.24	25,938.24	25,938.24
Trips/hr	3.67	4.40	4.40	4.40
TA Trips/vehicle/yr	5700			
Cab Trips/veh/yr	2375			
DISCOUNTING	Status Quo	LOS A	LOS B	LOS C
# TA vehicles	10	10	10	10
# cabs/contracted service	24	24	24	24
TOT ITS Maint. Costs	0	20000	20000	20000
r (discounting rate)		0.05	0.05	0.05
t (length of benefits)		1000	1000	1000
PV (WITHOUT VEH. COST)		-3,892,012	420,095	867,488
0 Vehicles				
Cost p. vehicle	100,000	0	0	0
	NPV	-3,892,012	420,095	867,488

LEVEL OF SERVICE	Status Quo	LOS A	LOS B	LOS C
WT	1	0.25	0.5	1
Scheduling Ease	(24,72)	(0,24)	(24,48)	(24,72)
User Friendly Fleet (% ADA)	50%	100%	75%	50%
Aggregate Pax Travel Time Savings (hours/year)	n.a.	8722	8722	8722
Standing Order Service	See Table V-1			

WT=Window Arrival Time beyond scheduled time (hrs)

Sched. Ease= Advanced Scheduling Requirements (incity, outcity)

APPENDIX F: DECISION-MAKING TEAM QUESTIONNAIRE

MODA Session Participant Questionnaire

1) Did you enjoy participating in the Intelligent Transportation System decision analysis project?

2) Did you learn anything from your participation? Please explain.

3) What surprises were there for you?

4) Did you have enough information to participate at your level of comfort? What would have made it better?

5) Did any part of the process make you feel pressured or uncomfortable? Please explain.

6) What could the project team have done to make the process better?

7) Do you feel applying the Multi-Organization Decision Analysis (MODA) process helped the Decision-Making Team reach consensus? **If yes**, please list specifically how the MODA process assisted as compared to other decision-making processes in which you have participated.

If no, how would you improve the process?

8) Where/how (if at all) do you think the results of a public hearing could enter the MODA process?

9) Do you feel the use of surrogate representation accurately represented the real world?

10) Do you think that actual organizational representatives would have access to their own staff who could complete the analysis for the Decision-Making Team?

11) If the project had substantially more resources, how much more time (hours) do you feel would been needed to more fully explore the decision presented to the team?

12) Do you feel the MODA process assisted in making disparate views, particularly societal issues, a more integral part of the decision-making inputs?

Thank you.