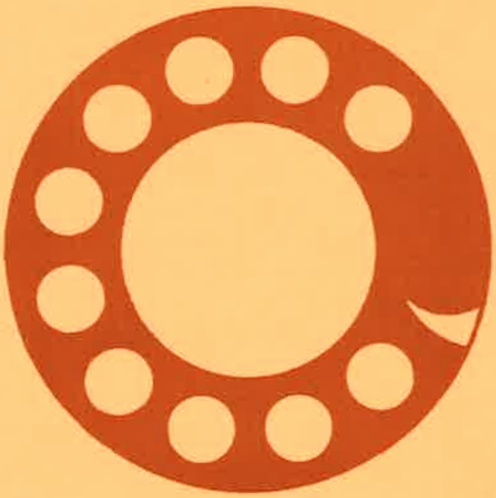


DEMAND-ACTUATED TRANSPORTATION SYSTEMS

Special Report 124
Highway Research Board
National Research Council National Academy of Sciences National Academy of Engineering

Special Report 124

DEMAND-ACTUATED TRANSPORTATION SYSTEMS

Subject Areas

15 Transportation Economics

84 Urban Transportation Systems

HIGHWAY RESEARCH BOARD DIVISION OF ENGINEERING NATIONAL RESEARCH COUNCIL
NATIONAL ACADEMY OF SCIENCES NATIONAL ACADEMY OF ENGINEERING
Washington, D.C. 1971

ISBN 0-309-01963-X
Library of Congress Catalog Card No. 77-177264
Price: $3.80
Available from
Highway Research Board
National Academy of Sciences
2101 Constitution Avenue, N.W.
Washington, D.C. 20418

FOREWORD

The Highway Research Board, as part of an extensive self-study and subsequent reorganization, established the Committee on New Transportation Systems and Technology in January 1970. The approved scope of this new committee included "...research into new concepts of transportation development, including new or emerging modes of travel, modification of existing modes and facilities, and the necessary requirements of new transportation modes as related to patterns of urban development." Because one of its basic functions is to help stimulate and disseminate research findings and accomplishments, the committee was fortunate that during the initial period of membership selection and work program development it had the opportunity to sponsor jointly with Purdue University a conference in September 1970 on demand-actuated transportation systems. The conference also provided an opportunity for the first midyear meeting of the fledgling committee, and details were completed then for sponsorship of papers at the 50th HRB Annual Meeting. Discussions at this Purdue conference, therefore, contributed in large part to the success of the committee program at the 1971 Annual Meeting.

This Special Report contains the papers and discussions generated at the Purdue conference and is the first in what is intended to be a series of documents concerning new transportation systems and technology. Some of the research projects reported at this conference had their genesis directly or indirectly in the extensive study of new systems of urban transportation conducted by the U. S. Department of Housing and Urban Development and completed in 1968. A summary of this study was published in the report, Tomorrow's Transportation: New System for the Urban Future. Other work reported on was originally supported by research and demonstration grants made under the Urban Mass Transportation Act and administered by either the Department of Housing and Urban Development or the Department of Transportation. Perhaps more significant, however, are the reports on research studies initiated and completed entirely with private funds. Expenditure of private research funds to explore thoroughly a new concept is strong indication that demand-actuated transportation systems represent realistic possibilities for future urban transit, as the general conclusions of this conference stress.

Partly through the work of this committee, the accomplishments of government-sponsored research and demonstration projects may be given greater distribution for public information and evaluation. Only by careful reporting and documentation of research activities relating to improved public transportation systems and technologies is the public interest well served. The success of this conference and the effectiveness of the committee's efforts to fulfill its basic function depended on the cooperation of Purdue University, but more particularly on the energy and hard work of Kenneth W. Heathington, Associate Professor of Civil Engineering at Purdue, and James A. Scott, Highway Research Board staff member. The Committee on New Transportation Systems and Technology is pleased to sponsor this Special Report.

—Leon M. Cole

CONTENTS

GENERAL CONCLUSIONS

Kenneth W. Heathington
School of Civil Engineering, Purdue University

This conference brought together personnel working in the area of new transportation systems and technology. There has been, and is currently, a great need for research and planning of new transportation systems. Perhaps at no other time in history has this country been faced with such a great demand for transportation and, at the same time, has showed such small gains in transportation compared with other technological areas. Relatively few technological changes have occurred in public transportation in urban areas since the turn of the century. At a time when the cost of implementation is so great and time required for new innovations to be implemented so long, it is especially necessary that adequate research and planning be performed prior to implementation of new transportation systems. It would be difficult to overstress this need for adequate research and planning.

NEED FOR RESEARCH AND PLANNING

To separate planning and research is often difficult and, perhaps, it should not be done. Yet, planning relies heavily on research findings. It is impossible to have effective planning without adequate research support. When all of the work that has been done in this country since the turn of the century is considered, probably fewer improvements in new technology in transportation systems have been made than in any other field. If one looks at the progress that has been made in medicine, science, space, and in almost any field of endeavor and then reviews the technology in urban transportation, one will find that there has been little change since the turn of the century. One might well argue that, if in the field of transportation one could have the objectives and resources defined as they have been in the space program, many of the problems in urban transportation could be resolved.

The need for research is great in the transportation field and has been great for many years. The need for research will not lessen as time goes on. As the population continues to expand, however, and as the requirements placed on the transportation systems become greater each year with more movement of goods and people and provision of services, the systems that seemingly are inadequate now will become grossly inadequate in the future. A coordinated, intense effort is needed in research for new transportation systems and technology.

If one looks at the vast amount of resources allocated to research in transportation in the present century, one finds that almost all of this has been highway oriented. Only recently have steps been taken to provide limited resources for research, planning, and implementation in the field of public transportation. If this trend of neglecting research in public transportation systems should continue, someday, somewhere, the movement of people will simply stop. There is a saturation point somewhere in time and space. Highway research will not resolve urban transportation problems. However, the small increases that have been in the field of highway engineering far exceed improvements that have been made in the field of public transportation.

One cannot really overstate the need for research on new transportation systems and technology. Without this research public transportation will continue to play a passive role and will continue to decrease in the important role that it should play in urban areas.

Without adequate planning, any implementation will have a very small chance of being successful. Careful evaluation of alternative schemes must be made because of the tremendous resource allocation to transportation systems—both of a monetary and of a social nature. Suboptimization will often occur where effective planning has not been utilized. There have been many criticisms of planning and many are justified. However, in the transportation area, much planning has been performed without supporting research. To be effective, planning must be accompanied by a strong research program. This had been lacking in this country and the consequences are becoming quite evident.

NEED FOR IMPLEMENTATION

The fruit of research and planning is implementation. Without implementation one can see few results coming from planning and research. One may well argue that as far as demand-actuated transportation systems are concerned much of the research and planning has been accomplished. Now is the time for implementation. Perhaps the time for implementation has been drawn out too long. There is generally a long time interval between research and implementation. This time interval can extend several years, perhaps a minimum of five. This is perhaps far too long. The great concern to any rational individual, however, is that implementation should not come about except through adequate planning and research. Implementation without research and planning leads only to frustrations and failures, and perhaps will never lead to optimization of any given or derived system.

The problem seems to be that the research and planning people are not the implementation people. That is, as soon as a given system has been researched, the researchers immediately turn their attentions to other projects without attempting to aid in the implementation. Thus, the people that are interested in implementation have to bridge the gap between the research findings and constructing and operating a given system. Often the operators do not understand the research methodologies or, in some instances, even the research findings. The researcher is not inclined often to work with the operators to see that his research findings are properly implemented. It seems that a good method for bringing research people and those in the field together in a fashion that would permit a good exchange of ideas has been lacking for many years—if it ever existed. Often the operators seem to be suspicious of the researchers; likewise, the researchers seem to be suspicious of the operators. This comes about by having different interests and not really understanding the problems and requirements of each other. This lack of understanding and appreciation of both researchers and implementers has contributed to the problems in urban transportation. The ideal situation would be to have researchers, planners, and those involved in implementation all brought together to work within the same framework with the objective of providing new transportation systems and technology. The researchers, planners, and operators could, perhaps, be the same individuals. Without this environment, the prospects for successful improvements in public transportation will be dim.

RECENT IMPLEMENTED AND PLANNED DEMAND-ACTUATED TRANSPORTATION SYSTEMS

Since September 1970, there have been 2 demand-actuated transportation systems implemented (one of these actually began in July 1970). At the time of this writing one additional project has been approved by the Urban Mass Transportation Administration, and a fourth project is under evaluation. A fifth project is being planned that will be a many-to-many project.

Toronto Project

During the summer of 1970, the Ontario Department of Highways initiated a many-to-one dial-a-bus service experiment feeding the Pickering Station of the Go Commuter

Railroad Service, serving the Toronto metropolitan area. This service utilizes 4 buses during peak hours and a central manual-dispatching system. In February 1971 the project began a limited many-to-many service during the off-peak periods of the day. Patronage has grown to 500 passengers per day; the former fixed schedule service had failed for lack of patronage. Weekday revenues meet about 44 percent of weekday costs, but peak-hour service almost pays its way.

Columbia, Maryland, Project

Columbia, Maryland, is one of the few new towns under development in the United States. The current population of 13,000 persons has intercity bus service to Washington and Baltimore, but service within the city has been restricted to 2 buses operating with fixed routes and schedules. The system has been carrying only about 40 to 50 passengers per day. In January 1971, Columbia instituted dial-a-bus service on a many-to-many basis. By calling a central dispatcher, residents of Columbia can obtain door-to-door service to anywhere in Columbia for 25 cents. The concept has been an immediate success. Usage of 175 passengers was reported the first day and is now averaging 300 per day, more than 5 times the usage of the previous service. Cost of the service is approximately $1.00 per ride.

Haddonfield, New Jersey, Project

The U. S. Department of Transportation has approved a dial-a-bus project for Haddonfield, New Jersey, a suburb of Philadelphia. A rail rapid transit line was recently established between Philadelphia and Haddonfield, and the dial-a-bus experiment will be established as a many-to-one feeder to the Haddonfield Station. The system will initially be dispatched manually. However, Mitre Corporation was given a contract to develop a simpler scheduled algorithm and software package that can be operated on a small computer. It is hoped that ultimately Haddonfield will become computer-controlled by using the software developed by Mitre.

Rochester, New York, Project

A dial-a-bus project is planned for Rochester, New York, where the U. S. Department of Transportation is considering the support of a demonstration of the first computer-dispatched dial-a-bus. By making selected modifications to the software program package for dynamic bus scheduling developed as part of the M. I. T. dial-a-bus research, an operational computer-dispatch system can be developed.

Lafayette, Indiana, Project

Plans are being completed for a demand-actuated transportation system to be operated in the greater Lafayette area. The proposed system will operate in the off-peak periods with a fixed-route, fixed-scheduled system being utilized in the peak periods. The proposed project is planned as a local project under a capital grants program of the Urban Mass Transportation Administration. The demand-actuated transportation system will be a many-to-many system with the scheduling evolving from a manual to a computer operation. Purdue University will provide the technical expertise.

MAIN POINTS OF CONFERENCE

There are many conclusions that can be made from this conference. No attempt will be made to cover them all; however, a few should be emphasized at this time. These will be summarized briefly to focus on the main points brought out at the conference.

1. A substantial amount of research has been completed on demand-actuated transportation systems. This research has been sponsored from both private and public sources. The completed research projects, while using generally available data and previously gathered information, were conducted independently of one another, yet their findings and conclusions on demand-actuated transportation systems tend to converge and to be mutually reinforcing.

2. A substantial amount of expertise on demand-actuated systems has been developed within several organizations. This expertise includes scheduling, dispatching, vehicle design, and general operations. This expertise is probably much greater than the average transportation planner or researcher realizes. Confidence has been instilled into many individuals located throughout a vast area both geographically and organizationally.

3. There is a need for extensive implementation of demand-actuated transportation systems. It was generally felt that there had been sufficient preliminary research and planning and that implementation is needed now. It was felt that there are few advantages to be gained by delaying actual demonstration.

4. The few demonstrations that have occurred have been reasonably successful. All of these have looked promising, and some have experienced a substantial increase in demand for the service.

5. There is a definite need for a computer-scheduled system. Many of the researchers at this conference felt there was little justification as far as research and planning is concerned to implement a manually scheduled operation, particularly in light of the Toronto project. Some argued that there would be no useful results obtained from such a project and that resources used would be wasted.

6. There is a need for a more coordinated effort at the federal, state, and local level. There needs to be a more coordinated effort between demonstration projects, capital grant improvement programs, and other types of programs that are related to public transportation.

7. The time required for evaluation of proposed projects is too long. The time needed to obtain approval for funds of specified projects results in inefficiency and does not permit optimization of research in public transportation.

8. There is a need for faster implementation. The time lag between research planning and implementation is too long. Some implementation may be less effective because of this time lag.

9. There is a need for closer relationship between operators and researchers. There is doubt that the transit industry, by itself, will pick up the innovations suggested or explored by researchers and planners. There is a strong feeling that innovations will not come about from within the transit industry and that researchers will have to become operationally oriented if the research is to be implemented.

10. There is a feeling that the federal government should provide leadership, particularly from a financial point of view, in helping to establish new concepts in transportation. There were arguments for a stronger effort from the federal government to help finance research and implementation in the field of public transportation.

This conference has served the purpose of exploring the extent of the expertise existing in demand-actuated transportation systems. It established an up-to-date analysis of the state of the art of demand-actuated transportation systems. This conference has highlighted the weaker areas of knowledge and made suggestions as to where projects in demand-actuated transportation systems should be directed. The results of this conference should serve as general guidelines for the evaluation of proposed projects in demand-actuated transportation systems. The results should be of benefit to researchers, operators, and administrators.

WELCOMING REMARKS

Richard J. Grosh
Purdue University

Transportation has been, and perhaps always will be, one of the key elements to the economic development of any area. Because of this, a large amount of resources are allocated to transportation in both rural and urban areas. In both of these areas, the resource allocations have been used primarily for the promotion of the use of private transportation. Of course, public transportation in urban areas is receiving more attention; however, by comparison, the emphasis is light. Furthermore, one might question the present ranking of these priorities in the transportation area.

Traditionally, public transportation has been so important that here in the Middle West it has literally determined the location and the metamorphosis of the growth of cities. Nearly all of the major cities in the Middle West are located an almost equal distance from its nearest large neighbor. The distance between Fort Wayne and Chicago, Fort Wayne and Indianapolis, or Indianapolis and Dayton all seem to be approximately the same, and this can be traced historically to the optimum use of resources by railroads. These distances were optimum for refueling. Large industries grew up in the centers of the cities near the terminals of the railroad, the industries were then surrounded by essential services, and then the people who worked in the industries moved farther out—in this order of priority. Again, this basically has gone back to the cost of public transportation. Thus, I feel that public transportation has had a very long-term influence on our style of living and also our standard of living. With proper management, this will continue into the future.

Unfortunately, however, the technology of public transportation in urban areas has remained about the same for the past 70 years. Present recommendations for public transportation systems in urban areas contain approximately the same structure as at the turn of the century. During this same 70 years, we have witnessed a great change in technology in almost every other area of endeavor. Perhaps this change, or lack of it, in some instances is due to the available resources required to instigate new concepts in technology. However, there is no reason why we should not be as inventive in transportation as in space, medicine, or any other field of science. Some would argue that problems in urban transportation are public problems and should be dealt with only with public funds. With this position I could not agree because, without adequate transportation, private enterprise cannot fully develop its potential. Hence, it has a vested interest in what happens to public transportation and should participate in the solution or the invention of solutions to some of the current problems.

In short, it is past time for new and ingenious concepts to be introduced into public transportation. In the future, many concepts from this conference will have to be fully researched, planned and, if proved feasible, implemented. I believe that this conference can contribute to the strengthening of feasibility studies so that some modifications to our transportation system can be brought about fairly soon on a demonstration basis.

DEMAND BUS FOR A NEW TOWN

Robert D. Stevens and Richard L. Smith
The Bendix Corporation

Columbia, Maryland, is a new town under construction in the Baltimore-Washington corridor. More than 10,000 persons now reside in Columbia, and its population is expected to be more than 100,000 by 1982. The acreage assembled for the development is larger than Manhattan Island.

Columbia was planned and is being built with a neighborhood-village-downtown hierarchy. Downtown will provide shopping, office, and other facilities typically located in a downtown. Each of the several villages will comprise a village center with shopping, office, educational, recreational, and religious facilities and several neighborhoods. A village will contain between 10,000 and 15,000 people. Each neighborhood will be the home of 1,500 to 2,000 people. About 25 percent of the land in Columbia will remain as permanent open space. The open space will include parks, bodies of water, pathways, and common areas. The street network consists of freeways, parkways, village loop roads, neighborhood loop roads, and local cul-de-sac streets.

A bus system operating on its own right-of-way was determined to be the most appropriate means of public transportation. Consequently a 50-ft exclusive public transit right-of-way was planned. The location of the right-of-way is being integrated into the land use plan such that 40 percent of the ultimate population will be within a 3-minute walk of the transit right-of-way. Figure 1 shows the location of the transit right-of-way.

Transit service was to be provided by small buses operating on short headways on the separate right-of-way. In general, the transit right-of-way parallels the village roads and crosses the neighborhood loop roads within a few feet of their intersections with the village roads. As more of the right-of-way was set aside, Columbia planners decided to reevaluate the decision on the means of providing transit.

To undertake this study, the Columbia Association (an association of the residents that collects dues in lieu of town taxes) applied to the U. S. Department of Transportation for a grant to operate a demonstration service and to make a technical study. The grant was approved, and the Columbia Association retained the Bendix Corporation to conduct the study and to assist in the demonstration program. Both of these programs included work on demand bus.

The demonstration program has a twofold objective: (a) to determine the optimum method of providing transit in a developing new town and (b) to provide inputs to the design of the ultimate Columbia transit system being developed in the Columbia transit program.

The current failure of public transportation to meet people's needs is well known. One need only observe declining ridership patterns on public transit systems in city after city. As a result of ridership declines, routes are cut and schedules are reduced. An innovative approach is required to remedy such spiraling deterioration in public transit operations.

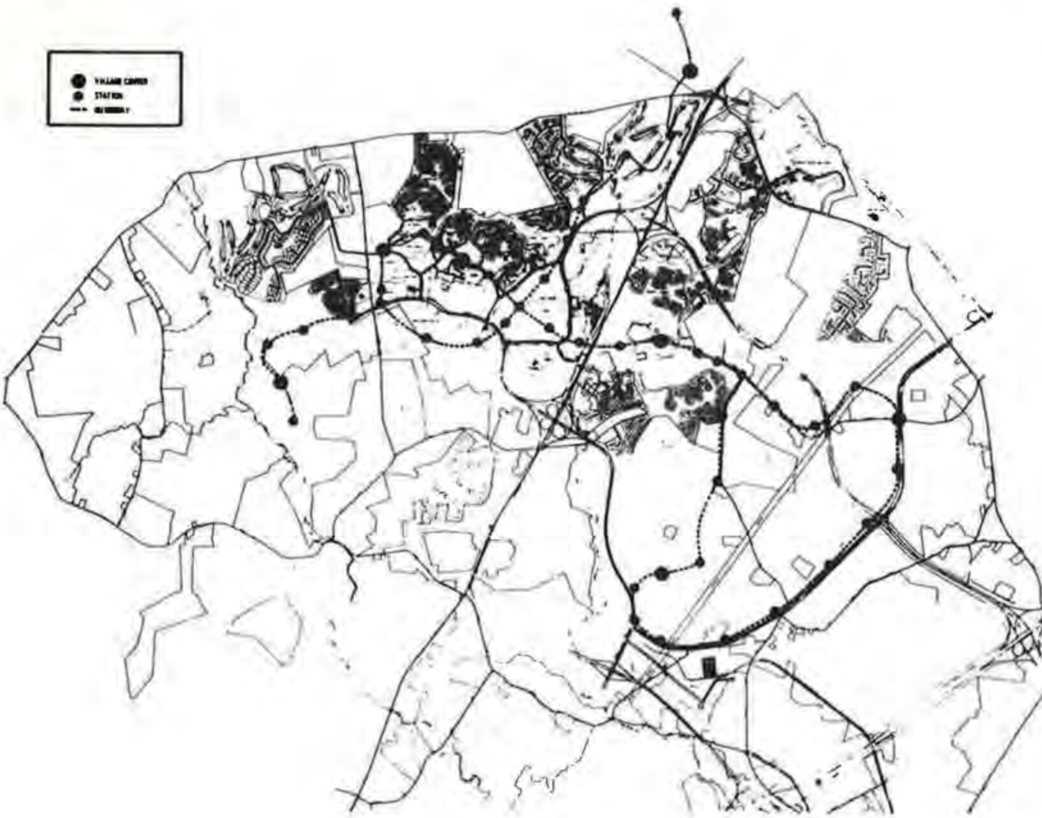


Figure 1. Transit right-of-way.

The failure of public transit to approach the type of service offered by the private automobile is easily identified as its primary fault. Public transit is seldom chosen for its convenience, cleanliness, quiet and smooth ride, or the short walk and wait times at both ends of the trip. The objective of the demonstration program is to provide innovative transit service to minimize these objections.

The approach taken in the demonstration program was to formulate a series of postulates relating to public transit and then to outline a process to verify these postulates. The postulates included statements on fare options, management techniques, and types of service offered. The verification of the postulates is being accomplished by opinion surveys, mathematical analysis, and demonstration experiments.

The postulate relating to demand bus was stated as follows: "People would prefer to have an active role in the transit system, giving them some measure of control over the system response to their specific needs."

Thus, it was decided that 2 types of transit service should be tested in Columbia. The 2 kinds of operation were (a) a fixed route-fixed schedule service and (b) a demand-actuated service. Valid experimental results were obtained and the number of variables was reduced by designing the 2 types of service to provide the same frequency of service, the same hours of service, the same fare, and the same quality of ride by using new, clean, small, air-conditioned vehicles. The only real difference between the 2 services is the method of operating. The main question that requires an answer is whether travel patterns, street network of loops and cul-de-sacs, and neighborhoods of relatively low density in Columbia make it more conducive to scheduled or demand-operated transit or to no transit at all.

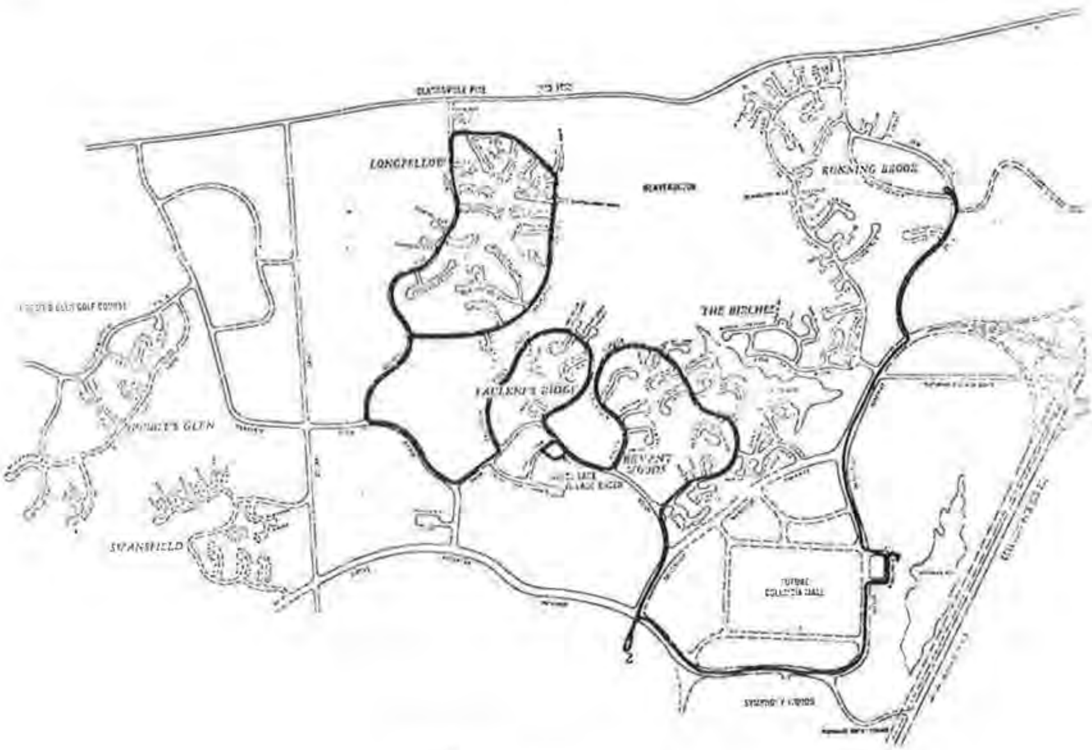


Figure 2. Scheduled bus route.

Scheduled transit service was put into operation on a half-hour headway, later reduced to a one-hour headway, on a route that traverses each neighborhood loop road in Wilde Lake Village as shown in Figure 2. At the same time, work was initiated to develop an operating procedure for demand-actuated service in another village.

The rationale for considering demand bus for Columbia was based on the following demand service characteristics: (a) It only operates when required; (b) it only operates where required; (c) it provides door-to-door service; and (d) it gives people some measure of control over the system response to their specific travel needs.

The procedure used in designing the demand-actuated bus system for Columbia included an examination of the service area, vehicle characteristics, the trip-maker, the service procedure, and the command and control network.

Several desirable service area characteristics were delineated: (a) A low-density area not served well by scheduled service should be selected; (b) trips in the area should be collection or distribution oriented; (c) a single terminal should be the major trip destination; (d) streets and the street pattern should readily accommodate the vehicle; and (e) alternate routes should be available between various points in the area.

The vehicle should be low capacity (about 8 to 16 passengers), easy to handle and suitable for turning around in driveways on cul-de-sac streets, comfortable, and able to accommodate equipment necessary for the demand operation.

Service should be available to all residents, workers, and visitors in the service area on either a one-time or a precommittal basis. The service should accommodate any trip purpose including grocery shopping.

The service procedure is concerned with how service is provided including the method of routing and the hours and frequency of operation. The command and control network requirements were investigated to determine the most economical communication link among the potential user, the driver, and the dispatcher, if any. Communication systems investigated included two-way radio, mobile telephone, teletype, answering service, tape recorder, telephone, and computer.

The resulting demand bus service procedure for Columbia calls for an 8-passenger, club wagon vehicle that would operate to any house or business within the Oakland Mills Village service area shown in Figure 3. The vehicle would be based at the village center and depart hourly on demand, i.e., if there were at least one person to serve. Service between the village center and downtown would be on a scheduled basis. The route is shown in Figure 4. Service requests in the demand bus area would be made via telephone to a dispatcher. The dispatcher would transmit the requests to the driver via telephone at the village center just prior to the vehicle's scheduled departure time. Each residence and business in the service area would be provided an approximate vehicle arrival time at that location. The vehicle would depart the village center when a demand is registered and generally would follow the village road. Service would be provided to the door even on cul-de-sac streets. Driveways would be used to facilitate turning around and, thus, minimize travel time. The guaranteed time of arrival at houses in the first part of the service area would be within a 2-minute time interval. Residences near the end of the service area would have a 9-minute guaranteed service time interval.

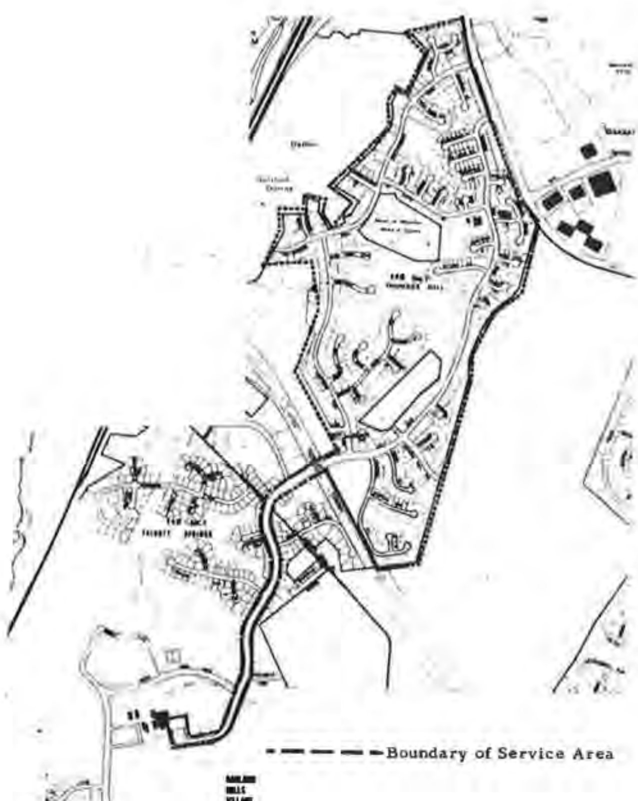


Figure 3. Demand bus service area.

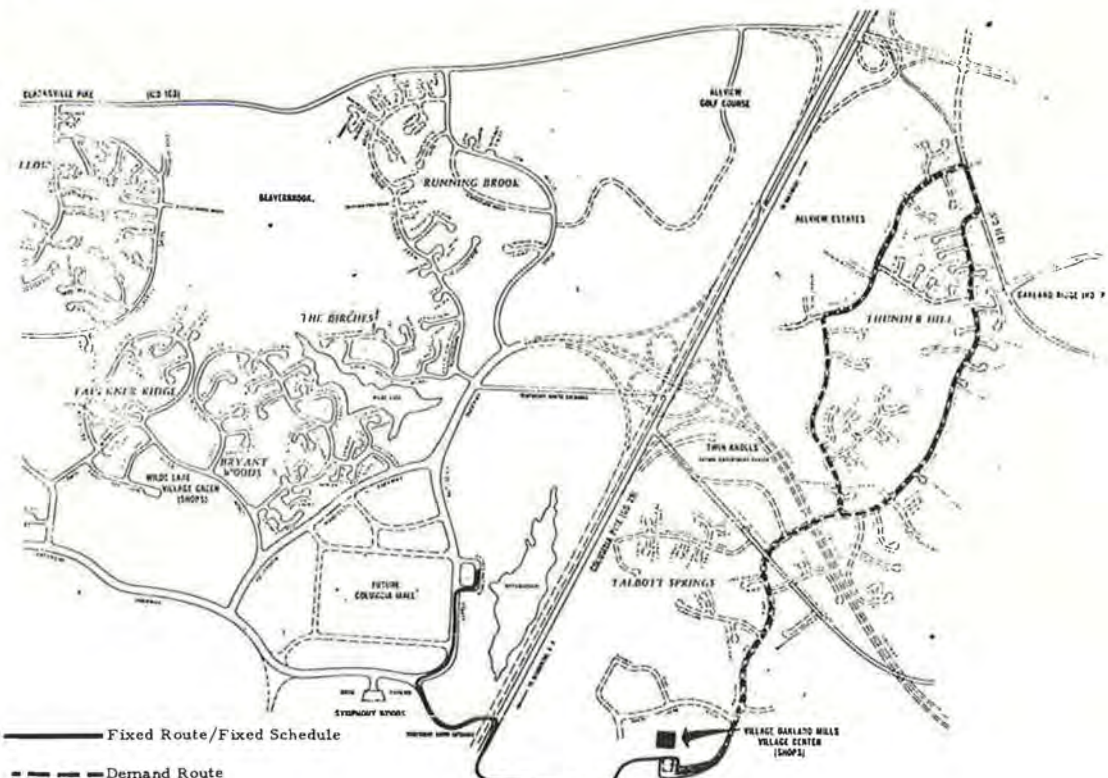


Figure 4. Demand bus route.

This type of demand-bus operation was simulated for Oakland Mills Village in Columbia by simulated vehicle runs and by actual vehicle runs based on randomly selected demands in accordance with the estimated demand level. The results indicated that such a service procedure was feasible.

Implementation of the service is now dependent on approval by the U. S. Department of Transportation of the second phase of the demonstration program. The service will go into operation upon approval. A schedule has been prepared for improving the demand bus operation in the field as experience is gained through actual operation.

After the demand bus has been operated for one year in Oakland Mills Village, the scheduled and demand service areas will be switched. Service will again be provided for a year. The ridership and costs associated with both types of service in the 2 villages will be analyzed, and the best operating method for neighborhood bus service in Columbia will be selected.

One reason for designing this comparison between demand and scheduled bus is to assist in the selection of an operating procedure for the ultimate Columbia transit system. The general characteristics of this system are being developed in the Columbia transit program. The methodology used in this program was to formulate a number of transit system configurations and then to evaluate their suitability for Columbia.

Eight transit configurations were synthesized. They varied from a scheduled bus operation on a street or roadway, to a demand bus on a roadway, to an automatic personal rapid transit system on an exclusive guideway. Each of these was considered (a) alone as a primary system utilizing the right-of-way to service the 40 percent of the residents who will live within walking distance of the right-of-way and (b) together with a scheduled or demand bus feeder system to serve all of Columbia. The system parameters associated with the 8 configurations are given in Table 1. A configuration that would use a paved roadway on the right-of-way is called "roadway," while one that would use an exclusive guideway on the right-of-way is called "guideway."

A demand analysis was made for Columbia to derive total person trips by purpose. Walk trips were then separated. Trips on transit were obtained by using selected system characteristics to perform the modal split. The ridership each configuration would attract was projected by a demand sensitivity analysis, taking into account travel speed, frequency of service, hours of operation, fare, and type of service. As a result of the demand projections, the number and the size of vehicles required for each configuration were developed. Ridership varied from a low of 1,300 per day on a low-frequency, scheduled bus to more than 40,000 on an automatic, personal, demand transit system.

One configuration, Roadway III, is a demand bus operation for all of Columbia. This configuration would use 15-passenger buses. A person would be guaranteed service within 10 minutes of a request for service. A given vehicle would take a person to any point in the same village, downtown, or any point along the route to downtown. Service to other points could require a transfer.

This demand-bus operation would attract more riders than any other bus system and would surpass all but one guideway configuration in projected ridership. Even though it would attract 10 percent more riders than the next best bus system, it would require 60 percent more miles of travel.

Demand bus was also considered for those configurations with feeder operations, namely, Guideways I and III and Roadways I and IV. Guideway I and Roadway I have a comprehensive or short-headway feeder operation, while Guideway III and Roadway IV have a nominal or long-headway feeder operation. Scheduled service and demand service were considered for these operations. At the present time, it appears that demand bus is not suitable for the nominal feeder operation primarily because the long headways and the low number of vehicles make it impossible to guarantee service within a reasonable time interval.

TABLE 1
SUMMARY OF SYSTEM PARAMETERS

Configuration	System	Density of Area Served	Days per Week	Service (hr/day)	Peak-Hour Headway (min)	Average Vehicle Speed (mph)	Number of Vehicles	Vehicle Capacity (seated passengers)	1985 Riders per Day
Guideway I	Primary	High	7	24	2	35	470	6	40,370
	Comp. feeder	Low	7	18	18	15	21	15	11,220
	Total	All Columbia					491		40,370
Guideway II	Primary	High	7	24	2	35	310	6	29,150
Guideway III	Primary	High	7	24	2	35	320	6	30,100
	Nominal feeder	Low	6	12	90	15	10	25	950
	Total	All Columbia					330		30,100
Roadway I	Primary	High	7	24	9	15	19	50	17,870[a]
	Comp. feeder	Low	7	18	18	15	45	15	9,580[a]
	Total	All Columbia					64		27,450
Roadway II	Primary	High	7	24	9	15	19	50	17,870
Roadway III	Demand bus	All Columbia	7	22	10	15	78	15	30,170
Roadway IV	Primary	High	7	24	9	15	19	50	18,620
	Nominal feeder	Low	6	12	90	15	10	25	750
	Total	All Columbia					29		18,620
Roadway V	Nominal single	All Columbia	6	12	90	15	17	25/50	1,360

[a]This is the only case where riders on primary and feeder systems are additive.

The trade-offs made to select the recommended configurations primarily involved the ridership projections and the financial analysis. Some results of the financial analysis are given in Table 2. Roadway IV would require the lowest percentage of capital support, and Guideway III would reach a peak debt at the earliest time. Roadway V is the least-cost configuration, while Roadway III, the Columbia-wide demand bus, is the highest.

Alternate financing assumptions were considered. These resulted in different percentages of capital support being required for the guideway configurations. As a result, 3 configurations were selected: (a) Guideway III with its automatic primary system and nominal, scheduled bus feeder system, (b) Roadway IV with its scheduled bus primary system and nominal feeder system, and (c) Roadway V with its nominal scheduled Columbia-wide bus system. The characteristics of these 3 configurations are given in Table 3.

Demand bus operation did not survive the selection process primarily because (a) on a Columbia-wide basis it required too many miles of operation and too many vehicles and (b) on a feeder basis it could not provide an acceptable service-time interval without requiring a considerable increase in the number of vehicles over a scheduled service.

TABLE 2

SUMMARY OF FINANCIAL ANALYSIS

Configuration	Cost			Annual Revenue and Cost at Full Development		Capital Support Required, Including Land (percent)	Total Support Required During Development Period		Peak Cumulative Capital and Operating Cash Required	
	Capital	Land	Total	Revenue	Operation and Maintenance Costs		Operating	Capital	Year	Amount
Guideway I	36,827.6	4,295.0	41,122.6	2,542.0	2,439.3	86	5,742.4	41,832.0	1983	42,180.6
Guideway II	33,893.0	4,295.0	38,188.0	1,916.4	1,360.0	78	667.0	30,541.4	1979	32,947.8
Guideway III	30,221.0	4,295.0	34,516.0	1,476.7	622.1	69	33.8	23,993.9	1977	26,446.6
Roadway I	12,416.2	4,295.0	16,711.2	1,887.0	3,863.9	74	23,352.3	35,768.5	1985	35,768.5
Roadway II	9,852.7	4,295.0	14,147.7	1,397.7	1,708.9	70	6,852.1	16,704.8	1985	16,704.8
Roadway III	13,667.3	4,295.0	17,962.3	2,022.7	6,464.2	76	36,640.8	50,308.1	1985	50,308.1
Roadway IV	7,033.2	4,295.0	11,328.2	947.8	1,028.9	62	3,850.2	10,883.4	1985	10,863.4
Roadway V	2,228.6	–	2,228.6	66.2	244.4	100	2,163.4	4,414.0	1985	4,414.0

Note: Amounts are in thousands of 1970 dollars.

TABLE 3

SUMMARY OF ALTERNATE CONFIGURATIONS

Configuration	Vehicle Concept		Service Concept		Capital Cost (millions of dollars)	Capital Required (percent)	Net Revenue	Technical Risk	Ridership	
	Primary Right-of-Way	Low-Density Areas	Primary Right-of-Way	Low-Density Areas					Daily Trips	Relative (percent)
Guideway III	6-passenger automated	25-passenger bus	Nonstop, personal operation	90-min headway	34.5	53 to 69[a]	Sufficient to amortize 31 to 47 percent of capital cost	Significant	30,100	100
Roadway IV	50-passenger bus	25-passenger bus	90-min headway	90-min headway	11.3	62	Sustained annual deficit of $81,000	Minimal	18,620	62
Roadway V	50-passenger bus[b]	25-passenger bus	90-min headway	90-min headway	2.2	100	Sustained annual deficit of $178,200	Minimal	1,360	4.5

[a]Percentage of capital required depends on financing.　[b]Does not own right-of-way.

Thus, demand bus does not appear to be the best form of transit for Columbia either on a city-wide basis or as a feeder service. Although a demand bus system does not appear feasible for Columbia, one of the recommended configurations is a demand-actuated system with small vehicles operated automatically on an exclusive guideway.

CASE STUDY OF A DEMAND-RESPONSIVE TRANSPORTATION SYSTEM

H. J. Bauer
Transportation Research Department, General Motors Research Laboratories

Demand-responsive transportation service (referred to in this paper as D-J for demand-jitney) is essentially a door-to-door public transportation service. A potential system user telephones a central dispatcher indicating a desire for transportation and informing the operator of his location and desired destination. Through the use of a computer, the ability to meet the demand within specific guaranteed waiting and travel times is determined. After the guaranteed conditions are accepted by the customer, a vehicle (which may already be servicing other patrons) is dispatched through an electronic communication link to pick up the new customer. It is intended that the fare for D-J service will be below that of the usual taxicab because the productivity of the vehicles is increased through ride-sharing.

It was the primary purpose of this study to provide information to aid in decisions regarding the merit of demand-responsive transportation systems and the need for vehicles specifically designed for D-J transportation systems. The study was also designed to develop improved analytical tools for the objective evaluation of new concepts (modes) of transportation and novel or conventional transportation systems designed to meet specific community needs.

This case study of a demand-responsive public transportation system has shown the following:

1. Technically the concept is feasible and within the present state of the art;
2. Financially the system, as applied to the rigorous requirements of the case study community, can support itself from the fare box without capital investment subsidy under certain conditions of fare and service level;
3. The political acceptance of the system was limited because the social benefits apply primarily to nonautomobile users, a small percentage in the case study area;
4. The system has sufficient potential social benefits to warrant implementation of demonstration programs; and
5. Engineering design effort should be initiated for a vehicle specifically for demand-responsive service because none of the vehicles currently available is suitable.

Many organizations have studied various aspects of demand-responsive transportation systems. This study differed from the others in several ways.

1. The case study reported here is based on the transportation requirements of a real community.
2. Rather than select a case study city with "ideal" characteristics for D-J, this study selected a community based on its representativeness of about 100 cities in the nation whose population density might lead to a need for a demand-responsive transportation system. Validating the utility of D-J for this particular community provided a more meaningful analysis of the potential nationwide merits of the

system and, therefore, provided a better understanding of a market for the potential vehicle or equipment or both.

3. The study developed and analyzed an entire D-J system including operational and maintenance requirements, operating strategies, overall financial analyses, and potential social-political reactions to D-J implementation.
4. The system design (vehicles, facilities, and operating strategies) was not based merely on the intuitive or professional knowledge of the system designers. Nor was the ridership estimation based on arbitrary percentages of known trips being made in the community at some specific point in time. Both of these (system design and ridership estimation) were based on a series of 3 detailed, personal interviews conducted for the study team by an established, professional marketing and product research firm. The sponsor of the study was not identified in the surveys. The entire D-J system was simulated by computer in order to establish how the system operates under a variety of parameters and strategies.

The detailed system design, computer simulation, and findings of the ridership estimation survey provided the basis for a detailed cost analysis of the system under various conditions of patronage, fare, and operating guarantees of waiting and travel times. The fiscal posture of the system was determined from the standpoint of the fare box as the sole source of revenue and from that of federal support in terms of two-thirds grants for capital investment.

The basic flow and interactions of the various activities involved in the system study are shown in Figure 1.

THE CASE STUDY CITY

The community that was selected as the case study city is representative, in terms of population density, of a sufficient number of U. S. cities so that a meaningful judgment might be made of the national potential of D-J systems. Further, the use of this community would provide better insight into possible commercial markets for vehicles and equipment related to D-J operations than would the use of an "ideal" city.

The realistic design and evaluation of a transportation system require considerable knowledge of the community for which it is intended. In this study particular attention was paid to the analysis of transportation requirements of the area's residents. Because people's travel patterns and habits are a function of several factors, an analysis was made of socioeconomic characteristics, land use activity systems, and transportation systems in the community with which a D-J system would have to be integrated.

The study area is approximately 6 miles square. Population growth has been rapid. In 1960 the resident population was about 100,000. The city planning department estimates the present population to be near 200,000, with an expected growth by 1980 to approximately 215,000. The net residential density in 1965 was 10,300 persons per square mile. (The overall population density equaled 4,700 persons per square mile.)

Travel data used for the D-J study were based on a regional origin-destination survey conducted in 1965. The population figures used in the D-J study are those for 1965: approximately 175,000.

Some pertinent socioeconomic characteristics of the case study area are given in Table 1. According to the planning commission, the composition of the population is changing. In 1966, more than 60 percent of new "move-in" workers were in white collar occupations. Of this 60 percent, about 45 percent were in technical, professional, and managerial classifications. Incomes and automobile ownership may be expected to rise above those given in Table 1.

Age distributions of the population in a community are also significant for transportation planning. These characteristics are given in Table 2.

The 1965 distribution of land use is given in Table 3. It is estimated that today there are over 52,000 dwelling units in the area, about 6,000 of which are multiple family units

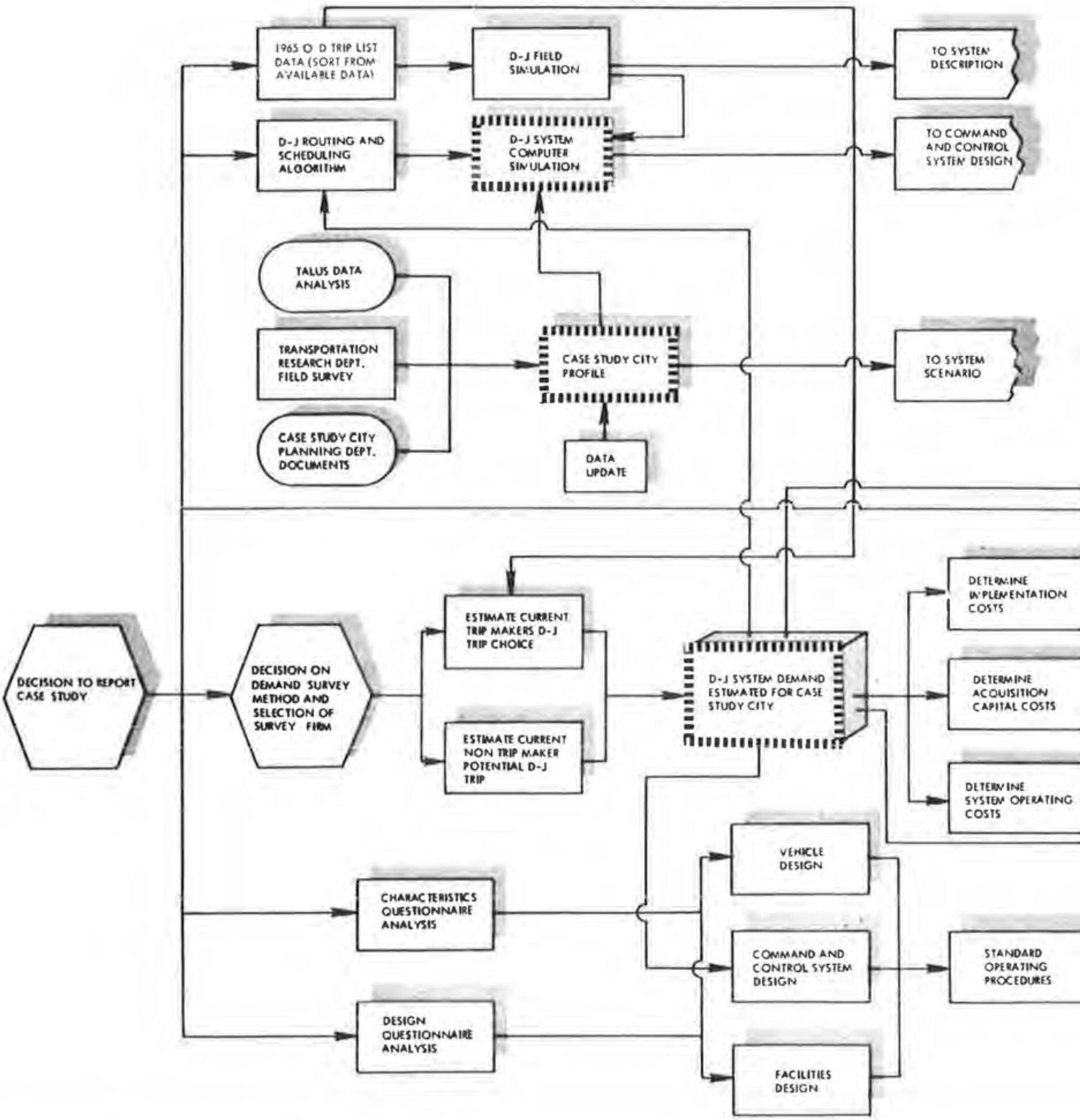
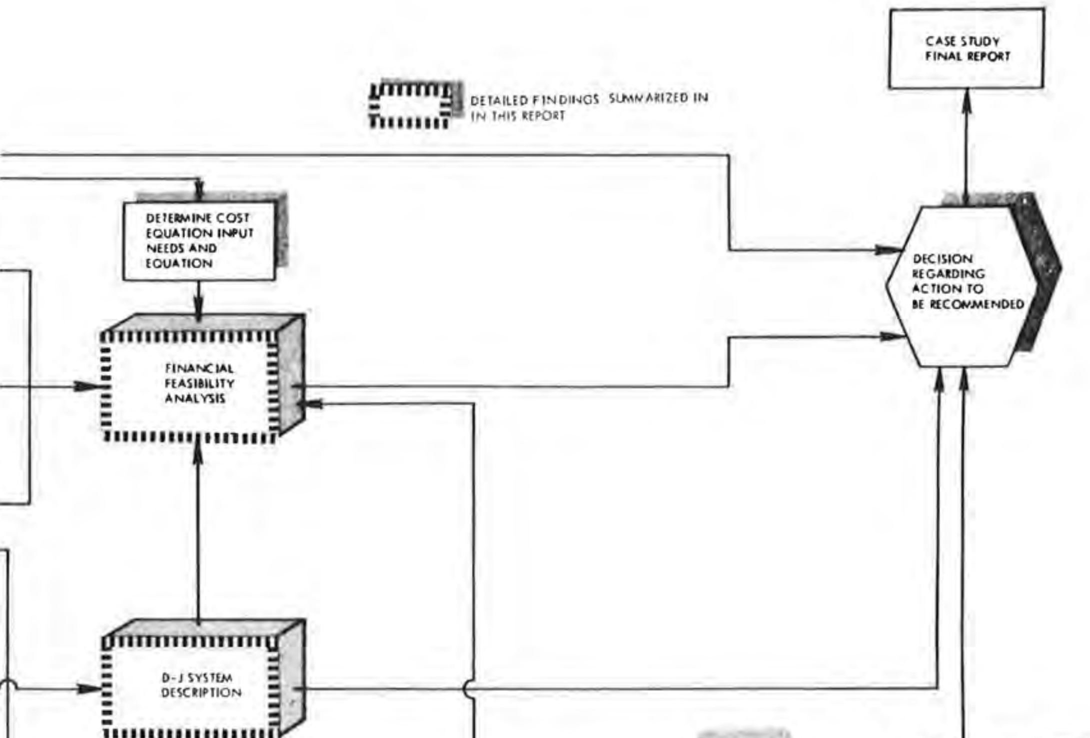


Figure 1. Sequence of events of D-J system study.



CASE STUDY FINAL REPORT
DETAILED FINDINGS SUMMARIZED IN IN THIS REPORT
DETERMINE COST EQUATION INPUT NEEDS AND EQUATION
DECISION REGARDING ACTION TO BE RECOMMENDED
FINANCIAL FEASIBILITY ANALYSIS
D-J SYSTEM DESCRIPTION
D-J SYSTEM SCENARIO
DECISION ON METHODOLOGY FOR SOCIAL POLITICAL ACCEPTANCE EVALUATION
SOCIAL POLITICAL ACCEPTANCE EVALUATION

TABLE 1

SOCIOECONOMIC CHARACTERISTICS OF CASE STUDY CITY

Characteristic	Percent	Characteristic	Percent
Family income (median $9,000)		Occupation of household heads	
Under $3,000	5.2		
$3,000 to $4,999	6.4	White collar	38
$5,000 to $7,999	32.5	Blue collar	62
$8,000 to $9,999	25.1	Retired	7
$10,000 to $14,999	24.2	Household automobile availability	
$15,000 to $19,999	5.1		
$20,000 or more	1.5	None	3
		One	52
		Two or more	45

Source: Local 1965 survey.

and 2,000 are mobile homes. The average household size of the community is 3.8 persons. Residential densities vary, ranging from 2 to 8 dwelling units per net residential acre. The community-wide average is 5 units per acre. This distribution is usually classified by urban planners as "medium to low."

There are approximately 1,500 retail and service businesses in the city. Most of these are in the 24 commercial centers relatively evenly distributed through the case study area. There is no clear-cut central business district. In addition, there are 5 regional shopping centers, 4 of which are located within 5 miles of the case study area.

There are 800 industries in the community. Most of them employ fewer than 100 persons. The majority of the industry is located along 2 major corridors. There are more than 55,000 manufacturing jobs in the community.

There are also 98 other significant trip generators. The group includes hospitals, schools and colleges, and branch libraries.

Transportation facilities consist of about 400 miles of residential streets and collector roads, 85 miles of major thoroughfares, and a fixed route-fixed schedule bus system of 6 routes. Neither of the 2 railroads that run through the community provides passenger service originating in the community. Details of the bus transit service in the city are given in Table 4.

There is 24-hour taxicab service provided by 3 companies operating in the area. The rates are 90 cents for the first mile and 10 cents for each additional ¼ mile.

TABLE 2

POPULATION BY AGE GROUP IN CASE STUDY CITY

Age Group (yrs)	Number of Persons	Percent of Total
0 to 4	25,000	14.2
5 to 9	26,000	14.8
10 to 14	17,000	9.7
15 to 19	12,000	6.8
20 to 29	24,000	13.7
30 to 44	38,000	21.8
45 to 64	26,000	14.9
65 to 74	5,000	2.9
75 and over	2,000	1.2
Total	175,000	100.00

Source: Local 1965 survey.

TABLE 3

LAND USE IN CASE STUDY CITY

Land Use	Acres	Percent of Total Area	Percent of Developed Land
Residential	11,000	49.5	67.7
Commerical	800	3.6	4.9
Industrial	3,000	13.5	18.5
Public and semi-public	1,300	5.8	8.0
Recreation	140	0.6	0.9
Total developed	16,240	73.0	
Unknown, extractive vacant, and agricultural	6,000	27.0	
Total	22,240		

Source: Local 1965 survey.

TABLE 4

TRANSIT SERVICE AND RIDERSHIP

Bus Route	Peak-Hour Headways (min)	Normal Headways (min)	Hours of Operation	Days of Operation	Basic Fare[a] (cents)	Average Weekday Ridership
1	10	30	6:40 a.m. to 6:50 p.m.	Monday through Saturday	30	2,000
2	24	40	5:00 a.m. to 11:50 p.m.	Monday through Saturday	30	3,300
3	60	60	7:00 a.m. to 8:00 p.m.	Monday through Saturday	30	165
4	60	60	6:00 a.m. to 7:10 p.m.	Monday through Saturday	30	1,150
5	60	60	5:25 a.m. to 7:30 p.m.	Monday through Saturday	35	875
6	30	40	6:00 a.m. to 6:00 p.m.	Monday through Friday	25	300

Source: Local published schedules, 1969.

[a]Senior citizens, 10 cents.

The city has a nonpartisan government. An analysis of bond elections, the allocation of funds in municipal budgets, and general policies reflected in capital improvement programs indicate that the community generally concerns itself with adequate police and fire protection, flood control, education, taxes, and low density residential zonings. Transportation, public or private, has not been an issue. Insofar as the social-political response to the possible implementation of a D-J system will be important, this political posture and history become meaningful.

CASE STUDY AREA TRIP-MAKING CHARACTERISTICS

In the design of the D-J system for the case study city, it became necessary to identify who is making what kinds of trips, where in the spatial arrangement of land use activities the trip-makers begin and end their various types of trips, and what the characteristics are of the trips in terms of mode of transportation used, length, and time of day the trips are made. Specifically, it became important to know which, of all the trips made by the residents of the case study community, were trips that might be served by D-J. Second, it was imperative to obtain an estimate of what percentage of these "eligible" trips might be diverted from the mode currently used to make the trip. An eligible trip was defined as a trip that began and ended in the community (internal trip) and that either began or ended at home. All trips associated with school (in a school bus or school car pool) were excluded. In view of the importance of peak-hour demand in the design of a transportation system, it also became necessary to know the temporal distribution of the trips. The data relative to all of the eligible trips were acquired from 3 major sources: origin-destination information from a 1965 survey, land use surveys conducted as part of this study, and a ridership estimation survey conducted for the study team by a professional market research firm. (The latter survey will be discussed under the consideration of ridership estimation.)

A total of 406,000 person trips per day of all types were made by the residents of the case study community as reported in 1965. Of these, 97 percent were made by automobile. Only 175,000 of the 406,000 trips could be considered eligible for the D-J system. (How many of these would be theoretically diverted to D-J was a problem to be solved later in the study.) The average trip length for all types of internal home-based trips was 11.1 minutes (Table 5). Forty-seven percent of the internal home-based trips were for shopping and personal business purposes. Ninety percent of all eligible trips made in the community were made by automobile. The hourly distribution of the eligible trips is shown in Figure 2.

It was necessary to identify nonresidential activities in the land use pattern of the community in order to estimate their potential as trip generators. Each of the identified nonresidential activities or potential destinations was given an "attraction index" that measured the probability of attracting trips to a given locale. The assignment process provided a mechanism by which estimates of ridership on the D-J system could be applied to the trip-making behavior of the case study area residents. These assignments and their consequent demands (trip requests) were later modified in terms of the results of the ridership estimation survey (described later) in order to determine the actual number of demands as a function of time of day and specific destinations.

TABLE 5

AVERAGE LENGTH OF HOME-BASED TRIPS BY PURPOSE

Purpose	Length (min)	
	All Trips	Eligible Internal Trips
Work	20.7	13.7
Personal business	13.1	9.1
Social-recreation and eat meal	15.6	10.1
Shopping	11.4	9.0
School	16.6	15.8
All trips	15.6	11.1

Source: Local 1965 survey.

DESIGN OF THE BASELINE D-J SYSTEM

In a competitive consumer-oriented market, user satisfaction is one of the most important considerations in achieving system success. In the past, public transportation system planners, designers, and operators have found it difficult to satisfy consumer requirements when confronted with the competition of the private automobile. If new systems like the D-J are to be successful, they must be designed to provide service

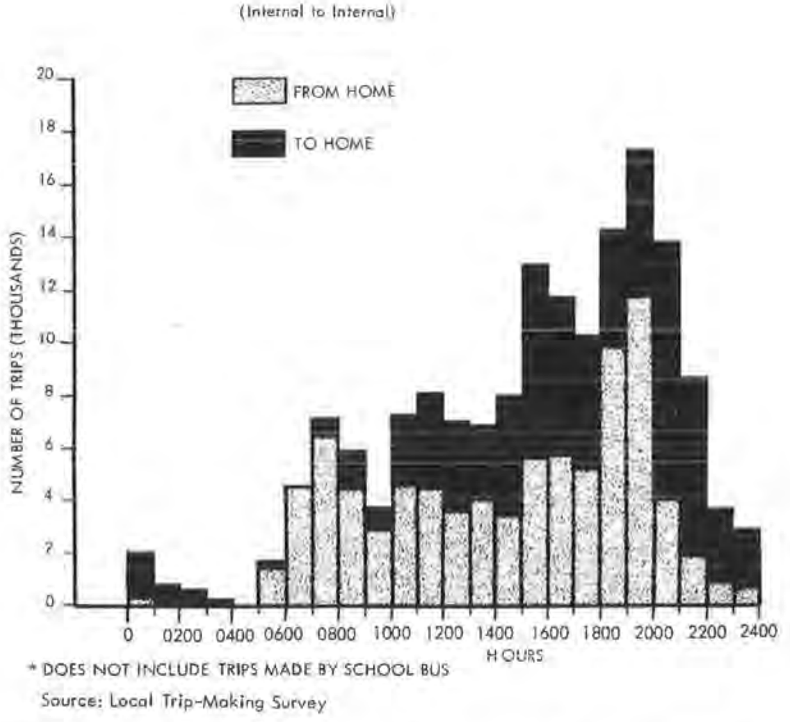


Figure 2. Hourly distribution of all eligible internal daily trips made in 1965.

and environments that are attractive and competitive within the transportation consumer market. In order to meet this need in transportation system design, a series of attitudinal surveys was developed and administered to about 1,600 residents of the case study area community. The surveys were conducted by a professional and thoroughly experienced market research firm under contract to the investigators.

The market research study sought to achieve 4 specific objectives:

1. To gather information from potential users of the D-J system about their relative preferences for specific system characteristics and specific design solutions being considered for incorporation into the D-J system;
2. To classify the information obtained in terms of the total population sampled and of 8 market subgroups and to analyze these differences;
3. To identify the relative values of various trade-offs and their importance to the potential D-J users; and
4. To draw specific conclusions about the design of the D-J system from the user's point of view.

The methodology employed in the surveys is derived from the field of experimental psychology. Specifically the method evolved from the branch of experimental psychology called psychophysics (2, 10, 12, 13, 16). The 2 methods employed were those of paired comparisons and semantic scaling. The former was used to establish a scale of preferences for a set of transportation system design characteristics, and the latter was used to determine the "strength" of preferences for particular design solution alternatives to be implemented in the D-J system.

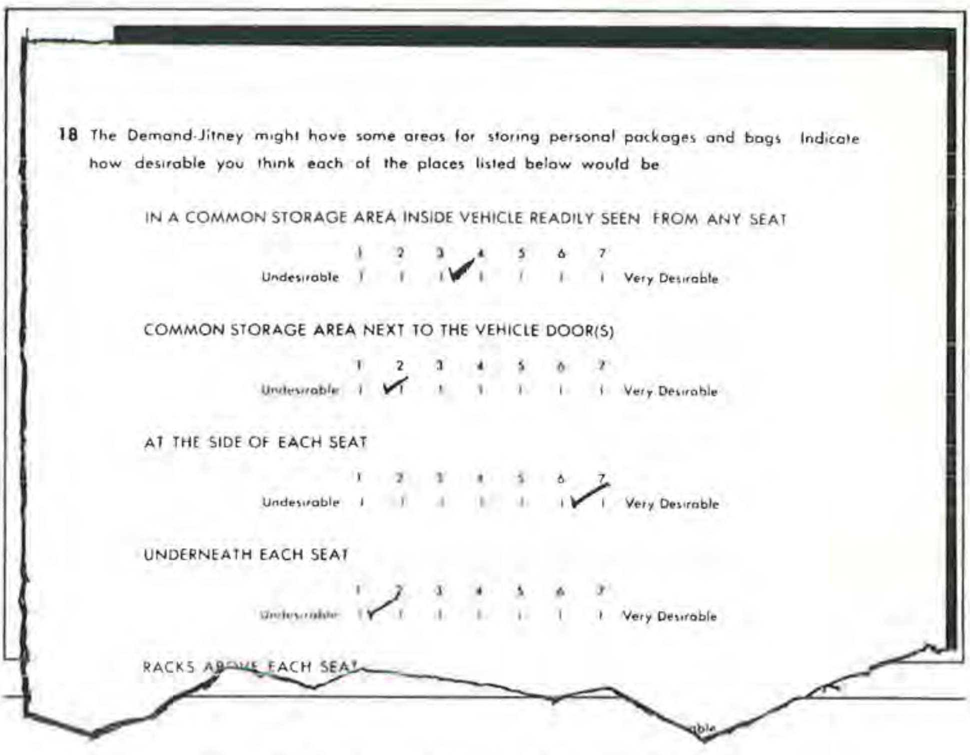
In the paired comparisons technique, each item of the total series is presented to the respondent paired with each other item at least once (e.g., items A, B, and C are presented as A and B, A and C, and B and C). One item of each pair must be selected in each case. Preference is determined for each item relative to each other item. The following items were used in this study:

1. Shorter time spent traveling in the vehicle;
2. Shorter time spent waiting to be picked up;
3. Arriving at your destination when you planned to;
4. Ability to adjust the amount of light, air, heat, and sound around you in the vehicle;
5. More space for storing your packages while traveling;
6. Stylish vehicle exterior;
7. Freedom to turn, tilt, or make other adjustments to your seat;
8. Availability of coffee, newspapers, and magazines in the vehicle;
9. Small variation in travel time from one day to the next;
10. More phones available in public places used to call for service;
11. More protection from the weather at public pickup points;
12. More chance of riding in privacy;
13. More chance of meeting people in the vehicle;
14. More chance of being able to arrange ahead of time to meet and sit with someone you know;
15. More chance of rearranging the seats inside the vehicle to make talking with others easier;
16. Lower fare for passengers;
17. Making a trip without changing vehicles;
18. Less time spent walking to a pickup point;
19. Being able to select the time when you will be picked up;
20. Longer hours of available service;
21. Vehicle whose size and appearance do not detract from the character of the neighborhood through which it passes;
22. Calling for service without being delayed;
23. Being able to talk to, and ask questions of, systems representatives when desired;
24. Easier entry and exit from the vehicle;

25. Room for accommodating baby carriages, strollers, and wheelchairs in the vehicle;
26. Assurance of getting a seat;
27. Less chance of meeting with people who may make you feel insecure or uncomfortable;
28. More room between you and others in the vehicle;
29. Being able to take a direct route, with fewer turns and detours;
30. Being able to take rides that are pleasant or scenic;
31. More chance of riding with different kinds of people; and
32. Convenient method of paying your fare.

The semantic scaling technique presented specific alternatives (in this case, design solutions for system design). Each solution was rated on a numerical scale where one end of the scale was the negative extreme (dislike very much) and the other end of the scale represented the positive extreme (like very much). The D-J design solutions were rated on a 7-point scale where 1 was the negative extreme. (A sample questionnaire page is shown in Figure 3.)

The 2 questionnaires were implemented by means of home interviews. Surveys were conducted with the residents of the case study city. The sample size was 1,600 households. A modified probability procedure was used to select the sample. One-half of the sample responded to the paired comparisons questionnaire, while the other half responded to the semantic scale questionnaire. The questionnaires were designed to be self-administered by the respondent with the interviewer administering the introductory sections and helping the respondent where necessary on the self-administered portion. The 8 market groups that served as the basis for the detailed analysis (over and above the total sample) were low income households (less than $5,000 yearly income); the elderly (more than 60 years of age); nondrivers (no valid driver's license);


18 The Demand-Jitney might have some areas for storing personal packages and bags. Indicate how desirable you think each of the places listed below would be

IN A COMMON STORAGE AREA INSIDE VEHICLE READILY SEEN FROM ANY SEAT

1 2 3 4 5 6 7
Undesirable | | | | | | | | Very Desirable

COMMON STORAGE AREA NEXT TO THE VEHICLE DOOR(S)

1 2 3 4 5 6 7
Undesirable | | | | | | | | Very Desirable

AT THE SIDE OF EACH SEAT

1 2 3 4 5 6 7
Undesirable | | | | | | | | Very Desirable

UNDERNEATH EACH SEAT

1 2 3 4 5 6 7
Undesirable | | | | | | | | Very Desirable

RACKS ABOVE EACH SEAT

Figure 3. Sample question of design solution questionnaire.

the young (under 20 years of age); housewives (females not employed); husband and wife both employed; multicar households (more than one car available); and one-car households (no second car in household). Data for no-car households were not analyzed separately because of the small sample size.

In addition to these basic subgroups, survey data were also examined in terms of 3 different trip purposes: work trips, shopping trips, and school-related trips. Scales were developed relating the responses of each of the subgroups of concern. Correlation coefficients among the various characteristics were also calculated.

The scale representing the responses to the paired comparisons questionnaire for the total sample is shown in Figure 4.

Scale Analysis: Vehicle

If the system is conceived of as serving the population as a whole and not any particular subgroup, the vehicle design should provide for entry-exit configurations that are easier to use than those generally found on current buses. The vehicle should be air conditioned, provide more personal space per passenger than is common in today's transit vehicles, provide for personally controlled microclimate, and have convenient parcel storage areas close to each seat. Less emphasis would be placed on providing for privacy or for a variety of social group seating possibilities or on providing adjustable and movable seats. Vehicle styling, although still an integral component of design, would have to be considered as being shaped by, rather than shaping, the more important requirements mentioned earlier. The exterior design would have to have a clearly understandable, variable identification system so that a specific vehicle could be recognized by passengers. A review of current commercially produced domestic and foreign vans and small buses indicates that a vehicle meeting these needs is not available.

Scale Analysis: Service and Convenience

Insofar as D-J system service characteristics are concerned, arriving at a destination when planned, having a seat during the trip, and not having to transfer during a trip are the 3 most important characteristics as expressed by the survey respondents.

The hours of system operation that seem most desired by the potential users are 9 a.m. to 7 p.m. As might be expected, the respondents strongly prefer being picked up at their doors as opposed to such places as nearest major street or nearest corner. The most accepted waiting times would be between 5 and 20 minutes. Respondents indicated that they would not care to arrive at their destinations more than about 10 minutes earlier than the expected arrival time. The respondents tended to be concerned with what the absolute amount of extra travel time involved in using the D-J system would be rather than how many times longer the trip would take if made by the D-J system rather than by automobile. The demand estimate survey (discussed later) reveals that 2:1 (D-J:automobile) is the most acceptable ratio. On-board music and beverage availability would not have a significant influence on D-J ridership. The fare payment method preferred was the traditional one of paying with cash and receiving change. The most desirable fare structures were a fixed basic fare, followed closely in preference by a fare based on distance traveled. The data indicate that these are 2 different points of view and not that both are equally preferred by respondents. Examination of the survey data shows that the fare that respondents would be willing to pay is between 40 and 50 cents. The respondents strongly favor discounts to students traveling to and from school, retirees, handicapped, and children accompanied by an adult.

Scale Analysis: Summary

Those D-J system characteristics that may be classified as dealing with levels of service (e.g., arriving when planned) were most important to the potential system users. Characteristics associated with vehicle design were rated as the least important group. Stylish vehicle exterior was rated the lowest of any of the 32 items investigated. Items relating to convenience formed a middle group in importance (Fig. 5).

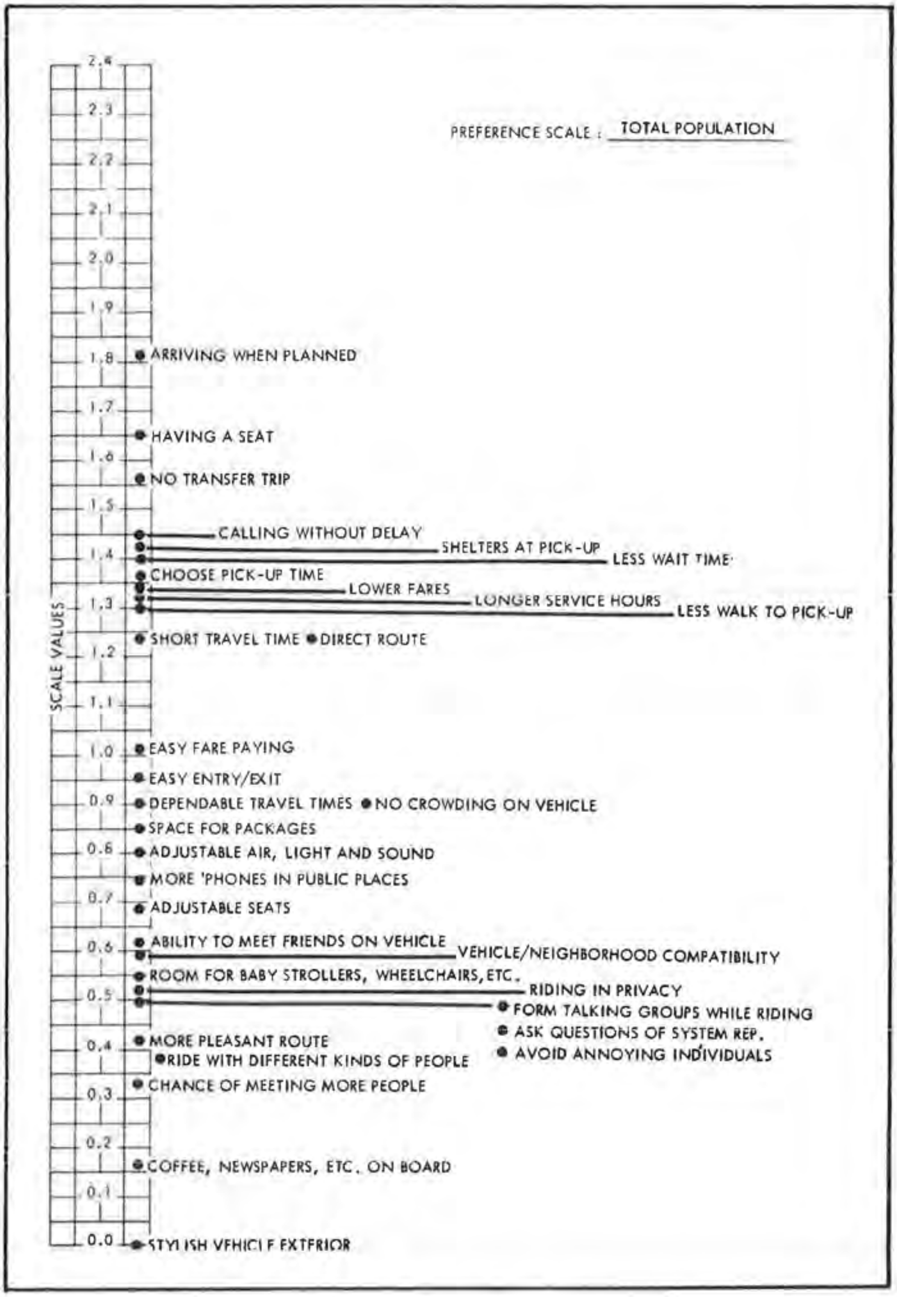


Figure 4. Scaling of paired comparison preference of total sample regarding D-J system characteristics.

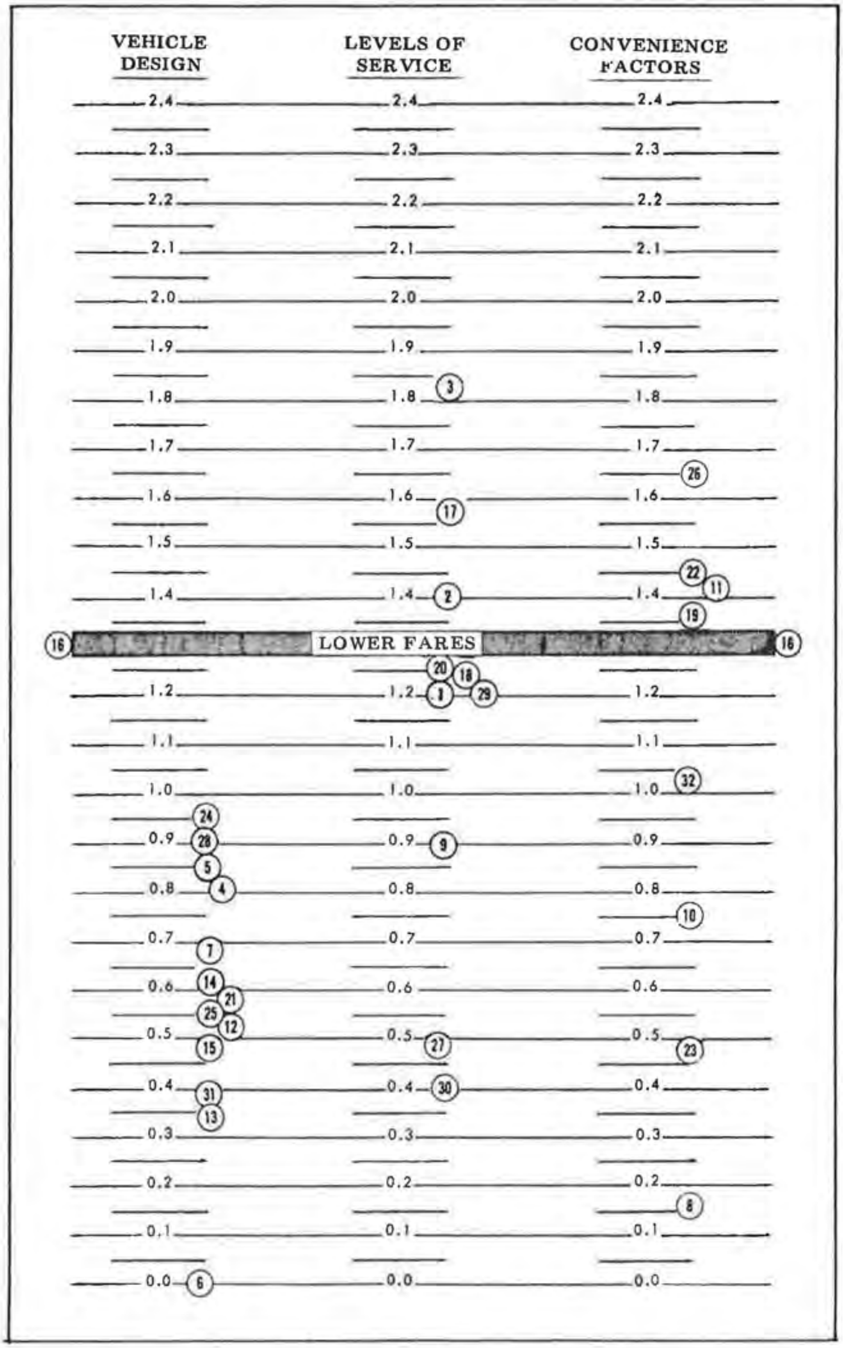


Figure 5. Scaling of D-J system characteristics by main groupings based on total sample.

This summary is pertinent to the sample population as a whole. The data were also analyzed in terms of various user groups as noted earlier. Analysis of the subgroups revealed that only 3 of the 8 groups showed major variations from the preferences exhibited by the total sample. The elderly and the low-income respondents attached a greater importance to lower fare than the total population. The elderly were more concerned with convenience in waiting for the vehicle and less concerned with travel and wait time. The low-income group preferred protection from weather over all other characteristics considered. The young, although less concerned with lower fares, demonstrated a higher preference for on-board conveniences such as music and the ability to talk with fellow passengers.

The D-J system characteristics served as the basis for the development of the base-line system that was later presented to respondents in a third survey (discussed later). This survey was designed to provide information regarding the percentage of trips currently being made in the case study city that might be diverted to the D-J system. This base-line system also served as the foundation for the detailed system description used in performing the financial analysis of the D-J system.

COMPUTER SIMULATION STUDIES

The purpose of the computer simulation study of the D-J system was to determine how the system would function under a variety of given parameters and operating strategies. The information derived from the simulation was essential for system performance evaluation and system scaling prior to an actual operating demonstration. Some of the outputs of the simulation were used in the development of the system definition and system cost modeling.

The computer simulation program includes an objective function that makes it possible to ascribe various relative values to a number of community characteristics and customer-oriented service characteristics in order to evaluate their effect on system operation. The community characteristics that were varied were the area (square miles) within the community that would be served by the D-J system, the estimate of the ride demands per hour, and the assumed average velocity (mph) attained by the D-J vehicle. The customer-oriented service characteristics used as simulation inputs included the guaranteed maximum time a customer would have to wait to be picked up after placing a ride request and the guaranteed maximum riding time to the desired destination (D-J trip time to automobile trip time ratio).

The simulation output data were available in 2 forms: computer printouts and graphic (dynamic) displays. Among the data available as permanent record (printout) were the following: number of vehicles required to meet the customer service guarantee at given demand levels and assumed vehicle velocities, total system mileage accumulated for the period of the simulation, mileage accumulated by each vehicle in the system during the simulation, average trip length, average system speed (as distinct from the input average speed), average customer waiting time, average actual trip time, minimum and maximum waiting times for the list of demands during the simulation, and minimum and maximum trip times for the list of trips made during the simulation. The simulation may be stopped at any time during its operation. A "bus table" printout may then be requested. The table gives the number of ride requests that have been assigned to each vehicle in the system as well as the number of pickups and deliveries that have been made by each vehicle in the system up to the time the simulation was interrupted.

The simulation program is written for a computer that supports graphic display hardware. This hardware is in the form of a cathode ray tube (CRT) with a display area of approximately 144 sq in. Inputs to the simulation and intermediate data output requests are made with a light pen to the CRT or an input keyboard or both. During the simulation, the following graphic displays may be called for: the route or tour of any one of the vehicles as it progresses through the time span of the simulation (any vehicle in the system may be selected for display); the assigned tours of all of the vehicles; and the location of all of the vehicles.

A network model of the case study community streets and roadways has been developed. It includes approximately 10,000 links and 4,000 nodes. This network model will, in subsequent work, replace the rectilinear x-y coordinate method of determining point-to-point distances in the case study city computer simulation.

RIDERSHIP ESTIMATION

Critical to the analysis of any proposed transportation system is an estimate of the number of people who will use the system (ridership). In the evaluation of the D-J system, 2 classes of information pertaining to ridership were sought from over 1,000 residents of the case study city: qualitative and quantitative. The first of these was to aid in the design of the quantitative questionnaire and to answer questions such as the following: What do residents of the city view as the most important advantages and disadvantages of the system? With reference to both those who would and those who would not use the system, what problems might be anticipated if the D-J system were to be implemented in the community at this time? What communications methods would be most desirable to convince the public to try the system? Toward what market group ought the system to be oriented for maximum citizen benefit? Who ought to own and operate the system? What modifications should be made to the base-line system (as described to respondents) in order to make the system more attractive to potential users?

Answers to questions such as these were obtained through the use of the traditional, well-accepted market research technique of in-depth group interviews. These interviews, as well as the home interviews used to obtain quantitative estimates of ridership, were conducted by the same market research firm that had previously conducted the attitude survey pertinent to preferences for transportation system characteristics and the survey dealing with specific system design alternatives. As in the previous surveys, the project sponsor was not identified, and members of the study team were intimately involved in the development of the survey instruments and the training of interviewers.

In both surveys (qualitative and quantitative) the respondents, as well as the interviewers, became thoroughly familiar with the various significant aspects of the D-J system as projected for possible use in the case study community. The qualitative interviews were conducted with 5 specific market groups: men who live and work within the community, women who live and work within the community, housewives in the middle-middle socioeconomic class, men and women from households that do not own an automobile, and teen-agers between the ages of 13 and 16 years.

In-Depth Interview Survey

The following are some of the essential findings of the in-depth group interviews:

1. The most important feature of the D-J system is its door-to-door service;
2. The system is viewed as being able to provide occasional relief from the necessity of doing one's own driving;
3. The system has potential for providing increased mobility and independence for members of the community; and
4. The system design for providing presumably reliable information regarding waiting and travel times is a significant enhancement for a public transportation system.

The in-depth interviews also revealed some relatively negative attitudes toward the D-J system. Among them were the following:

1. The concept of public transportation is contrary to the life style of freedom and flexibility of travel;
2. The system is relatively inappropriate for the short-distance and multiple-stop trips that are a significant portion of the trips typically made by the community residents;
3. Teen-agers feel that there is a certain social stigma associated with their use of public transportation systems for social-recreation trips;

4. The immediate out-of-pocket cost of using the D-J is generally disproportionate to the perceived out-of-pocket cost of automobile travel; and
5. Some concern was expressed that the implementation of the system might ultimately raise taxes in order to support the D-J system.

Home Interview Survey

The qualitative interview technique employed to gather subjective information about D-J potential uses and acceptance also served a second purpose; it facilitated the design of the interviewer-administered questionnaire that was used in the second, and major, data gathering effort for ridership estimation. The point of departure for the group sessions was the questionnaire to be used in the home interviews. Thus, the group sessions served as a pretest for the questionnaire and provided insights into its construction and generated guidelines for its modification prior to use in the field.

Because the measurement of user preferences for the various D-J system characteristics also involved home interviews in the case study city, a procedure to be followed for the quantitative aspects of the ridership estimation, it was important to ensure that no overlap existed between the 2 samples. No individual was to be included in more than one of the attitude surveys. The sample selection technique for the second part of the ridership estimation survey was similar to that used for the other surveys in order to maximize survey compatibility. A quota system was used in determining the sample in order to ensure minimal sample sizes for each type of individual who might be expected to exhibit major differences in attitude toward the use of the D-J system. The quotas and the types of persons are shown in Figure 6.

The questionnaire used for the home interviews for ridership estimation was of the "branch and bounds" type. The interview would begin with a certain set of conditions describing fare rate, for example, and then progress (branch out) according to the response given. The interview would continue until some designated cutoff response (again, this might be a fare level) was given, i. e., a bound was reached, and then the interview was to be shifted to another branch or, depending on the situation, terminated. The questionnaire was interviewer-administered. Some visual aids (drawings and charts) were used to ensure that the respondents understood what was required of them or to serve as memory devices during the 30- to 90-minute interview. These interviews, like those in the previous surveys, were also conducted by the same market research firm.

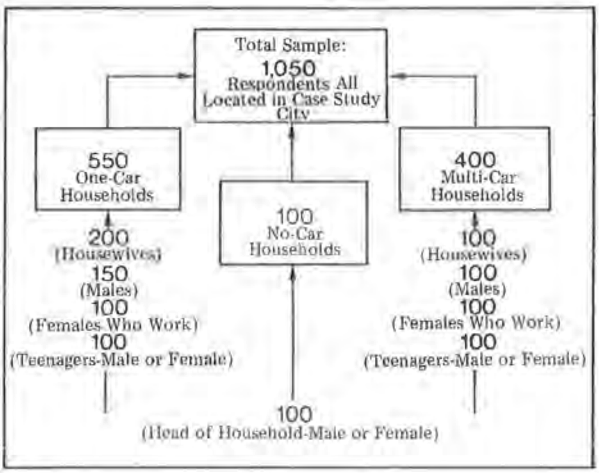


Figure 6. Types of persons interviewed in the demand estimation home interview survey.

The base-line D-J system that was developed from the first 2 surveys was presented to the respondents as the D-J for implementation in the surveyed city. The basic parameters that were varied (tested for influence on ridership) were fare charged, maximum waiting time between calling for service and arrival of the vehicle, and ratio of travel time via D-J to travel time for the same trip by private automobile (D-J:automobile ratio). The limits for these parameters were established on the basis of preliminary runs of the system simulation model and earlier surveys. The matrix of the variables resulted in 16 different specific systems. These are given in Table 6.

The ridership estimates were not obtained by simply applying the percentage of trips diverted to D-J directly to the total number of trips being made within the case study city. In determining system equipment requirements and costs, one must know how many trips are being made on an hour-by-hour basis. This hourly travel volume, by trip type, had been established previously for the case study community for the trips actually being made. The information for the development of these actual time-trip profiles was taken from a regional survey. The percentage of trips diverted to D-J for the various D-J systems and by trip types was applied to these real-trip distributions. This resulted in hour-by-hour profiles of the estimated ridership for the system.

TABLE 6

PARAMETERS USED IN RIDERSHIP ESTIMATION SURVEY

System		One-Way Fare (dollars)	Time Waiting (min)	Ratio of D-J Trip Time to Automobile Time
Group	Number			
A	1	0.50	15	2:1
B	2	0.50	25	2:1
C	3	0.50	15	3:1
D	4	0.50	25	3:1
A	5	0.75	15	2:1
B	6	0.75	25	2:1
C	7	0.75	15	3:1
D	8	0.75	25	3:1
A	9	1.00	15	2:1
B	10	1.00	25	2:1
C	11	1.00	15	3:1
D	12	1.00	25	3:1
A	13	1.25	15	2:1
B	14	1.25	25	2:1
C	15	1.25	15	3:1
D	16	1.25	25	3:1

The basic diversion to D-J (modal split) for the various parameters of fare, waiting time, and D-J:automobile travel time ratios is shown in Figure 7. An illustration of total eligible trips and diversion to D-J by time of day for System 1 is shown in Figure 8.

The estimated ridership for D-J varies considerably depending on the specific system, trip purposes, and the demographic group involved. Figure 7 and data given in Table 7 show that, in terms of the population in general, the diversion from other modes of travel to the D-J system ranged from a high of approximately 15 percent to a low of approximately 4 percent. The highest ridership, as might be expected, would be for System 1, referred to in Table 7 as "most favored" from the standpoint of the potential

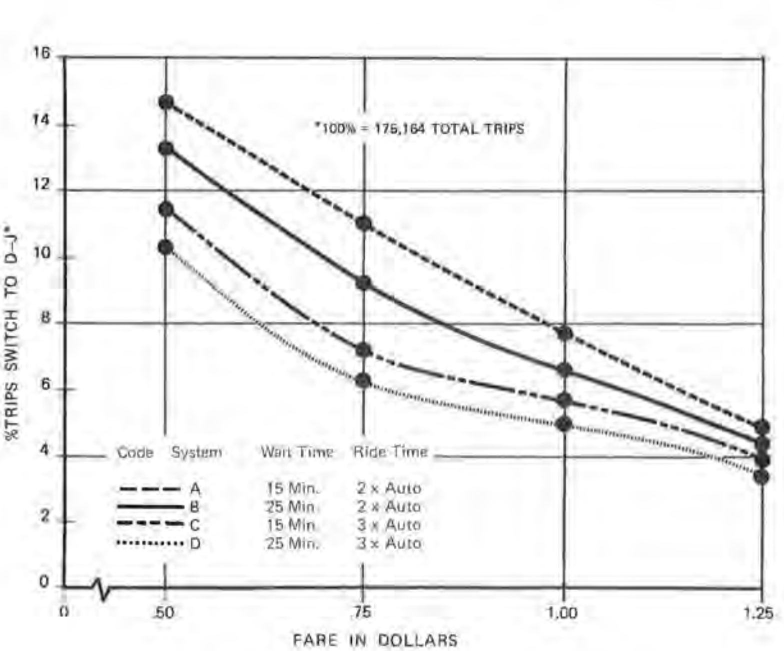


Figure 7. Basic diversion to D-J based on fare.

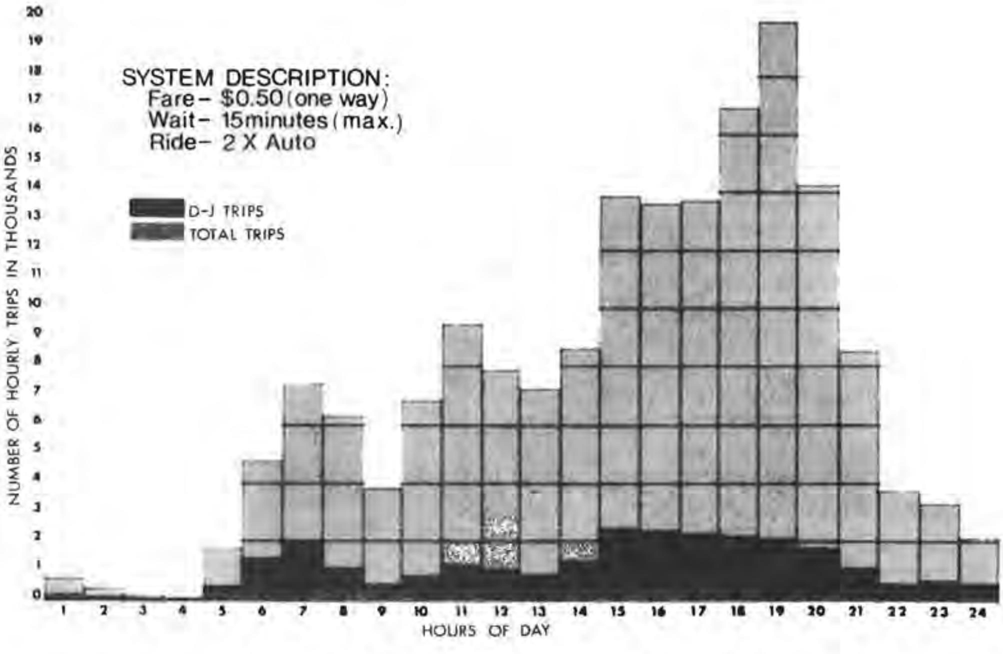


Figure 8. Hour-by-hour diversion to D-J for system 1.

TABLE 7

COMPARISON OF 2 D-J SYSTEMS IN CASE STUDY CITY

System Favored by Potential D-J Users	Potential D-J Trips Per Day	Percent Switched to D-J	Number of D-J Trips Per Day	Peak-Hour D-J Demand	Number of Vehicles Required	Computer Required
No. 1—Most favored 50-cent fare 15-min maximum wait 2 × automobile travel time	175,164	14.9	26,042	2,350	178	Yes
No. 16—Least favored $1.25 fare 25-min maximum wait 3 × automobile travel time	175,164	3.6	6,236	594	52	Yes

patrons. Similarly, logic holds that the lowest ridership would be expected for the system (No. 16 in Table 6) that offers the least service at the highest price. However, all of the subgroups analyzed indicated at least 10 percent diversion to the D-J system at a fare rate of 50 cents per one-way ride.

In general, the diversion to D-J was for shopping and work trips as opposed to social-recreation and personal business trips. At the 50-cent fare rate, these types of trips could compete with current automobile usage.

The diversion to D-J varied considerably among the various market subgroups and trip types for those systems that charged $1.25 one-way fare. Housewives and teenagers in one-car households indicated substantial use of the D-J system for shopping trips. Secondary family workers (e.g., working wives) indicated use of the D-J for their work trips, while members of no-car households indicated use of D-J for shopping and personal business trips.

It is postulated, on the basis of the data from the quantitative ridership estimate survey, that the demand shown for those systems charging \$1.25 fare is directly related to the availability of an automobile. Those persons who do not have access to an automobile or cannot drive (no valid driver's license or infirmity) would use the D-J for the most essential types of trips that they make. At this level of fare (\$1.25) the D-J system would complement, rather than compete with or substitute for, the private automobile as a means of transportation.

RIDERSHIP ESTIMATION

The impact of the D-J system in the case study community may, on the basis of the survey data, be viewed as providing a competitive or at least a complementary mode of transportation relative to the private automobile. The usage (competition or complement) depends on the interaction between fare level and trip purpose.

It must be realized that the D-J system if implemented in the case study city would not solve a major transportation requirement simply because there is not a significant public transportation need in this community! It was stated earlier that this city was not an "ideal" community for the application of a D-J system precisely because there is no serious public transportation need in the community. This area, however, representative in terms of population density of more than 100 U. S. communities, would provide a better understanding of a potential product market. It is felt that significant ridership could evolve in a community that did, in fact, have a public transportation problem.

SYSTEM COST STUDY

Previous studies of demand-responsive transportation systems have not included system description and cost studies in sufficient detail to allow policy or marketing decisions. If a D-J system is to be implemented, an accurate financial analysis is crucial to decision-making. This study used the results of the ridership estimation analyses and a detailed system description to assess the financial feasibility of the D-J system as applied to the case study city. The financial feasibility of the system was evaluated in terms of revenues derived from the fare box only and from the standpoint of federal subsidy. (Estimates are based on 1970 dollars.)

The cost study was directed to attain 4 specific objectives: detailed definition of a D-J system structure, identifying all of the essential components required for its operation; development of a cost model that measures accurately system costs and is consistent with current and projected public transportation system costs; determination of the profitability of the described D-J system as it would be applied and responded to (ridership level) in the case study city; and assessment of the sensitivity of system costs to various parameters.

The cost model for the D-J system was developed in accordance with traditional economic procedures, but it was also specifically tailored to the demand-responsive transportation system concept. The model is applicable to areas other than the case study community with appropriate changes in certain input variables.

The components of the D-J system cost model are functions of several variables that include hourly demand (ridership), maximum specified waiting time between requesting service and being picked up, maximum specified D-J to automobile travel time ratio, and assumed average speed of the D-J vehicle. The model incorporates manual or computerized routing and scheduling procedures. Costs were estimated on the basis of specific itemized unit costs, amortization periods for capital items, and an interest rate of 10 percent.

The cost study was conducted in 4 phases (Fig. 9): (a) System definition or breaking down system components required for operation; (b) system scaling or determining how many of each component are required; (c) cost model development or establishing cost as a function of input variables; and (d) analysis or determining profitability for specific system and its sensitivity to wage rates, interest rates, and subsidies.

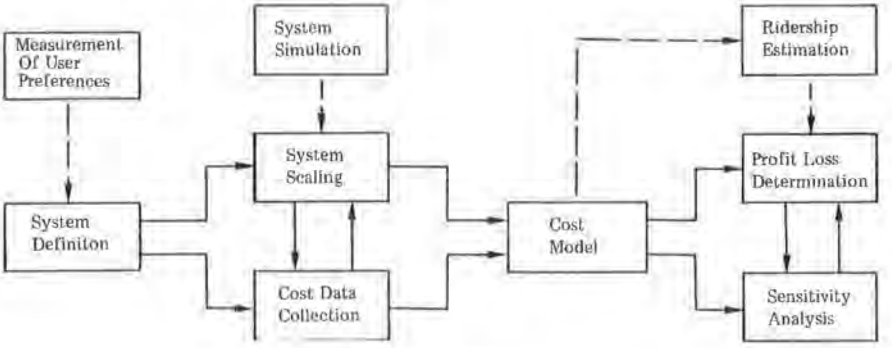


Figure 9. Cost study framework.

The cost estimates for the D-J system took into consideration the length of the operating day and the hourly distribution of ride requests (demand). The inefficiency a transportation system encounters as demand levels vary during an operating day was also considered.

Costs were expressed as a function of both peak demand and the demand for the specific hour in question. These demands were determined on the basis of the ridership estimation survey cited previously. Hourly demand and peak demand for systems 1 and 16 are given in Table 8.

TABLE 8

D-J RIDERSHIP ESTIMATION BY HOUR FOR 2 SYSTEMS

Hour[a]	Total Trips	System 1		System 16	
		D-J Trips	Percent of Total Trips to D-J	D-J Trips	Percent of Total Trips to D-J
1:00 a.m.	746	171	23.0	48	6.5
2:00	450	109	24.3	31	6.8
3:00	145	29	20.3	9	6.1
4:00	81	26	32.6	8	9.3
5:00	1,746	488	27.9	139	7.9
6:00	4,860	1,390	28.6	394	8.1
7:00	7,364	1,946	26.4	542	7.4
8:00	6,230	1,067	17.1	277	4.4
9:00	3,851	513	13.3	118	3.1
10:00	6,826	832	12.2	182	2.7
11:00	9,497	1,159	12.2	265	2.8
12:00	7,868	1,062	13.5	263	3.3
1:00 p.m.	7,238	868	12.0	177	2.4
2:00	8,645	1,238	14.3	281	3.2
3:00[b]	13,835	2,350	17.0	594	4.3
4:00	13,600	2,290	16.8	581	4.3
5:00	13,796	2,180	15.8	535	3.9
6:00	16,929	2,091	12.4	457	2.7
7:00	19,877	2,163	10.9	462	2.3
8:00	14,195	1,650	11.6	334	2.4
9:00	8,399	1,019	12.1	209	2.5
10:00	378	449	12.0	103	2.8
11:00	3,205	508	15.8	113	3.5
12:00	2,033	440	21.8	116	5.7
Total	175,164	26,042	14.9	6,236	3.6

[a]Ridership estimates based on 24-hour day; cost figures based on 16-hour operation only for hours between 6:00 a.m. and 10:00 p.m.

[b]Peak demand during this hour.

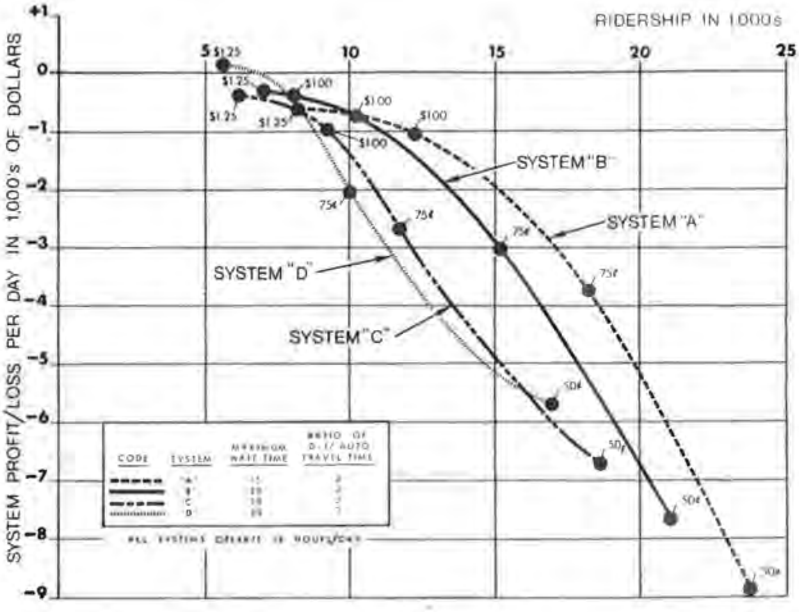


Figure 10. Profit and loss versus ridership, fare-box revenue.

The following are some of the general findings from the ridership estimation and the cost analyses (Fig. 10):

1. Systems 1 through 15 were found to show an operating dollar loss;
2. Manual assignment of vehicles, as opposed to computer assignment (Fig. 11), was found to be economically superior only for demands of less than 225 per hour (all systems investigated exceeded this demand level); and
3. In order for the D-J system to break even financially, the actual ridership on the system with \$1.25 fare, 25 minutes maximum wait, and a trip time 3 times that of the automobile would have to be 93 percent of the estimated ridership (Fig. 12).

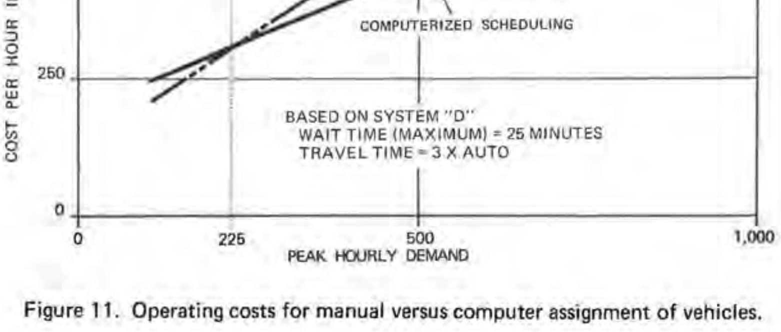


Figure 11. Operating costs for manual versus computer assignment of vehicles.

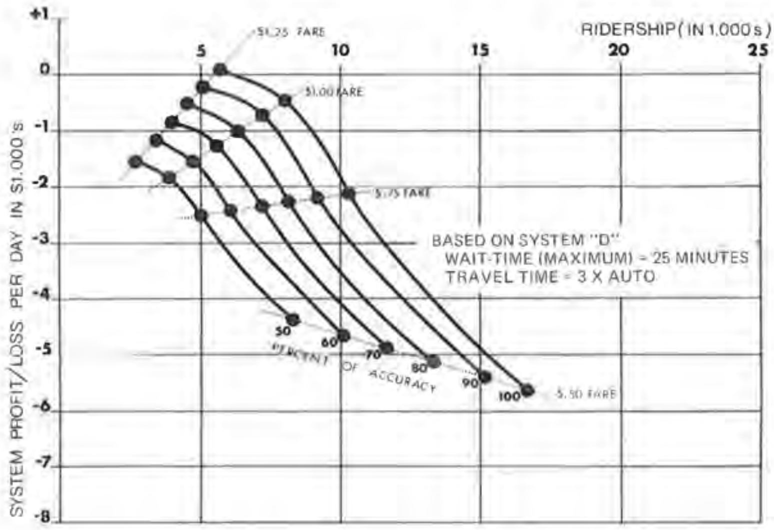


Figure 12. Influence of accuracy of ridership estimate on profit.

Financial Posture: Fare-Box Revenue

The system that would divert 15 percent of the trips being made to the D-J would produce a system loss of approximately $9,000 per 16-hour operating day (Fig. 10). On the other hand, the "worst" system described (4 percent diversion to D-J) could be implemented just above the financial break-even point. However, it is to be noted that the system that loses the most money serves about 24,000 riders during the 16-hour operating period. The system that barely breaks even serves only about 6,000 demands per 16-hour day. (These figures assume that the capital investment aspect of the sys-

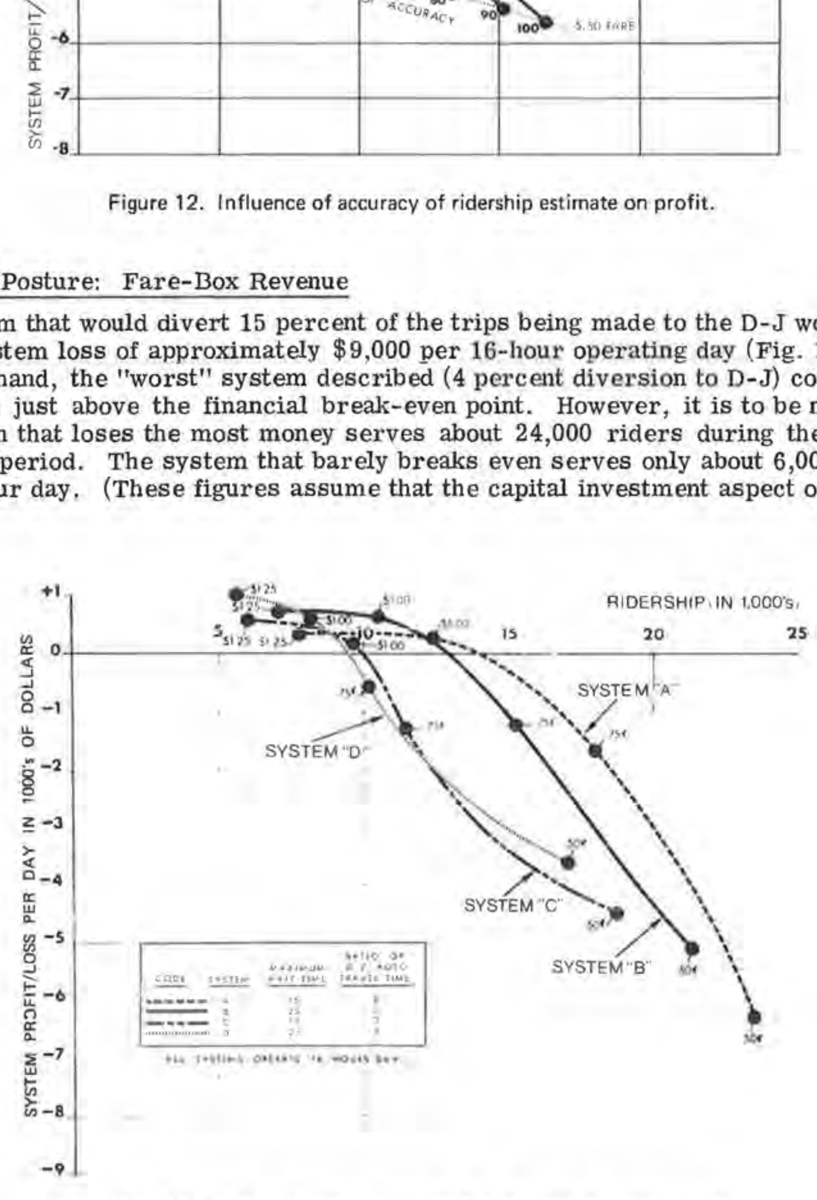


Figure 13. Profit and loss versus ridership, two-thirds capital grant.

tem has been geared to handle peak loads, while personnel allocation varies with hourly demand levels.)

Financial Posture: Fare Box Plus Subsidy

If one assumes that the system is instituted under a federal grant for capital investment, both systems 1 and 16 can be made profitable (Fig. 13). However, the fare of the 15 percent diversion system would have to be raised to just under \$1.00 per one-way ride (as opposed to the 50-cent fare). At the \$1.00 fare, the system could produce about \$500 per day but serve only about 12,000 demands per day. If the fare for this system were to remain at 50 cents, the loss would change from approximately \$9,000 to about \$6,500 per day. The 4 percent diversion system could, under a capital grant, produce about \$1,000 per day and still serve about 6,000 riders per day.

Financial Posture: Wages and Interest Rate

The D-J system is highly labor intensive. System cost is very sensitive to wage rate (Fig. 14). In terms of System 16 (self-supporting), reducing the wage rate 65 cents reduced the fare rate required for profitability from \$1.25 to less than \$1.00 and changed the ridership from 5,600 to 9,000 demands per day.

Changes in interest rate did not have a substantial effect on system cost (Fig. 15).

Financial Posture: Summary

In summary, it may be said that, insofar as implementation of the D-J system in the case study community is concerned, one configuration (System 16) would be marginally profitable. The application of federal capital assistance grants would make systems A, B, C, and D profitable, depending on the fare charged. The sensitivity of system costs to labor rates (all labor = 65 percent of total system cost) and the high wage scale in the case study area make the financial analysis of the D-J in this community a severe test of feasibility. The relatively low sensitivity of system cost to capital cost items permits freedom in system design without significantly affecting profit.

ANALYSIS OF POLITICAL ACCEPTANCE OF D-J

The implementation of a transportation system is not dependent solely on the technical feasibility of the system or its financial posture. In order to be a success the system must enjoy the support of a variety of social and political "actors," that is persons and groups significant in the social and political structure of the community.

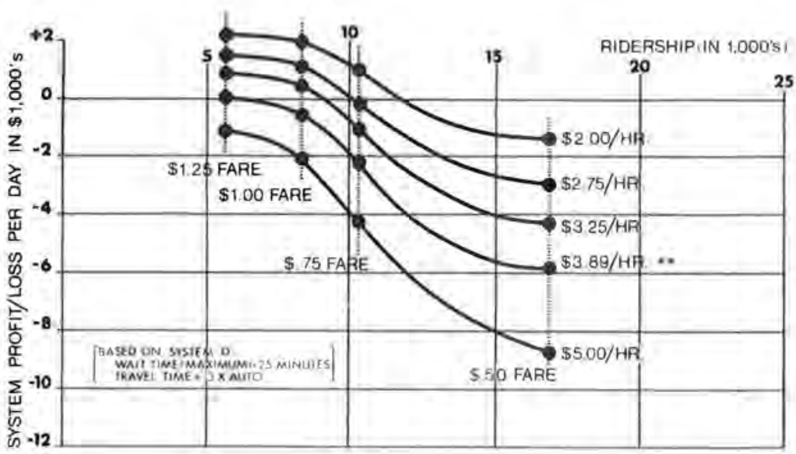


Figure 14. Profit and loss versus ridership, effect of wage rate.

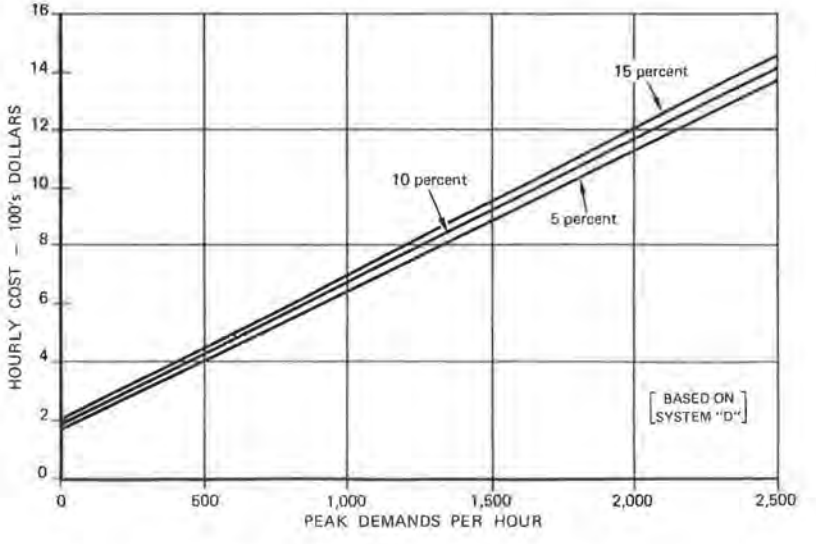


Figure 15. Influence of interest rate on hourly cost.

This support is particularly critical prior to, and at the time of, implementation because of the possibility of the need to float a bond issue or assess mileage taxes or do both and the granting of licenses and franchises for the operation of the system. The issue is further complicated by the question of who is to own and who is to operate the transit service. The actors generally involved in decision-making regarding transit services are shown in a generalized way in Figure 16.

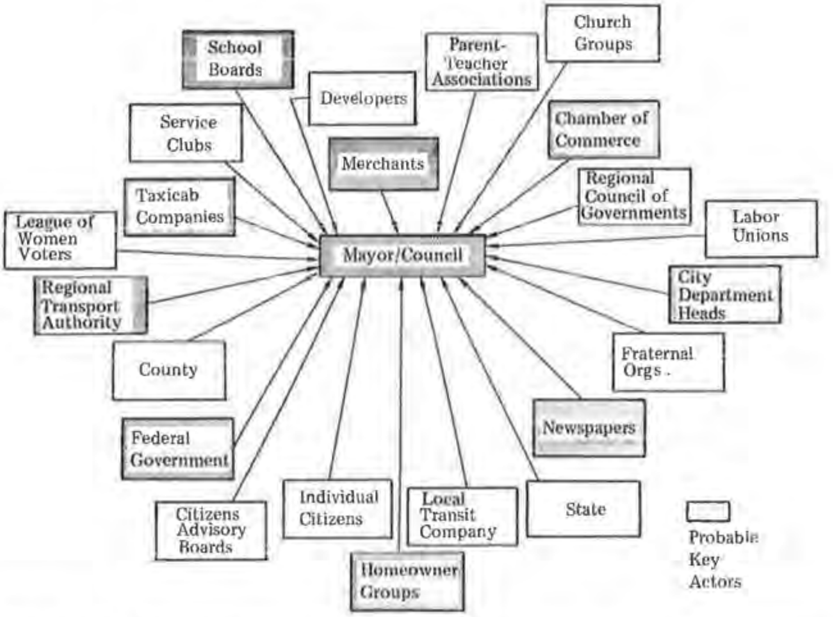


Figure 16. Principal groups involved in transportation system implementation decision-making process.

The purpose of the research into the social-political structure of the case study community was to (a) describe and analyze the relationships and factors that must be considered in designing systems for implementation within a political decision-making framework and (b) specifically analyze the probable political acceptance of the D-J system as proposed for introduction into the case study city.

Two conceptual models were developed and used to assist in the analysis of the probable political response to the D-J system concept in the case study city: a political response model and a people-resource-environment model. The former views the process of introducing a new urban transportation system into a community and that of trying to achieve political acceptance for it. The model defines the local political decision-making process. The second model is a component of the political response model. It describes the D-J system within a broader social, environmental, and organizational framework. The people-resource-environment model views the system as being used by people within an environmental context.

The data used in the development of the models and in the social-political evaluation of D-J were derived from the following sources: local land use study and interview data file acquired in 1965; case study community data files and published reports on land use, population, and transportation; federal and state guidelines and legislative records relating to public transportation system planning and funding; case study community municipal charters, organization charts, budgets, and annual reports; newspaper accounts of events and issues in the community for the previous 5-year period; interviews with selected individuals both within and outside of the case study community; analysis of attitudinal surveys of consumer preferences conducted as part of other aspects of the D-J system study; in-depth group interviews with selected groups from the case study community; ridership estimates for the D-J system made as an integral part of the overall D-J study; internal reports prepared as part of the overall D-J system study; and selected publications in the field of urban transportation planning, design, and evaluation.

The probable political responses to the implementation of a D-J system in the case study city can be viewed primarily in terms of alternatives to funding arrangements. A D-J system owned and operated privately could gain tentative political approval in the case study community, at least as far as the residents interviewed were concerned. (This is the form preferred by the respondents to the system design questionnaire.) Such a system, while admittedly providing few significant social benefits, would nevertheless require little from the city administration financially or administratively. The "private" system would initially appear innocuous politically.

However, the system is likely to affect the taxicab companies and bus routes (fixed schedule and route) in the community. Thus, it would appear that final political decisions about installation of D-J would have to be preceded by agreements made with the taxicab owners and the operators of the existing transit bus lines.

Funding the D-J system through federal grants obtained by the regional transportation authority could put the case study community into a position of conflict. The community would put few if any of its resources into the D-J system under such an arrangement, but control of the system would reside with the regional authority. This would create ideological as well as practical conflicts. Included among the problems raised would be issues such as fare rates, racial composition of employees, and program and service changes.

The likelihood of the regional group and the case study community coming together on the implementation of D-J is seen as not very promising. The regional group's priorities list (for effort and dollars) places improvement of local transit systems well near the bottom of the list.

A third alternative funding scheme would be to obtain federal grants through local city proposal and request. This posture is seen as an unlikely implementation method. The city would be required to contribute more than $2 million toward a project that is viewed as providing only marginal community benefits.

The D-J system (or any transportation system) in order to gain strong political acceptance must seek implementation in a community that has a definite, politically recognized need for a new public transportation service. The analysis of political issues and organization of the case study city does not indicate a significant need for the system nor a potential for significant political acceptance.

GENERAL DISCUSSION

Technically, the D-J system could be implemented in the case study city. A system with a 50-cent one-way fare, 15-minute maximum waiting time, and a travel time no longer than twice that required to make the trip by automobile would divert to the D-J system about 15 percent of the approximate 175,000 daily, weekday trips made that begin and end in the community. This would result in a peak-hour ride demand of over 2,000 requests and require 178 vehicles if the service guarantees of waiting and travel times are to be met. Routing and scheduling of vehicles would have to be accomplished by computer, and electronic means have to be used to communicate vehicle assignments.

The interpretation of the fiscal picture must be done with the realization that the computations on which the projections are based are generally the worst conditions. For example, the ridership estimates are based on a community where 90 percent of the trips from which D-J could draw (eligible trips) are currently being made by automobile. In a city where automobile travel is a lesser percentage of the trips being made, the trip diversion to D-J, and thus the fiscal picture, could change substantially.

The wage rates used in this study reflect perhaps the highest in the country.

Another factor that could change the fiscal posture of the system is interest rate. Ten percent was used in this analysis. It is not inconceivable that a community desiring to implement a D-J system could obtain much lower interest rates, particularly on a government loan.

All of this discussion has assumed that one system strategy is elected for installation in a given city. In the case study reported here, a single set of parameters was assumed to be universal for all operating hours and days. Such need not be the situation. It would be possible to vary the operating parameters during the various hours of the day or days of the week. All 3 basic factors (fare, waiting time, and trip time) could be modulated in a manner to enhance the financial status, and the system could be operated, by dynamic changes, to be maximally cost effective at all times of the day and each day of the week. The fares, maximum waiting times, and riding times could be optimized on the basis of hourly demand changes rather than held at fixed levels for all operating hours for each day of the week.

The D-J system has greater potential than that suggested by the rigorous analysis reported here based on one specific case study city.

ACKNOWLEDGMENTS

This summary report is the culmination of the effort of many members of the Transportation Research Department of the General Motors Research Laboratories. The study was planned and organized under the project management of Eugene T. Canty, who guided the work during the major portion of the model building and data gathering phases. Later project management was assigned to Herbert J. Bauer.

REFERENCES

1. Canty, E. T., Sobey, A. J., and Wallace, J. P. New Systems Implementation Study. General Motors Research Laboratories, Feb. 1968.
2. Guilford, J. P. Psychometric Methods. McGraw-Hill, New York, 1936.
3. Heathington, K. W., Miller, J., Knox, R. R., Hoff, G. C., and Bruggenman, J. M. Computer Simulation of a Demand-Scheduled Bus System Offering Door-to-Door Service. Paper presented at the HRB 47th Annual Meeting, 1968.

4. Howson, L. L., and Heathington, K. W. Algorithms for Routing and Scheduling in Demand-Responsive Transportation Systems. General Motors Research Laboratories, Res. Pub. GMR-944, Jan. 1970.
5. Jones, P. S. Dial-A-Bus. Proc. Symposium on Urban Alternatives, Stanford Research Institute, 1964.
6. The Genie System. In The Metran Study, M.I.T. Press, Cambridge, Mass., 1966.
7. Mosteller, F. Remarks on the Method of Paired Comparisons—The Least Squares Solution Assuming Equal Standard Deviations and Equal Correlations. Psychometrika, Vol. 16, No. 1, March 1951.
8. Mosteller, F. Remarks on the Method of Paired Comparisons—A Test of Significance for Paired Comparisons When Equal Standard Deviations and Equal Correlations Are Assumed. Psychometrika, Vol. 16, No. 2, June 1951.
9. Mosteller, F. Remarks on the Method of Paired Comparisons—The Effect of an Aberrant Standard Deviation When Equal Standard Deviations and Equal Correlations Are Assumed. Psychometrika, Vol. 16, No. 2, June 1951.
10. Stevens, S. S., ed. Handbook of Experimental Psychology. John Wiley and Sons, New York, 1951.
11. Study of Evolutionary Urban Transportation. Westinghouse Air Brake Company, Feb. 1968.
12. Thurstone, L. L. The Measurement of Values. Univ. of Chicago Press, Chicago, 4th impression, 1967.
13. Torgerson, W. S. Theory and Methods of Scaling. John Wiley and Sons, New York, 7th printing, 1967.
14. Vitt, J. E., Bauer, H. J., Canty, E. T., Golob, T. F., and Heathington, K. W. Determining the Importance of User-Related Attributes for a Demand-Responsive Transportation System. General Motors Research Laboratories, Res. Pub. GMR-941, Jan. 1970.
15. Wilson, N. H. M. CARS—Computer Aided Routing Systems. Dept. of Civil Eng., M.I.T., Cambridge, Mass., Res. Rept. R69-12, April 1967.
16. Woodworth, R. S., and Schlosberg, H. Experimental Psychology. Henry Holt and Company, New York, 1955.

DIAL-A-BUS SYSTEM FEASIBILITY

Daniel Roos
Massachusetts Institute of Technology

Dial-a-bus, a public transportation system offering the desirable characteristics of automobile and taxi travel at a cost only slightly higher than conventional transit, provides door-to-door service with maximum waiting and travel time guarantees. This is made possible by a digital computer that schedules a fleet of small buses to efficiently serve passengers as requests are received.

The basic operational characteristics of dial-a-bus have been described elsewhere and will not be restated in this paper (1, 2, 3, 4). The principal objectives here will be to review the results of research conducted at the Massachusetts Institute of Technology for the Urban Mass Transportation Administration and related to the feasibility of dial-a-bus systems. In particular the following subjects will be discussed: algorithms to schedule dial-a-bus vehicles, alternative system designs for dial-a-bus, cost of dial-a-bus service, and anticipated demand for dial-a-bus.

SCHEDULING ALGORITHMS

The scheduling algorithm decides which vehicle should service each rider and what sequence of pickup and delivery each vehicle should follow. The objective in designing algorithms is to utilize a minimum number of vehicles that provide a given level of service for all riders without violating waiting, travel, and total service time guarantees for each rider.

Algorithm development work was first limited to many-to-one service, i. e., many origins to one destination or one origin to many destinations (5). More recent work has produced algorithms for a complete range of dial-a-bus service. Such algorithms are commonly classified as many-to-many, i. e., many origins to many destinations.

Initial algorithms utilized a single-stop, look-ahead scheduling technique whereby the next stop of a vehicle was selected by the computer whenever a pickup or delivery occurred. More recent work has utilized a provisional-tour approach where a new demand is provisionally or tentatively inserted in a planned tour when the demand is received. The provisional-tour technique considers the state of the entire system at all times, whereas the single look-ahead method utilized only a limited subset of all information. The more sophisticated provisional-tour technique has been able to improve system performance by up to 40 percent (6).

Basically the provisional-tour technique works as follows: When a new demand is received, the trip origin and destination must be inserted in some vehicle tour without violating the waiting, travel, and total time constraints of the new demand, or the constraints of any new demand already scheduled. The decision on where to insert the demand has 2 components: On which vehicle route should the origin-destination pair be inserted? and Where specifically on that route should the insertion take place? The algorithm techniques have been described elsewhere and will only be summarized briefly here (6, 7).

The technique is based on calculating a series of slack times for fulfilling the constraints of each demand. Slack times represent the difference between the latest possible time an event (pickup or delivery) can occur and the time an event is predicted to occur. Slacks are calculated for the waiting time, travel time, and total time of each demand on the system and represent time that could be used to serve other demands without violating the constraints of the examined demand.

In general, many possible choices exist for insertion of the new demand without violating service guarantees to existing demands. Some mechanism must, therefore, be established to decide which of the many possible insertions is best in terms of overall system performance, a difficult decision because of the dynamic nature of the system. If the insertion were to be made based only on the existing system state, the choice would be easy; however, this is not the case because unpredictable new demands will arise and affect the current decisions.

An important aspect of the work was, therefore, to develop and compare selection criteria for insertion of a demand once all feasible insertions were determined. Several

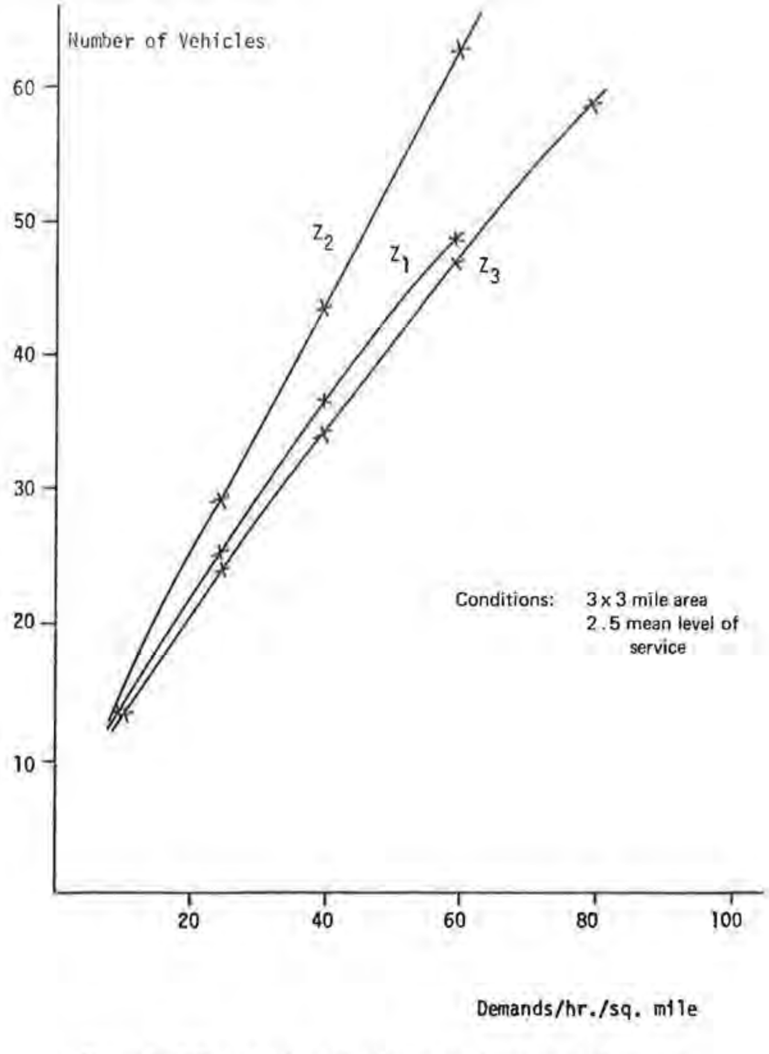


Figure 1. Effect of selection criterion on algorithm performance.

selection criteria were tested to see which produced the best results. Z_1, shown in Figure 1, is a selection criterion that maximizes service to the current system users, whereas Z_2 in contrast maximizes service for future users. The best result, Z_3, is a combination of Z_1 and Z_2 and maximizes service for both current and future users.

VEHICLE PRODUCTIVITY

A good measure of overall system efficiency is vehicle productivity: How many requests can be served by each vehicle in an hour? A large number of simulations were performed by using the provisional-tour algorithm for many-to-many service and objective function Z_3 to establish the effect of the following factors on vehicle productivity: demand density, service area size, and level of service.

Figure 2 shows the implications of demand density. Performance decreases considerably below 20 demands/sq mi/hr and then increases up to about 80 demands after which it diminishes and essentially becomes linear. These results have important implications regarding what type of areas a dial-a-bus system will best serve. More will be said about that later.

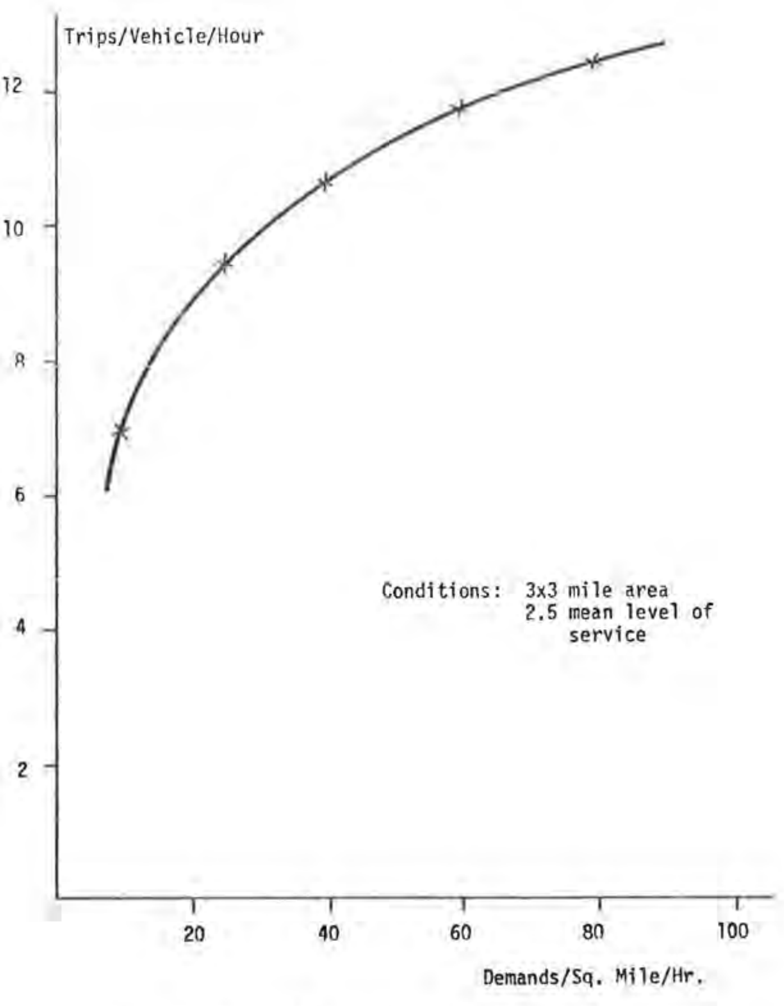


Figure 2. Effect of demand level on vehicle productivity.

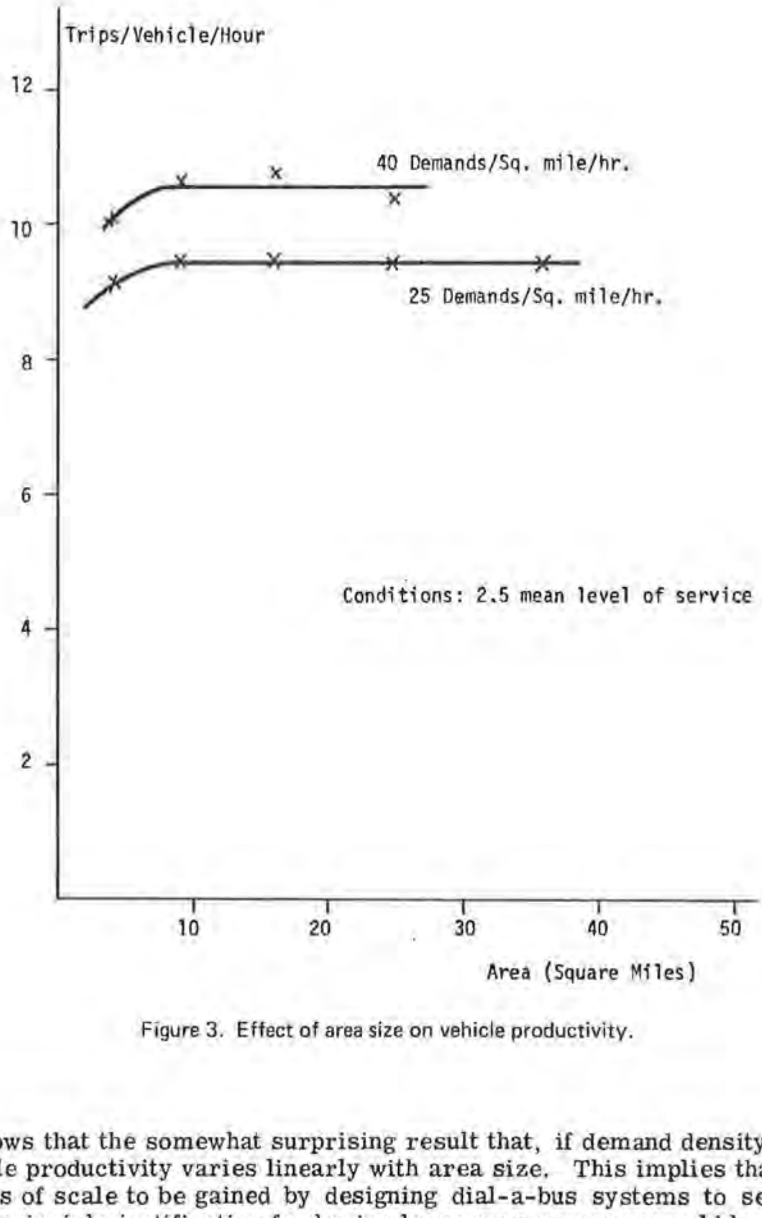


Figure 3. Effect of area size on vehicle productivity.

Figure 3 shows that the somewhat surprising result that, if demand density is held constant, vehicle productivity varies linearly with area size. This implies that there are no economies of scale to be gained by designing dial-a-bus systems to serve larger areas. The principle justification for having large area coverage would be to ensure that all origin-destination pairs were included in the service area.

Figure 4 shows the importance of level of service—the ratio of total service time by dial-a-bus to total travel time by an automobile. The rate of curvature increases sharply between levels 2 and 3. If a better level of service is achieved, the vehicle fleet size would have to be significantly increased. If dial-a-bus were offered with various levels of service at different costs, level-of-service curves would assist in determining the relative costs to be charged.

Many other factors affect vehicle productivity; these include vehicle speed, time required to pick up and discharge passengers, trip length, and the demand pattern used. The last factor is particularly important because vehicle productivity for many-to-one service is almost twice that of many-to-many service. Typically a situation may exist where high activity centers in an area will produce some many-to-one situations even

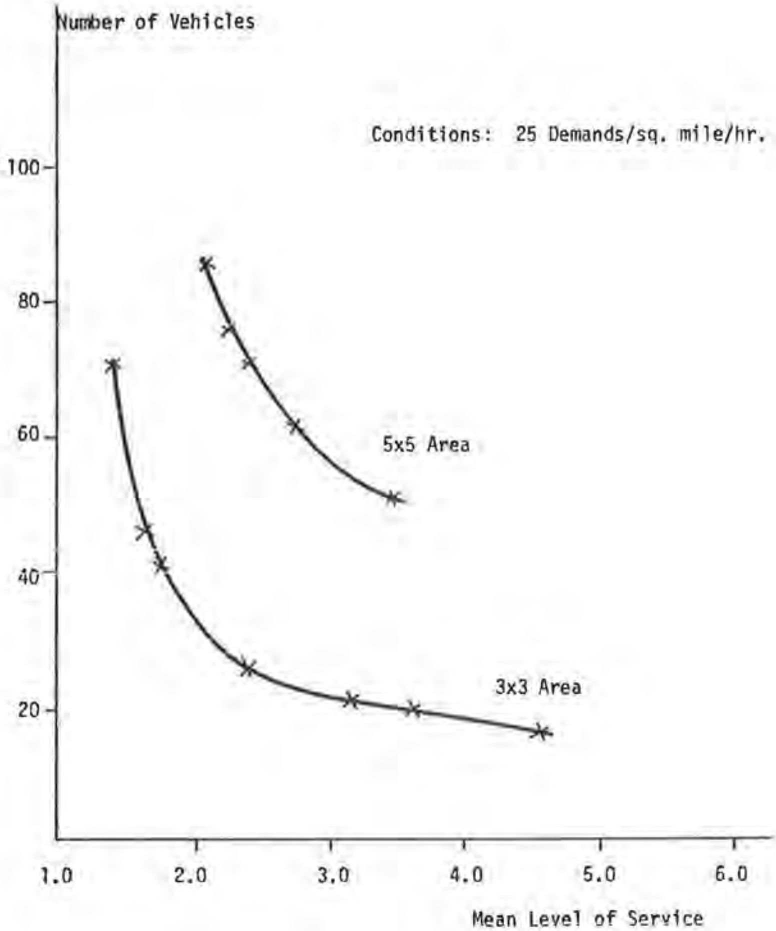


Figure 4. Relationship between number of vehicles and level of service.

when a general many-to-many service is offered. In this case, vehicle productivity will fall somewhere between the pure many-to-one and many-to-many situations.

At present, it is estimated that, for generalized dial-a-bus service, vehicle productivities of 10 to 20 requests per hour are feasible. Because more than one passenger may either board or get off at any stop, it is highly likely that the number of passengers carried per hour will be greater than these figures. Vehicle productivities can be increased by algorithm improvements and service variations. In particular, algorithms could be designed that allow for prescheduled trips. The demand responsive characteristics would then be superimposed over the prescheduled trips.

DIAL-A-BUS SYSTEM DESIGN

The principal components of a dial-a-bus system include customer communication to allow the customer to request service, vehicle communication to allow the vehicle driver to receive scheduling instructions, vehicles to provide service to the customers, and a computer to supervise the operation of the total system. Each of these system components is briefly reviewed here and explained in more detail elsewhere (8).

Customer Communication

The major device to be used for customer communication is an ordinary telephone. Generally, customers will use a private or public telephone; however, in high activity centers direct lines can be provided. Either voice or digital communication is possible. With voice communication, an operator receives trip requests from the customer; with digital communications, the customer uses the buttons of his touch-tone telephone to enter his trip request directly into the computer. Standard or repetitive trips made by the customer will be assigned a simple code number for easy insertion of the requests.

If digital communication is provided, voice communication is still needed for those without touch-tone telephones or those who choose to talk to an operator. An analogy can be drawn with the present long distance system where both direct dialing and operator assistance are available. Because digital communication is less expensive than voice, a customer could be given a cost incentive for exercising the digital option.

Vehicle Communication

A similar choice between voice and digital communication is also available for vehicle communication. The voice operation will be similar to existing taxicab dispatching. The digital operation will utilize small printers in the vehicles for drivers to receive instructions and keyboards for them to transmit messages. Digital operation offers the following major advantages over voice operation (9):

1. Far fewer channels are required (channels are currently very difficult to acquire from the Federal Communications Commission);
2. The vehicle printer provides a permanent record, whereas with voice communication the driver must remember his instructions; and
3. For large systems, digital communication is cheaper because it reduces the number of dispatchers required.

Vehicles

Simulation results indicate that vehicles with seating capacities of 10 to 20 are required. Within this range, a wide variety of possible vehicles exist, varying primarily with respect to comfort, maneuverability, endurance, life, operational and capital costs, and safety. At one extreme are the converted van vehicles costing approximately $4,000 to $6,000 and having limited seating, comfort, and endurance. At the other extreme are minibus vehicles costing between $10,000 and $20,000 and having greater capacity, better comfort, and longer endurance. Because dial-a-bus will operate in low-density areas on residential streets, the appearance of a medium- or large-sized bus might cause objections. Although a large amount of equipment currently exists that could be used for dial-a-bus operation, no vehicle has been specifically designed for that purpose (10).

Computer

Major computer considerations include performance, reliability, and cost. With regard to performance, the machine must have adequate storage and processing capabilities to run the system in real time. Reliability is essential to maintain customer satisfaction. Fail safe-fail soft capabilities must be provided through identical or functional redundancy. Within adequate performance and reliability standards, one would also like to minimize cost (11).

Several options exist with regard to computer systems. These include the following:

Dedicated Versus Time-Sharing Operations—Time-sharing provides the opportunity for dial-a-bus to utilize only that portion of the computer it requires. Dial-a-bus must have, however, a high enough priority use with respect to the other time-sharing users that service requests can be promptly handled. A far more important problem is the decreased reliability of a time-sharing system because any other user can cause the system to crash. For these reasons, time-sharing computers are not recommended.

Integrated Versus Separate Communications—The digital communications functions can be handled by a small communications-oriented computer or integrated as part of the scheduling computer. If a separate computer is utilized, schemes can be developed whereby the communications computer can assist in scheduling operations when the main computer is down. Many different configurations of scheduling and communications computers can be developed with different costs and varying degrees of reliability. Some possible configurations are 2 integrated scheduling computers, 1 communications computer and 2 scheduling computers, 2 communications computers and 1 scheduling computer, and 2 communications and 2 scheduling computers. It is anticipated that most dial-a-bus systems will utilize reasonably simple computer configurations, but in a few cases in larger metropolitan areas the larger more complex systems will be justified.

Remote Versus Local Site Locations—The scheduling computer can be located in the city where dial-a-bus service is offered, or it can be located any distance from that site. In the latter case, either the communications computer or a message concentrator would transmit the message received over telephone lines to the remote computer. The additional communications cost must be considered when a decision is made on the best location for the scheduling computer.

Summary

An operational dial-a-bus system that has been developed by M.I.T. uses the IBM 360 computer. This program can easily be adapted to any community that desires to operate a dial-a-bus service. It is, however, an experimental system with limited backup and capacity and, as such, should be used for only initial demonstration purposes.

The principle conclusions involving system design are as follows:

1. Dial-a-bus is technically feasible for it uses existing equipment and state-of-the-art technology;
2. The computer and communications costs are only a small portion of the total costs (this is discussed on a later section); and
3. A wide variety of systems are feasible. For example, one can envision small computers such as a Varian 620-I controlling 20 to 50 vehicles, medium-sized computers such as the IBM 360 Model 40 or 50 controlling several hundred vehicles, and large-scale computers such as the IBM 360 Model 85 controlling several thousand vehicles.

DIAL-A-BUS COSTS

The cost of operating a dial-a-bus system should be equal to the cost of a conventional bus operation plus the additional cost for the vehicle scheduling and communication operations. (The use of smaller minibus vehicles for dial-a-bus will result in some reductions in operating costs, but these differences are small in terms of total costs.) The cost for vehicle scheduling and communication operations will depend largely on the available technology and the efficiency of the operation. For this reason, costs have been developed for 2 separate systems: (a) an initial system utilizing existing algorithms and computer programs and voice communication and (b) a production system utilizing improved algorithms and computer programs and digital communication. The costs used are based on the research findings (12).

Cost ranges for initial and production systems are given in Table 1. Ranges are used because of the sizable cost differences between transit operations due primarily

TABLE 1

EXPECTED COSTS FOR DIAL-A-BUS

Item	Initial System	Production System
Basic bus operating cost per hour	\$5 to \$12	\$5 to \$12
Anticipated vehicle trips per hour	8 to 16	12 to 20
Basic operating cost per trip	\$0.31 to \$0.150	\$0.25 to \$1.00
Additional dispatching cost per trip	\$0.30 to \$0.50	\$0.15 to \$0.30
Total cost per trip		
Range	\$0.61 to \$2.00	\$0.40 to \$1.30
Expected	\$1.30	\$0.85

to differences in labor rates. The basic cost in both the initial and production systems varies between \$5 and \$12 per hour. (These figures are based on an analysis of many existing bus systems.) If we assume that productivities in an initial system are 8 to 16 passengers per hour, then the base cost per trip varies between \$0.31 and \$1.50. (These productivities were chosen to reflect some underutilization during the off-peak hours.)

The additional cost for dispatching in the initial system (30 to 50 cents per trip) consists of the following components:

Component	Cost (cents)
Customer communication	10 to 20
Vehicle communication	5 to 10
Computer processing	15 to 20
Total	30 to 50

For production systems, these costs will decrease as a result of economies provided by digital communication and improved algorithms operating in newer more economical computers. The estimated dispatching costs of 15 to 30 cents consists of the following components:

Component	Cost (cents)
Customer communication	5 to 10
Vehicle communication	2 to 5
Computer processing	8 to 15
Total	15 to 30

As a result of the improved productivities and decreased dispatching costs, the cost per trip in a production system should decrease to a range of from \$0.40 to \$1.30 with an expected cost of \$0.85.

These cost figures compare quite favorably with existing transit and taxi operations. Transit fares of 30 to 50 cents are now common for the base trip; an additional charge is frequently made for transfers between lines. In many cases, the fare-box revenues are only covering operating costs, and in some cases even a portion of the operating costs are subsidized. Therefore, actual costs for bus transit can often run as high as 75 cents or more per trip. Taxi fares vary from city to city, with a 2- to 3-mile trip generally costing between \$1.10 and \$1.90 plus tip. Dial-a-bus, therefore, appears to fall where it should, somewhere between the cost of conventional fixed-route buses and taxis.

DIAL-A-BUS SERVICE APPLICATIONS

Dial-a-bus will complement conventional transit service in two ways. First, it will serve as a feeder to line-haul transit stations. As new rapid transit express bus services are provided, the potential feeder role of dial-a-bus becomes increasingly important. The limited transit dial-a-bus service recently begun in Toronto, Canada, illustrates the importance of dial-a-bus in its feeder role to a commuter railroad (13).

Second, dial-a-bus will serve areas that cannot justify conventional public transportation. The number of these areas is sizable and should continue to increase as urban densities decrease and travel patterns become more diverse. As previously stated, dial-a-bus can operate with demand densities as low as 20 demands/sq mi/hr. If conservative modal split and ridership figures are assumed, that implies densities as low as 4,000 people/sq mi. In contrast, conventional transit usually requires at least 8,000 people/sq mi along its corridor of operation. In the range of 4,000 to 8,000 people/sq mi, the range in which growing urban areas and small cities fall, dial-a-bus should have a significant impact.

Models can be developed and people can conjecture about the potential demand for dial-a-bus; M.I.T. and other groups have engaged in these activities. One can also point to successful transit systems with limited demand-responsive characteristics (e.g., Peoria, Illinois; Mansfield, Ohio; Toronto, and numerous shared taxi and limousine services, 13, 14). However, the only way to accurately determine the dial-a-bus potential is to run a series of carefully controlled demonstration projects in real time, on real streets, with real vehicles.

SUMMARY

Scheduling algorithms were developed to provide many-to-many service by using a provisional-tour technique that resulted in an improvement of up to 40 percent when compared with simpler, less efficient techniques. The best algorithm performance was obtained by using a technique that attempted to maximize service for both current and future system users. System performance increased linearly with area size and was most cost effective between 20 to 80 demands/sq mi/hr and levels of service from 2 to 3 times that of automobile travel. Vehicle productivities of 10 to 20 passengers per hour can be achieved by using existing algorithms. These figures should improve as new and better algorithms are developed.

From a technical viewpoint, dial-a-bus is feasible for it uses existing equipment and state-of-the-art technology. In all but the smallest systems (fewer than 20 vehicles), digital communications are more desirable than voice communications. Computer requirements depend primarily on the system size. Time-sharing computers should be avoided because of reliability and priority problems. Vehicles with seating capacities of 10 to 20 should be utilized. Every effort should be made to provide a good reliable system design because the cost of the computer and communication components comprise less than 15 percent of total costs.

The cost per trip in an initial demonstration system with existing algorithms and voice communication should vary between \$0.61 and \$2.00, of which 30 to 50 cents is required for the dispatching operation. Later production systems utilizing improved algorithms and computer programs should reduce the cost per trip to between \$0.40 and \$1.30 and the associated dispatching costs to between 15 and 30 cents a trip. The major cause for the large cost variation is the different labor rates for the vehicle drivers.

Dial-a-bus will be complementary to existing public transportation by providing feeder service to line-haul facilities and providing service in low- to medium-density areas that cannot justify conventional public transportation. Whereas conventional transit generally requires demand densities of at least 80 demands/sq mi/hr, dial-a-bus can operate with demand densities as low as 20 demands/sq mi/hr.

Dial-a-bus, apparently technically and economically feasible, could serve an important role in providing necessary transportation to a sizable group of people and is one of the few new concepts in transportation that can be implemented in the very near future without significant investment in research, development, or capital equipment.

REFERENCES

1. Roos, D. Project CARS—Research and Demonstration Project Activities. Canadian Transportation Research Forum, May 1969; Dept. of Civil Eng., M.I.T., Cambridge, Res. Rept. R69-5.
2. Janes, P. S. Dial-A-Bus. Proc. Symposium on Urban Alternatives, Stanford Research Institute, 1964.
3. Canty, E. J., et al. New Systems Implementation Study. General Motors Research Laboratories, Feb. 1968.
4. Garcia, J. Demand-Actuated Road Transportation Performance and Demand Estimation Analysis. Institute of Public Administration and Teknetron, Inc.
5. Wilson, N., and Roos, D. An Overview of CARS. Dept. of Civil Eng., M.I.T., Cambridge, Res. Rept. R68-60, July 1968.

6. Wilson, N. H. M. Scheduling Algorithms for a Dial-A-Bus System. Urban Systems Laboratory, M.I.T., Cambridge, Rept. USL-TR-70-13, Aug. 1970.
7. Wilson, N., Sussman, J., Goodman, L., and Higonnet, T. Simulation of a Computer Aided Routing System. Urban Systems Laboratory, M.I.T., Cambridge, Rept. R70-16, Jan. 1970.
8. Roos, D., et al. CARS—A Prototype Dial-A-Bus System. Urban Systems Laboratory, M.I.T., Cambridge, Rept. R69-56, Sept. 1969.
9. Ward, J. Vehicle Communications for a Dial-A-Bus System. Urban Systems Laboratory, M.I.T., Cambridge, Rept. USL-TR-70-15, Dec. 1970.
10. Suomala, J. Dial-A-Bus Vehicle Specification. Urban Systems Laboratory, M.I.T., Cambridge, Rept. USL-TR-70-17, Dec. 1970.
11. Hamilton, D., et al. Computer Configurations for a Dial-A-Bus System. Urban Systems Laboratory, M.I.T., Cambridge, Rept. USL-TR-70-14, Dec. 1970.
12. Stafford, J. Economic Considerations for Dial-A-Bus. Urban Systems Laboratory, M.I.T., Cambridge, Rept. USL-TR-70-19, 1970.
13. Guenther, K. W. Incremental Implementation of Dial-A-Ride Systems. Paper presented at the Demand-Actuated Transportation Systems Conference and published in this Special Report.
14. Blurton, M. Final Report on the Peoria-Decatur Demonstration Projects. Bureau of Economic and Business Research, Univ. of Illinois, 1969.

INCREMENTAL IMPLEMENTATION OF DIAL-A-RIDE SYSTEMS

Karl Guenther
Transportation Research and Planning Office, Ford Motor Company

Ford Motor Company is currently pursuing a program of company-funded research in urban transportation. This work is being carried on by the Transportation Research and Planning Office that is staffed by a multidisciplinary team of researchers and engineers. The programs cover a wide variety of critical problem areas and place strong emphasis on the proper role of public transportation as well as the use of the personal vehicle (1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11). To make certain that these programs are relevant and useful, we work closely with transportation system operators and specific communities.

Typical of this approach is the work on dynamically dispatched public transportation. Dial-a-ride is one of our most active programs. Projects are being carried on in conjunction with several communities that are concerned with the problems of providing high-quality public transportation under today's economic conditions. Our research objective is to determine whether this promising new system can be offered at a price attractive to potential users and at cost levels acceptable to operators.

To accomplish this objective, we found it desirable to launch a program of field experimentation. This program is built on the findings of the dial-a-ride program funded by the U.S. Department of Transportation and draws heavily on work reported by other researchers. In this case, our role is to translate the theory developed for the dynamic dispatching concept into useful practice for the benefit of transportation operators and the public.

MOTIVATION FOR IMPLEMENTATION

There are sound reasons for moving toward implementation of dial-a-ride systems now, without waiting for more exotic hardware developments or additional studies. The most important is market identification and quantification. Public transportation is absolutely necessary for the nondriving segment of the population. Unfortunately, as this user group declines in relative numbers and in political power, service cannot be provided on an economically sound basis. In order to be viable, public transportation must lure a significant number of choice riders.

Sound though the basic research on dial-a-ride has been, the quantification of demand remains one weak area. Review of existing models forced us to conclude that nothing short of extensive field testing would answer these market questions for a new, untried mode. The current state of the art in demand modeling is simply inadequate to furnish highly reliable projections of choice ridership.

Field experimentation for the quantification of demand is not a one-way street. New models being developed by researchers will require field test data for calibration. Our program can, therefore, contribute to development of improved models as well as to the furnishing of absolute demand measures.

A second important reason for addressing implementation at this stage concerns the problems associated with launching new transportation services in today's economic and political environment. Too many sound concepts are lost because they cannot hurdle the many barriers to implementation. New ideas are risky, politically and economically. Implementation cannot be taken for granted; in fact, it must be fought for every step of the way.

The first and foremost hurdle is finding financial support. Private operators of public transport (those few who remain in the bus industry and the taxi firms) operate on a marginal, day-to-day basis. Short-term costs and revenues occupy their immediate concern; risk capital is nonexistent. Local governments, likewise, feel the pressures of increased demands for all kinds of services. These demands rise faster than revenues. Public responsibility dictates a cautious approach to high-risk ventures in public transportation or elsewhere. We cannot expect local government to underwrite pilot programs alone. Only where adequate public support is generated can they be expected to give any help at all.

State and federal governments have allocated almost all of their public transportation funds for the purchase of entirely conventional equipment. More than 87 percent of the moneys distributed by the Urban Mass Transportation Administration and its predecessors have been used for capital grants. Some help is available through the research and demonstration program, however; and there is a possibility that dial-a-ride projects will be allocated some share of these funds.

Finally, the manufacturers of hardware for transportation systems might be expected to participate in implementation. The obvious channel here is in development of prototype hardware. Development of the necessary dial-a-ride hardware is well within the capabilities of the private sector, providing a market has been defined. For example, the vehicle for dial-a-ride service (Fig. 1) was developed by Ford and is now being marketed because we became convinced that there is a significant potential in this area. Similar developments in digital communications and operating software needed for fully automated dial-a-ride systems can be anticipated from industry. However, the investment of millions of dollars in high-risk implementation projects is too speculative for private enterprise to undertake alone.

This suggests a cautious but deliberate incremental approach to implementation and one that takes advantage of the transportation operator's existing knowledge and investment, any government (local, state, or federal) support that can be obtained, and any private risk capital that can be attracted. This is precisely the Ford approach to dial-a-ride implementation. Surely, massive funding would be preferable and would permit more rapid diffusion, but the lack must not be allowed to deter a true test of this most promising concept.

Financing is not the only problem, however. Facing the implementation issue means dealing with regulatory problems (will dial-a-ride be regulated as a taxi, a bus, both, or neither?) and labor questions (how will present transport workers' unions respond to the new type of service, or how will taxi labor, now paid on commission basis, be renumerated?).

Figure 1. Courier vehicle used in Mansfield and Toronto dial-a-ride tests.

In an extensive survey of experimental and innovative systems, we have found that perhaps the most important single factor in the success or failure of new services is management support and dedication. Management at all levels must be committed to the new concept. There is no substitute for attention to detail and strong emphasis on customer service. An enthusiastic management will show the new service in its best light and can be a major factor in overcoming labor or regulatory problems that may arise.

These implementation problems, however formidable, must be addressed now if dial-a-ride is to have a chance for success in the relatively bleak field of public transportation. The Transportation Research and Planning Office is convinced of the validity of the dial-a-ride concept. We are now working with communities and operators in a variety of ways toward the goal of implementation. Dial-a-ride is worthy of an honest assessment in terms of its eventual success in the marketplace, but it must first be successful in the legislative and executive chambers of government, in the union hall, and in management offices.

DIAL-A-RIDE SERVICE SPECTRUM

Dial-a-ride covers a large range of potential systems from conventional transit bus operations to taxi service. Figure 2 shows this spectrum by using existing technology as the basis for comparison. The horizontal scale represents dynamic routing; the vertical scale represents dynamic scheduling. Once the constraints of fixed routes and schedules are relaxed, the degree of dynamic response in both of these dimensions is essentially a function of the dial-a-ride algorithm used.

In its most sophisticated state, dial-a-ride offers taxi-like service, the only important differences being shared riding, slightly longer travel times, and lower fares. However, there is a large spectrum of potential dial-a-ride systems that offer substantially less than full taxi service. These are commonly referred to as many-to-one and many-to-few systems. Many-to-one dial-a-ride actually begins where conventional bus service leaves off. Many-to-one indicates a focal point for the service such as a town center, rapid transit station, airport, medical complex, or other major activity center. The many-to-few concept is an expanded system in which between 2 and 10 focal points can be served.

As a first step in Ford's evolutionary program of implementation, a pioneering field experiment in dynamic routing within a fixed schedule has been undertaken in Mansfield, Ohio. This experiment is structured as a many-to-one dial-a-ride system.

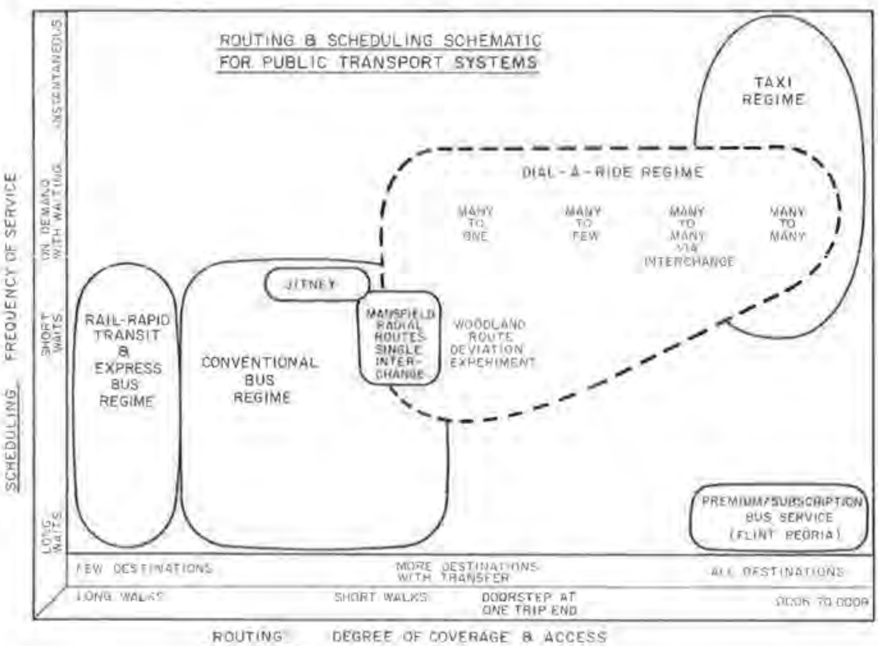


Figure 2. Routing and scheduling schematic for public transport systems

Route-deviation, doorstep service with a single vehicle in a well-defined service area has been operating in Mansfield since January 1970. A fixed-route loop in the Woodland neighborhood (Fig. 3) forms the basis of the service. In response to specific requests, the driver deviates from the regular route for doorstep pickup and drop off. A radio telephone for receiving calls for passenger pickup at home or other trip origin point within the defined service area is fitted to the vehicle (Fig. 4) and permits dialing directly to the driver. After picking up the caller at his doorstep, the driver returns to the fixed route at exactly the point he left it. A passenger may leave the vehicle at any point on the fixed route or transfer at City Square to other routes. Users boarding at City Square or along the fixed route may request doorstep drop off, and the vehicle will deviate as previously described and return to its fixed route. The service operates six days a week from 7:15 a.m. to 6:15 p.m.

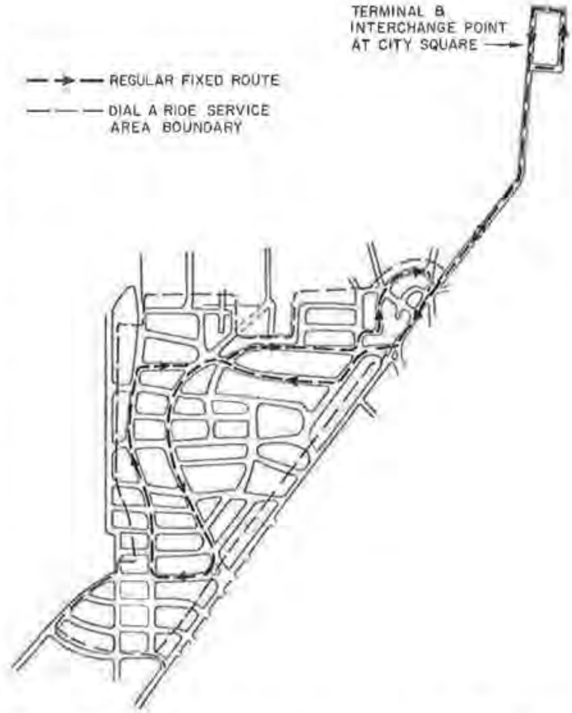


Figure 3. Route-deviation service area in Woodland neighborhood of Mansfield, Ohio.

An increment of 15 cents, in addition to the basic 35-cent fare, is charged for the extra service. Transfers to other routes cost 10 cents. It is important to note that the existing fixed route is retained and traveled by the same vehicle on normal half-hour headways. With doorstep deviation, two distinct classes of service at different prices are being offered simultaneously by a single vehicle with a single driver.

The single vehicle runs in harmony with the rest of the city buses, making its call at City Square each half hour as do all the other buses. Thus, a complete interchange with the entire system is provided.

Data collection consists of daily ridership and revenue tabulations by class of user; a 100 percent sample of all doorstep pickups and drop offs by time of day and address; a real-time record of vehicle speed and distance collected via recording tacograph; and comprehensive surveys of users and potential users. The results found to date have been encouraging. On a typical weekday, 76 riders use the bus, of which 15, or about 20 percent, elect the doorstep service. This is particularly impressive because of the excellent quality of fixed-route service that provides the basis for comparison. The route at present does not cover full operating expenses but has generated a 14 percent increase in revenue per household served. Route deviation has been found totally feasible from every standpoint. The driver is able to perform his tasks, including answering the telephone and collecting data, without feeling overworked. Customers understand the service and find it easy to use. Schedule adherence has been 100 percent since January although there have been as many as 8 deviations per half-hour tour.

No promotional campaign whatsoever has been undertaken because the existing communication system is already overloaded at times. To correct this, application has been made for an exclusive channel dedicated to dial-a-ride use only. Detailed statistical analysis of the first 6 months of ridership, revenue, customer response, and operating data is now under way and will be reported in full to the transportation research community in a forthcoming paper.

We recognize that the Mansfield experiment is small and that economic results obtained with the prevailing labor rate there are not transferable to larger urban areas. Nevertheless, this test is a particularly important one for the hundreds of small- and medium-sized communities that are having difficulty keeping their transportation systems solvent.

Another important many-to-one dial-a-ride experiment is the dynamically routed transit feeder demonstration recently launched by the government of Ontario in connection with its GO Commuter Railroad Service. Ontario is demonstrating how dial-a-ride can be used efficiently to to feed a line-haul transportation system. Market studies revealed that a very high proportion of those who had walking access to transit stations here used rail service, as data given in Table 1 show (12).

Figure 4. Bus driver in Mansfield receives radio-telephone request for doorstep pickup.

The relatively lower transit use with decreasing accessibility to stations is also demonstrated by the data given in Table 1. The offering of demand-activated personalized feeder service is an attempt to expand the contour of easy access for a suburban station beyond the usual walking distance. Simultaneously, this service precludes the need for capital expenditure to erect parking structures on high-valued land.

The Toronto test has no fixed-route basis like that in Mansfield, so that the vehicle tours in a given service area correspond only to demands that have been registered. However, as in Mansfield, a fixed schedule at the focal point is retained; in this case, it is determined by train arrivals and departures.

The next sequential step in the dial-a-ride spectrum is to eliminate the fixed schedule. To do this, vehicles can be dispatched into the service sectors either when a certain number of demands have accumulated or when a specified time has elapsed since the earliest unserviced demand. A proposal for operation of this type of service in a many-to-one mode has been made to a midwestern city of 100,000 population, and we hope it will be implemented within the next few months. The next subsequent stage, many-to-few dial-a-ride, is an extension of the many-to-one service concept and serves more than one activity center or focal point. This can be accomplished by overlapping many-to-one systems with a separate fleet of vehicles serving each focal point or by providing a fixed-route "tail" connecting several closely spaced activity centers at the end of the dial-a-ride tour.

TABLE 1

VARIATION OF TRANSIT MARKET SHARE AS A FUNCTION OF ACCESS TO STATIONS

Distance From Suburban Station	Distance From Union Station for Trip Ending in CBD (percent)			
	Short Walk	Transit Ride		
		Short	Medium	Long
Short walk	66	34	20	18
Automobile ride				
Short	47	19	8	6
Medium	19	11	4	3

In a large number of communities, a many-to-few pattern will serve a majority of the desired trips, providing that the focal points are properly defined and perhaps dynamically shifted according to the time of day. Because a substantial percentage of the trips also have one end at home, the service sector concept appears to be broadly applicable. However, numerous areas that have combinations of low-density, sprawled land use and topographic features do not have markets that can be adequately served by a many-to-few dial-a-ride. In these cases, a true many-to-many taxi bus service may be justified. Its viability will be governed by the diffusion of trip-making in the urban area under consideration. The critical question becomes whether the increase in demand can offset the increased costs due to more complex dispatch logic and lower vehicle driver productivities. (The work reported by the Massachusetts Institute of Technology suggests a productivity relationship of as high as 2:1 for many-to-one versus many-to-many dial-a-ride service.)

Our program at Ford Motor Company consists of going carefully through all of the steps between the conventional bus regime and the taxi regime, learning as we go, and basing our next implementation moves on experience gained with the previous experiments. We feel that certain cities and some areas within other cities will probably never proceed all the way to the many-to-many dynamically routed and scheduled dial-a-ride system. Learning about all of the potential dial-a-ride spectrum is, therefore, very important.

CRITERIA FOR EVALUATION

How is "success" in dial-a-ride field experiments to be judged? The answer to this depends on one's viewpoint of what success in a public transportation experiment really means. The first question asked invariably is, Will dial-a-ride make a profit? Surely, from a private operator's standpoint, the profit criterion is the most important one. However, in an industry that nationwide has operated at a deficit since 1963 and that posted losses of $129 million in 1968, operation at a profit would, indeed, be a revolutionary achievement. The real question people are asking is, Can dial-a-ride service reverse the trend of deficits in public transportation? We are indeed encouraged in this respect by the experiment in Mansfield where we are finding a revenue increase per household served on the order of 14 percent over fixed-route service in the same neighborhood.

Measures of success other than the fiscal definition are equally valid. A broader evaluation of costs and benefits is called for. Public transportation is provided at a deficit in most cases where it is provided at all. The community must, therefore, be concerned with the magnitude of subsidy required and the resulting benefits. Dial-a-ride provides substantially improved service to those who cannot or do not wish to use automobiles for all their trips. In the Mansfield test a substantial number of new job opportunities for domestic workers have been created by offering doorstep service. Dial-a-ride must be judged successful from a user's point of view if it meets his or her transportation needs at an acceptable cost. It, therefore, becomes imperative to measure and quantify all possible aspects of any field experiment undertaken, such that the community has a sound basis for assessment of all potential costs and benefits.

Finally, there is the question of implementation itself. There is some measure of "success" in the actual accomplishment of carrying out a field experiment. Without the cooperative support of city government, the sound professional participation of the local planning commission, and the enthusiastic participation of the private bus operator, the Mansfield experiment could not have been conducted. Overcoming the substantial hurdles to implementation requires real teamwork. This is not to suggest implementation of a system for implementation's sake, but it is to recognize that an important measure of success is, in fact, the existence of a system. Representatives from scores of other communities from North America and Europe have studied the Mansfield operation since its inception, many of them specifically concerned with how to go about solving the problems of implementation.

Ford's Transportation Research and Planning Office has every intent of pursuing dial-a-ride implementation plans beyond Mansfield. Each promises to be as challenging as the first. If there are "universal truths" that apply to all implementation situations, we have not yet discovered them.

Inquiries from numerous cities and towns in the 30,000 to 250,000 population class, transit feeder locations, and some intriguing private applications have convinced us that dial-a-ride, unlike some of the "new" technologies, is not a "solution looking for a problem." It is needed now in countless communities not only in North America but also in Europe and elsewhere.

Doorstep, route-deviation service such as that implemented in Mansfield illustrates how transit services can be upgraded while an important first step is taken toward a dial-a-ride system. The key elements in that service—small, maneuverable, relatively inexpensive vehicles; radio telephone controlled, doorstep service; and efficient, imaginative, and innovative management—can be assembled in other communities. It is our conviction at Ford that incremental implementation schemes provide the most satisfactory method of apply our growing knowledge of dial-a-ride system concepts to solving pressing transportation problems. New business opportunities for Ford may result from this research; but whether they do or do not, it is clearly in our best interest to do whatever we can to make public transportation in our cities more responsive to users and less burdensome to taxpayers.

REFERENCES

1. Wilkie, D. F. The Application of Numerical Optimization Techniques to a Travel Forecasting Problem. Third Hawaii Internat. Conf. on Systems Science, Jan. 1970.
2. Guenther, K. W., and Givens, W. E. The Courier: A Prototype Vehicle for Dial-A-Ride Service. SAE Congress, Paper 700186, Jan. 1970.
3. Guenther, K. W. Public Transportation Service Innovations: What Are the Lessons for Dial-A-Bus? Project CARS Seminar, Urban Systems Laboratory, M.I.T., Cambridge, Nov. 1969.
4. Weldon, F. L. An Overview of Transportation Hardware Potential. Fourth Internat. Transportation Seminar, Honolulu, Feb. 9, 1970.
5. Shackson, R. H. Technological Innovation. United Transportation Union Presentation, Chicago, April 23-25, 1970.
6. Guenther, K. W. The Mansfield Dial-A-Ride Experiment. 11th Annual Meeting of Transportation Research Forum, New Orleans, Oct. 1970.
7. Shackson, R. H. Technological Innovation and the Manufacturer. ASCE National Transportation Eng. Meeting, Boston, July 13-17, 1970.
8. Whorf, R. P. Salt Lake City—Transportation Interface System Study. July 1970.
9. Guenther, K. W., and Oxley, P. R. Dial-A-Ride for New Towns. Internat. Road Federation, Sixth World Highway Conf., Montreal, Oct. 1970.
10. Wilkie, D. F., and Stefanek, R. G. Precise Determination of Equilibrium on Travel Forecasting Problems Using Numerical Optimization Techniques. Highway Research Record 366, 1971.
11. Oxley, P. R. The Dial-A-Ride Bus Service. Public Road Transport Analysis Symposium, University College, London, Oct. 1970.
12. People on the GO. Department of Highways, Ontario, Report C4, June 1969.

SEMINAR ON DEMAND MODELING AND ESTIMATION OF DEMAND

INTRODUCTORY COMMENTS

Raymond H. Ellis

In formulating my introductory comments, I inevitably could not focus only on the problem of estimating demand for a demand-actuated system and ignore the entire problem of estimating the demands for urban transportation. It has become trite to say that the simple impossibility of dealing solely with an urban transportation system based on the automobile forces us to look at other forms of public transportation. During the past few years, we have structured a very rich variety of transportation concepts ranging widely in the technological and institutional innovations required to implement these systems.

I would suggest that there is a problem in the evaluation and demand estimation process to determine the consumer's response to the different types of alternatives, particularly combinations of alternatives. I would like to pinpoint some questions that have been bothering me about demand modeling and the estimation of demand for new systems. I would be very curious to see how the individual techniques and approaches respond to these problems.

Most of the demand work that has been done in the area of urban transportation is focused on what one might call a dual-choice problem—that is, public transit versus the automobile. Yet, when I start talking about a rich array of alternatives ranging from the private automobile to car pools, reserved lanes for car pools, fringe parking, conventional transit, dial-a-bus, taxi, and systems requiring higher degrees of technological innovation, it seems clear to me that in the urban situation we are going to have 3, 4, or possibly more modes operating in competition with one another. It is essential that the process for estimating demand be responsive to competition among the modes, particularly among 3 or more modes. I think the 2-mode problem is essentially where we are now. There are a few n-dimensional models or techniques available for dealing with this particular problem. I think each of them has its disadvantages.

The second type of problem that I see in estimating demand for urban transportation is what one might call the new mode problem for which we have no base-line data that can be used for purposes of calibrating a modal-split model or any sort of model. We really do not have a decent method for coming to grips with estimating the demand for a new mode. In this regard, I am looking forward to hearing some responses or disagreements on this particular point.

Third, I suggest that in many ways the techniques and the ideas that we have used to date have not given us the types of information we need to plan an urban transportation system. Who are the potential riders of the system? Particularly from the techniques that have developed from the highway planning process, we do not know who is using the systems in terms of the social groups, i.e., the elderly, the young, the housewives, and the families with different levels of car ownership and varying economic needs. This sort of information is frequently missing. It is frequently important because this is the way people define the public transportation problem. We have very litttle information on the peaking characteristics and the temporal distributions, yet it is clearly very important. We have relatively little information on the elasticity of demand to changes in the service levels or the changes in the performance requirements in terms of time or price, yet these also are quite important in designing a system.

Finally, there are factors that we simply have not considered to any high degree. For example, to the best of my knowledge, reliability, safety, comfort, and convenience have not been factored into the demand modeling process.

Perhaps, as one of my associates has suggested, we will not be able to develop techniques for predicting the demand for urban transportation until we have a theory of urban transportation—a theory of demand. Nonetheless, the transportation systems of our cities are in an element of chaos, and I think it behooves us to do something in response to these requirements.

I have outlined several questions for discussion. What type of demand analysis strategies have been used? Have the strategies involved a psychological approach, an econometric cross-sectional type of approach, a behavioral approach, or an approach based on a marketing-type study? What sort of mathematical models have been used? What variables or factors were considered? Did they include transportation variables (for example, time and price), trip variables (the characteristics of the trip), and the trip-maker? Regarding results of analyses, do we have some estimates of the demand curve for demand-actuated systems? What about the sensitivity of the analyses? How many sensitivity analyses were run? Can one begin to draw some conclusions about the nature of the demand for demand-actuated systems?

RESULTS OF RECENT DEMAND ANALYSES

Joseph H. Stafford

I will describe some of the strategy or the philosophy that we were trying to implement at M.I.T. One of the questions relates to data. Did we use attitude surveys, or did we try to use observations on actual behavior and actual choices? We rejected the attitude survey for our particular effort for several reasons. First, we thought it would be more expensive. Second, I did not really feel I had any great capability of doing it, and that is probably the main reason I rejected it. I really felt that the GM people were doing a far better job than we were capable of doing. I am very intrigued with some of the work that Jim Wallace started 3 or 4 years ago on the multi-attribute utility model. We experimented with it a little, and I became convinced that I did not know how to get around the post-decision rationalization kind of phenomonon that one has to come to grips with in attitude or intention surveys. I felt that we might end up with weights on rationalizations rather than with real utilities.

So after a very short time of trying a few things along that line, using mostly student term papers, we went the other route dealing with data that were essentially behavioral. That is, we tried to infer from choices that people were making, and we used predominantly the Boston home interview survey data. One thing that we did very much agree with the GM people on (we did not disagree with them on the attitude survey but felt that this was their thing and that we ought to wait for their results) was that disaggregation was going to be essential and that cross-sectional data on the zone aggregates were not going to tell us anything. We had to get down to the individual household and individual trip-maker to learn anything. This then suggested to us some sort of discriminant analysis such as probit-logit.

The other thing that I felt fairly strongly about was that we could not look at the trip. Although most of the previous studies had been done in terms of trip prediction, we had to recognize that there was both a long-run and a short-run decision. A person was making not a decision about a trip but a decision about a whole group of trips when he made the decision to purchase a second or third automobile. We might expect the quality of the public transportation service that was available to influence that automobile-ownership decision. Therefore, Paul Hauxy used the discriminant-analysis approach (with what little data we had available on accessibility or average walk times to the transit system) to see what accessibility would explain in automobile-ownership trends rather than the other approach in which automobile ownership is considered to be completely given exogenously. Not to my surprise, there was some effect on second car ownership, virtually no effect on first car ownership, and most of the effects of the quality of the public transportation system could be washed out with a very minor change in income. I do not have the exact numbers, but I hope this begins to put things into some perspective.

The other kind of approach we were taking is similar to what a number of other people have done on the so-called "value of time" models (Thomas and Haney at Stanford Research Institute, Lisco at the University of Chicago, and a number of others). All of those models have really been restricted to middle-class, rush-hour commuters in major metropolitan areas. We thought that, if we were going to look at a potential market for dial-a-bus, we had to get well beyond that and look at different trip purposes, different times of day, different people, and different income classes to see how people were making their choices in this broader context of trip-making behavior. That study is really just now beginning to get off the ground. We hope Rodney Plourde will be working on it all year.

Another approach that we took was to ask the question, What other kinds of data and observations of behavior choices can we work with in a disaggregate, carefully structured, and controlled experimental way prior to having dial-a-bus in the field? We were fortunate enough to talk Karl Guenther into allowing us to observe the Mansfield project. The Richmond County Planning Commission opened its files to Dennis Kershner, who just finished a master's thesis on using discriminant analysis.

We think that this value of time model that Lisco, Haney, Labe, and others have done makes a lot of sense. Houston Wynn's short-cut mode-split model is another example of this same kind of approach.

What can we do now with this disaggregate framework to build it back up into an aggregation for the whole community? Arnold Soolman, working that kind of an approach and taking the models as already given but plugging back in and deducing it the other way on a value of time framework, has put together some demand curves that seem to be reasonably consistent with our other kinds of observations on taxi cabs and bus systems. This method seems to calibrate reasonably well.

In summary, I can say that we have not settled on one model or one approach. We think it is going to be necessary to get into a very disaggregate kind of analysis where we have some new field observations and new data points. We are going to have to be careful of what we do to those data points to be able to extrapolate from a particular observation into any other situation. If we simply look at the balance sheet after the end of 12 months and decide whether the concept is go or no-go, we will have lost most of the useful information in the experiment.

Richard L. Gustafson

I will go over the methodology and the approach of our study at General Motors toward ridership estimation. We had a specific goal in mind in estimating the ridership for the particular case study community. We employed the attitudinal survey for the purpose of obtaining data for use in statistical analyses for the case study community. We applied the data from the attitudinal surveys to specific information concerning the trip-making behavior of the community. The attitudinal survey was conducted in 2 parts. The first part was in-depth group interviews from which we gained qualitative information concerning the residents' attitudes toward this transportation system. This aided us in preparing questions for the home interview survey. We conducted 5 of them for 5 different groups: retirees, teenagers, male heads of households, no-car households, and females.

The home interview survey was then implemented. In order to gain quantitative information concerning the particular subgroup, we established certain quotas. The marketing group that conducted the survey interviewed 100 households that did not have an automobile available to them. We required a quota of 1,000 households, and we needed 200 housewives, 150 males, 100 females who work, 100 teenagers (male or female), and 100 heads of households with no cars available. We divided the housewives, males, and females that work into no-car, one-car, and multi-car households to obtain quotas. We had 400 multi-car households, 550 one-car households, and 100 no-car households—a quota of 1,050. The actual results were, I believe, about 1,080 for the attitudinal survey. Then, in the data analysis section of our questionnaire, we asked the individual, What percentage of trips that you are now making would you divert to the demand jitney system that has been explained to you by the interviewer? With the help of the interviewer, the person was told to enter a certain percentage. As the interviewee got more and more specific about what particular trips he would divert, the interviewer continued to question him. If he showed no interest at all in the system, the interview was completed at that point.

We also had questions concerning the latent demand. The intent of this survey was to get microlevel data concerning the potential ridership in the case study community. We divided the groups into particular subgroups and classified the data by person type and by trip type. There is a modal split for each person type and trip type in the case study community. We developed these modal splits and then aggregated them to get total aggregate modal split for the community.

We took the disaggregated information and applied it to a survey of the community that had been taken previously by another organization. It had trip-generation behavior by household and by trip purpose and origin and destination information on all trips made in the community. We applied our modal-split data to the demographic information for each respondent to determine how many trips would be made by each person type and by each trip type in the case study community. There were 175,000 eligible trips in the case study community. These were factored to estimate the number of trips in each category and then aggregated by hour because we also had the time of day that the trip was made. We could make this information very detailed. In aggregating it, we came up with the total distribution of trips to be made on the demand jitney for the particular system we discussed. We used 3 parameters—person type, trip type, and system configuration—and described system configuration by 3 attributes—maximum waiting time, minimum travel time ratio, and fare. We had 16 system configurations, 6 person types, and 6 trip purposes.

The latent demand estimates were calculated and are available in another paper. From the questions that we entered on the survey, latent demand was found to be of little significance. In addition, we investigated the potential school trips to be made on the demand jitney system. First of all, we found that the community had an excellent busing system and that none of the to-school and from-school trips would be made on the demand jitney because the school bus is free. We calculated potential trips after school and found that they would have little influence on the total demand distribution of the demand jitney. Therefore, at that point, we discounted it for out total feasibility analysis. The figures will be made available as soon as clearance is received.

Karl Guenther

The problem in Mansfield was similar to a fire drill in that a private operator and a planning agency came to us at Ford Motor Company and asked us to wind up an experiment. Very frankly, there was not much thought on their part for an a priori prediction of the demand for a new service. On the other hand, in our own program we had made a value judgment that was perhaps not totally justified but that seems today to have been a wise decision. The work that had been going on, particularly at M.I.T., appeared to be reasonably promising, and a parallel effort was not warranted. We carry a fairly strong conviction that a field test is probably the only sure way to predict demand. It is not a prediction of demand a priori, but it does give you points on the demand curve. We also capitulated to GM very much for the reasons that Joseph Stafford talked about. So, we thought that, for the particular Mansfield test, it was not ridiculous to go into the field to measure the demand and report our findings. It was the cheapest and probably the most reliable thing that we could do at that point. We also have some modal-split models running that we are not at all pleased with, and we hope we will be applying our data findings to those. Any of the more elegant demand model formulations appear to be out of the question for calibration for an unknown mode at this point, at least with our available resources.

This is a 2-way street. We have fed data back into model development from our field experiment and plan to continue to do this as much as is possible. It is very difficult to get implementation-oriented operators and agencies to hold still while certain things are measured. Many times we had to go down to Mansfield to keep them from changing parameters or doing some wild things that would have, in our point of view, upset the limited experimental value of what we have done. They would want to run something for a week and then change it, and we had a hard time convincing them that it had not stabilized. So, we are feeding data back into the demand model building effort. We do not have a very elegant effort of our own, and we have completely ignored the survey approach.

We knew that the potential users of the system in Mansfield would probably be based on present transit ridership because the system exists and this is merely a modification of the transit system. It does not, in and of itself, represent implementation of a new service. We were not at all surprised to find that, in fact, that is what happened. We do feel that we got a little bit more into the serve-passenger market. This is based on the response to the question on our ridership surveys: What alternate mode would you have taken had you not been using the fixed route or route deviation Woodland bus for this trip? We found that the answer categories with the highest percentages are either "walk" or "ride with another person." So, we are getting into a potential serve-passenger trip market. I regret that I do not have those numbers.

In terms of setting the fare, this was a very simple process. The base rider fare in Mansfield was 35 cents, and we felt that it was very important to establish a differential price for the doorstep service rather than to offer it at exactly the same price. The question then became, What would the traffic bear? In this case, it was not what would the user bear but what would the city council approve, because it had to approve any fare increase. We arrived at a magic number of 50 cents, which seemed to all concerned to be some sort of a reasonable kind of differential for this kind of service. The fact that we do have 2 points on the demand curve leads us to believe that one of the things that we would like to do when we finish some more neighborhoods in Mansfield is to offer some alternative fare policies, if we can get the city council to agree.

There is another kind of demand, though, that is not addressed by demand for ridership. That is the demand for the particular vehicle that we designed for Mansfield. I suppose now I will have to be a little bit defensive and suggest that operators seem to want the kind of vehicle that we have. We had no intention of marketing it when we started out, but this particular Econoline, with some modifications to it, seems to be very appealing to private operators. That is a type of a demand that many transportation researchers are not too interested in, but it happens to be one that the person who signs my paycheck is very interested in. We are quite frankly a little bit surprised that it turned out that way, but William Howard made some interesting improvements on our Mansfield design.

William T. Howard

If I had to spend 5 minutes discussing the demand modeling that we did in Toronto on dial-a-bus service, I would have to stretch the words "none of" for 5 minutes. If I give you a little history, you can realize why we did this the way we did it. We did a very extensive market survey in 1965 or 1966 to estimate the demand for our commuter rail service. Things turned out very well but not the way the market survey showed it was going to turn out. One just cannot place too much emphasis on what people say they are going to do. Our market survey showed that on the rail system we would probably carry approximately 15,000 passengers a day, and this was practically right. However, it also told us that our heaviest demand would be from the innermost stations to the CBD, and this was 100 percent wrong. As I said earlier, we had to expand the size of a parking lot almost immediately after we went into service because we based our parking lot capacity on the market survey that was carried out. What we had estimated to be $1.8 million in revenue actually became $3 million in revenue because we were getting maximum fare from more people than we had anticipated. It worked out quite well after a rush job to extend parking lots at the most distant suburban stations.

On our dial-a-bus program we thought that we could probably operate for a year at the same price it would have cost us to do a survey. So here we are ready to nod to an after-survey without the before-survey and to find out some facts rather than fiction. We do plan to do a complete survey later this month and to include such things as income levels. It will certainly be available to anybody who is interested.

Karl Guenther

As long as we have people like William Howard doing our uncontrolled experiments, I think we are not in too bad a condition.

Kenneth W. Heathington

A lot of work can be done in planning. I realize surveys cost a lot, but we should figure out a way to get the same data without having to spend a lot of money for surveys. What I think we are missing is a theory of estimating demand. When systems like these and those being considered by the Urban Mass Transportation Administration are installed, we can begin to calibrate a model to find out whether our theory is any good. It seems to me that there is absolutely no correlation between implementation of projects and what we are doing in the way of theoretical modeling for demand.

William T. Howard

I would like to clarify our particular situation. I should not give the impression that we proceed haphazardly with everything we do. We have a very, very strong group in our transportation planning division. We were recently formed as a Research and Transit Systems Branch of the Department of Highways. As well as having transit planners in our own branch, we work very closely with the overall transportation planning group, and we develop sophisticated models for our overall transportation system. We are not working in isolation, although it appears so when we throw these programs in without much in the way of planning or estimating demands. It is not our intention to do so. We, as I stated earlier, are certainly planning to expand our dial-a-bus operation, whether in the form it is in now or in some other form; and the experience we are getting now can be applied in other areas. It also can be fed into our overall transportation planning techniques to ensure that we are going in the right direction.

Joseph H. Stafford

May I react just a moment with regard to this theory of transportation demand? I do have one doctoral candidate, Eduardo Aldana, who is working on something that I think might be characterized as the theory of demand. He is trying to put together much disaggregate information, in both a long-run and short-run context, into a microanalytic simulation. I think it is closely related to some of the reaggregation of the disaggregate data that GM has done. I think we are approaching a point on a theory of demand that is rich enough for us to begin to test some of these new concepts. I do not believe the picture is as bleak as Raymond Ellis and Kenneth Heathington may be suggesting that it is.

OPERATOR REQUIREMENTS FOR DEMAND ANALYSES

Fred Tumminia

It is hard to say how accurate demand estimates have to be for decision-making. Actually I am in a unique position. I am a researcher that escaped and went into the transit industry to try to do something there; and, of course, I have been meeting all kinds of obstacles. However, I do have an opportunity at this time, thanks to one of Joseph Silien's research projects, to disaggregate the market data by using an old survey and to start reaggregating it on the basis of data needed to plan a system. I have discussed transit planning that is concerned with conventional bus, conventional rail, new modes, and new systems of bus.

We are about 8 percent complete. We have a lot of problems disaggregating the data, and we are having a lot of problems reaggregating it. We are doing this from 2 points of view: One is the theory of good analytical procedures; the other is the decision theory of the transit operator. He has to be able to take this information from my group and make sensible decisions. He is going to put his political risks on the line. I hope I am not going to take half of the political risks to the point where he gets fired and I get fired.

There has not been that much good marketing work going on in the transit industry. The few marketers who have had experience with conducting a survey and with the actual behavior when a new service was introduced are still available to us. Unfortunately, the tendency of people to talk loosely tends to affect the quality of the survey. We need to have more information on the relationship between the responses in a survey and actual behavior. This problem becomes even more acute if the data are disaggregated.

Quite a few people have said that there is a lack of theory. I have not felt that in my experience. There are quite a few pieces of theory around in terms of decision-making, model making, and demand projections. Possibly what we need to do is synthesize them. The first theory relates to how people desire their life styles and what their self-images are in relation to the world. This theory treats people's activities—how they choose to live and how they make their day-to-day decisions. The second theory is the theory of the system itself as it relates to linking people's opportunities. That theory was available quite a few years ago. Essentially, the elements are available, although it would take a 3- to 4-year work program to develop a comprehensive theory.

Raymond H. Ellis

Did demand estimates have any influence on the selection of Haddonfield as a choice for a demonstration site?

Arthur Schwartz

Haddonfield was chosen partially because it is a very adjustable site. It is possible to expand the size of the area. If we find from our initial surveys that we should expect a relatively low demand per person per household, we would have to cover a larger area. We did not do any specific presite selection demand surveys.

We did, however, have some criteria for choosing Haddonfield. We were looking for a community where we might expect the following "demand indicators": (a) a combination of a central area that has some commercial content, and (b) a rail service to a major activity center, either New York or Philadelphia, that draws substantially large numbers of people and has a real parking shortage. If anyone wants to know the definition of parking shortage, it is when people start climbing curbs in the morning trying to find places to put their cars. Add that to your theory of demand.

GENERAL APPLICABILITY OF DEMAND-ESTIMATION PROCEDURES

Raymond H. Ellis

Is it possible to take the General Motors model and use it in Haddonfield?

H. J. Bauer

I think that in some respects it could be used there.

Richard L. Gustafson

We could have applied particular concepts in the model that we used to survey a particular community for developing some sort of idea of demand. There are obviously other aspects of the theory that were brought out in this particular attitudinal survey that might also be applicable to the problem of selecting that sort of area for a demonstration project.

Raymond H. Ellis

Would you have recommended this expensive data collection effort in Haddonfield in order to use this approach? Would you have had to reproduce all of your surveys in Haddonfield?

Richard L. Gustafson

We would not have had to do as extensive a survey as we did. One of the objectives of our research was to develop the tools and techniques for determining ridership as well as other aspects of user preferences.

Kenneth W. Heathington

I think one thing that is not firm at the present time is that the city selected by General Motors for the survey work will necessarily have the same preferences or scales of value as Haddonfield. The model formulations might work quite well, and I believe they would, but I am not sure that one can take the results from this particular city and transfer them directly to Haddonfield.

Richard L. Gustafson

I did not say that; I said only that it did not have to be as extensive.

Kenneth W. Heathington

This is what we do not have much information on and where we are really deficient in theory. We do not know how much is transferable from one area to another.

Arthur Schwartz

I want to point out that the example the General Motors people have already used is the one very serious shortcoming of all attitudinal surveys. When we confront someone with something that they have not experienced, how do we, in the short interview, try to make real to some person the concept that we are trying to evaluate. For example, the GM survey revealed a negative reaction by the people to zone fares. I do not think any of those people had ever seen a zone fare. They had no idea what the question meant.

Joseph S. Silien

We think General Motors has made a radical contribution in conducting this series of surveys. We are conferring with them, asking for their help in designing or commenting on, at least, the survey that we plan to take in Haddonfield, and using some of the techniques to get an estimate of demand. We started with the known demands of the number of people passing through the turnstile at a station on the rapid transit line. We also know the number of parking spaces available. We can predict with some certainty that more people want to go to that station than can get there. In that sense, the demand was considered in choosing Haddonfield as opposed to some other place along the line.

Raymond H. Ellis

Would you say that some of the discriminate models and logit models could be generalized with additional data for another city?

Joseph H. Stafford

We deliberately tried to do that in the work that Arnold Soolman did in Manchester, New Hampshire. We tried to develop reasonable estimates of the demand potential for that community of 100,000 by using data from the Chicago Skokie-Swift and the San Francisco Bay area. We did it on the basis of what I might call willingness to pay for a minute spent in a particular kind of activity or an environment. We used this sort of willingness to pay, in cents per minute, for the environment of the automobile in commuting trips or the environment of home, that is, getting home quicker or time spent walking and waiting versus being in the vehicle. Some of this same kind of data and some things that Lamb did in the Toronto parking garage selection were used. We built a reasonable estimate of what people would be willing to pay for dial-a-bus service that offered door-to-door travel to the member of the household who had the family car available, the member of the household that would need a second car in order to make these trips, and the potential serve-passenger trip-maker (a person who does not have a driver's license and who would have to rely on somebody else in the household). Clearly, there are weaknesses to this kind of deduction from all these other pieces of research that have been done. However, it did not look all that bad when we got it back together in terms of the aggregate and checked it out against what was actually going on with the fixed-route system there now. So, yes, I think we do feel reasonably comfortable about generalizing to other cities, but there is a difference between being reasonably comfortable and being sure.

Raymond H. Ellis

There is a question here of how much reliability we can place on our estimates. I want to offer one piece of evidence that I was struck by—a comparison of our work and the General Motors work. We looked at the demand for a demand-actuated system in a new town. Using essentially a technique that dealt with the attributes of the system, particularly the fare level, overall travel time, and waiting time that a person is going to encounter, we estimated the diversion to a demand-actuated system. The attributes were a 20 cent fare versus the 50 cent fare used in the General Motors study, roughly 2.3 times the overall travel time, a little higher than the number used in the General Motors study. On the other hand, the waiting time was somewhat smaller than the General Motors study. Overall, we roughly estimated that between 16 and 17 percent of those trips remaining within the community, equivalent to the definition used in the General Motors study, would be made on the new system. I was struck that this was fairly close, considering that these 2 approaches involve fairly different viewpoints. Our fare was lower, and waiting time was lower also. However, travel time was somewhat higher.

H. J. Bauer

Your net result was, from the user's point of view, probably a slightly better offer than the one we used.

VALUE OF TIME DIVERSION MODEL

W. Donald Goodrich

I have a different application of the value of time approach from that discussed by Joseph Stafford. At United Aircraft, we used a value of time analysis to do a demand estimate from the standpoint not of the operator but of the manufacturer. We did it primarily because it was expedient. The project is the helicopter access to San Francisco International Airport. Naturally, the corporation was interested because there was a potential customer, a company, incidentally, that has gone bankrupt since that time. We based our model on the characteristics of the operation itself: the flight time, the fare level, and the waiting times for the 8 heliports that were in existence in San Francisco. Also, we did some disaggregation of the 9-county Bay area in the sense that a matrix was overlaid, a demographic description was made of San Francisco to the extent that we identified where air travelers would be, and the income attributes were identified of those neighborhoods in which we inferred a value of time. Then we had a bimodal-split model, which we were bemoaning but which we were fortunate enough not to have to go beyond, wherein the air traveler could use the road system to gain access directly to the airport or he could use the road system in some way to gain access to the heliport and fly to the airport. By some quirk of fate, and somewhat to my distress because I have not put much credence in the value of time approach before this, 7 of the 8 heliports came within a tolerance of ± 1 percent of the actual demand in 1968. For the eighth heliport, San Jose, our predicted demand far exceeded the actual demand, and we did not know why. We still do not know why; and, of course, then the project lapsed, and we may never know why.

Arthur Schwartz

I would suggest that it might be the alternative air service available in San Jose.

W. Donald Goodrich

Much of this was taken into account in distributing the total air traffic in the Bay area among the 3 airports. We did a time lapse analysis in both 1968 and 1970 in allocating this total traffic. This research is reported in another paper. A simple approach was used to compare these actual data and, interestingly enough, it did come fairly close to reproducing what actually happened in that year.

Clark Henderson

What kind of values did you use?

W. Donald Goodrich

We did an income survey for 81 cities in 9 counties throughout the Bay area and developed a probability distribution on income, which we specified as having the characteristics of a log normal distribution. We had 91 distributions and, in fact, 783 points that were populated and accessible by road. The 91 distributions were spread over those 783 points. The distributions represented the income distributions of the total population of the Bay area. We wanted to know the income distributions of the air travelers, a subset of the total population, of course. Using some University of Michigan data, we arbitrarily factored the hourly income data (equal to annual income divided by 2,000) by a factor of 1.6. We used that as the distribution of the value of time, so that those having that value of time or greater represented the percentage of the air travelers from that mode who would select the high-priced but high-speed service. I cannot tell you the number from any mode because it depended on the relationship of the access time and cost by automobile and the access time and cost by the automobile and helicopter combination, as read on that distribution.

DIRECTIONS FOR FUTURE RESEARCH

Joseph H. Stafford

The question regarding where we are going in terms of type of demand work ought to be divided into 2 parts: Where are we going from here? and Where do I wish we were going from here? Where we are going from here is that Rodney Plourde and Eduardo Aldana are going to finish their theses, and I do not see anything else happening on the horizon. Where I would really like to go from here is to be able to get some more data of the sort we were able to get from Mansfield. These were very disaggregate kinds of data on choices people actually made for systems having attributes somewhat different from anything we have observed before. We could then begin to infer back from these data and gather new sets of information on willingness to pay to be in different environments and different activities by different people at different times of the day. I frankly do not see that happening soon.

Karl Guenther

In my point of view, the first thing that we would like to do is to continue to do what Joseph Stafford has suggested—providing more data to people who know how to use it. I might mention that we have a whole analysis department associated with our Transportation Research and Planning Office. I do not pretend to speak for what they are doing in transportation demand, but we do have 2 very capable people addressing the problem from a general point of view, that is, the new-mode problem, as earlier phrased.

Richard L. Gustafson

We also have our expert, but in our model we are developing attributes attaching an importance vector to these attributes, and moving from this line with an importance estimation model. This, of course, would be done for an abstract mode. Moving along those lines, we have been working with the mathematics department on some complicated problems with this. We have come up with a new method just recently, which is presented in another paper. We hope with this new technique that we may be able to program and come up with some reasonable and viable method of measuring abstract attributes and the importance of these attributes for estimating demand for an abstract mode or a third hypothetical transportation mode. This is the major work on demand models that we will be doing.

Kenneth W. Heathington

We start collecting data this month, and we are going to do a little modeling. We are at an advantage because many of the system attributes that other studies have found are not important. We have been able to eliminate and thereby reduce the costs involved in the demand modeling aspects. We are looking at levels of service and flexibility of pricing. Another project that we will begin later includes looking at more behavioral, very disaggregate models in terms of forecasting demand for specific trips or activities.

Daniel Brand

Just to counterbalance all the emphasis on data collection—experiments of our demonstrations of dial-a-bus—I think we need a theory of consumer behavior in the travel demand field. We need to develop hypotheses on the important variables that influence behavior from the standpoint of the trip-maker, the trip purpose, the characteristics of the trip itself, and the characteristics of the choices that are available to consumers, in this case the trip-makers when they make trips. We need to try to characterize the attributes in all these areas, form hypotheses as to these attributes, and collect the right kinds of data to test these hypotheses as opposed to perhaps congratulating ourselves, with all due respect, that we have dial-a-bus experiments going and that we are going to collect perhaps a limited subset of after data. We should be collecting the appropriate kinds of before-and-after data in line with the hypotheses. This is the scientific method. This is really the route that we should follow.

Raymond H. Ellis

I would like to second this. I know of only one fairly large-scale before-and-after study that has been undertaken in the country and that was the one for airport access when the rapid transit line was extended to Cleveland airport. Having that sort of information as a base does allow one to do things that one simply would not otherwise be able to do because of methodological problems.

Arthur Schwartz

I would like to bring us back down to scale with essentially William Howard's comment that it is cheaper to run the experiment than it is to run the survey. In this particular area of public transportation experimentation, unlike many that require substantial initial investment, the costs are relatively modest and the unrecoverable capital costs are even more modest. I would say that we are dealing here with an area where there is a large incentive to risk experimentation rather than to spend all our efforts on pre-analysis.

William T. Howard

In spite of the fact that I did get a scattering of applause when I made a certain statement, I would not think it was unanimous by any means. I just wanted to assure people that we do not intend to continue with this shotgun approach. I am sure that a lot of the work that has been done in demand modeling will certainly be used.

Joseph H. Stafford

I would like to react briefly to the comment that it is a low-cost thing and that it makes sense to experiment rather than to take a great many surveys. In any one specific case, I quite agree with that. The additional information we gain from many surveys could not help us make a much better decision in that specific case. However, one of the real beauties of this kind of low-risk experimentation is that, if it is done correctly and we set up the hypotheses, as Danield Brand suggested, and test them carefully, we can gain a lot of information that will be very useful to us in high-risk things like automated guideways, dual modes, and moving platforms. That, I think, may be the much more crucial issue in terms of our surveys and our demand modeling efforts.

Kenneth W. Heathington

I think that most of us who are familiar with traditional modal-split analysis and things of this nature can look at what has been done and almost argue that any first-year student of numerical analysis can fit the data. That is no problem. All one has to do is to plug in some control cards and data that will fit and one can make it come in within 1 percent, if one really wants to fudge it. It looks like there is absolutely no causation or causality or anything to this effect in the methodological formulations. There is very little sound theory. We come in after the fact and we begin to build models and say this describes the phenomenon. Does it really? It does in one sense describe the phenomenon. However, to be able to use that to forecast what will happen in another situation is completely different, and I think we are foolishly risking our attempts by looking at the effects afterward. We need to look at them before, and we need to calibrate the models and look at them afterward. Otherwise, I do not really have much confidence in the methodology.

SEMINAR ON SYSTEM ATTRIBUTES AND PERFORMANCE

INTRODUCTORY COMMENTS

Daniel Brand

The subject of this seminar potentially overlaps the subjects of each of the other seminars. Therefore, the diagram shown in Figure 1 (with apologies to the conference organizers and other seminar leaders) may yield a sharper and more productive definition of our topic. The diagram is not intended to be a complete analysis framework for planning innovative demand-actuated transportation systems (DATS). Rather, the boxes and arrows show how the subject matter of this seminar relates to the subject matter of the other seminars.

When we talk about attributes and performance (1 in Fig. 1) of demand-actuated transportation systems, we are describing supply characteristics as opposed to demand. We are defining and characterizing the transportation and nontransportation outputs of the demand-actuated system. Values for these are estimated by simulation (10) as a function of the system design and technology (7), including operating policies, capacities, network characteristics, control schemes, and regulations as well as pricing policy (8). The latter, pricing policy, is the subject of another seminar. System attribute and performance values are also a function of the usage of the system, as shown by the feedback loop from demand (2) to simulation (10). Finally, we are not concerned with whether the impacts are good or bad. This is covered from both the economic and system points of view in later seminars.

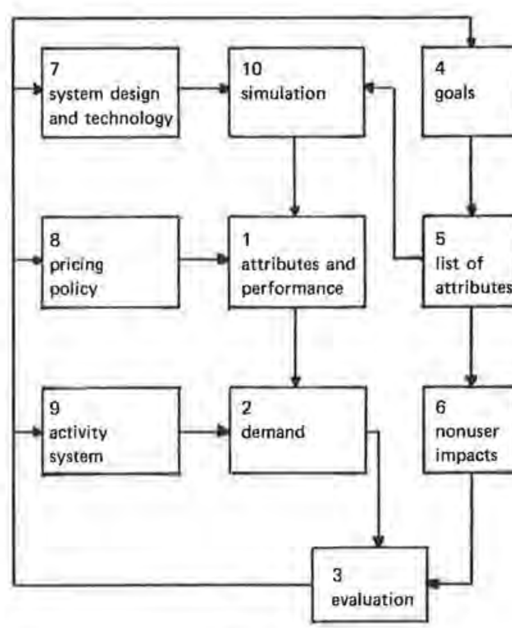


Figure 1.

One important way to define attributes and performance is from the point of view of the user. That is, the simulation (10) must output attribute and performance measures defined consistently with what drives consumer (traveler) behavior. This requires that the behavior of travelers be characterized in terms of their values and responses to the choices open to them. An important objective in this seminar, therefore, is to define and describe the choice variable of DATS, namely the DAT system attribute and performance variables, in terms of how they relate to demand (2). (We are not demand modeling, however. This was the subject of a previous seminar.)

A second important way to describe the attributes and performance of demand-actuated transportation systems is in terms of their nonuser impacts (6), that is, how their impacts on the environment and on suppliers of transportation and other services are viewed by nonusers. Thus, we are concerned in this seminar with attributes and performance from 2 points of view. We want to discuss hypotheses and research results as to how the attributes and performance of demand-actuated transportation systems affect users and nonusers of these systems.

We begin with a discussion of the attributes and performance of innovative demand-actuated transportation systems from the point of view of nonusers. These are the impacts on users of other transportation systems, on operators of transportation systems and subsystems, on persons and the environment near the system (or formerly occupying the same space as the system), and on government.

NONUSER IMPACTS: OPERATOR AND GOVERNMENT

Daniel Brand

To assess the impact of innovation on an industry, we often find it useful to go back a bit into history to see how that industry evolved. Richard Solomon did just that with respect to the transit industry as part of the CARS Project at M. I. T. (1).

Richard J. Solomon

Most of the men who guide the transit industry today either were founders of the bus systems that they still head or were young assistants in electric street railway companies that evolved into today's transit operations. In other words, the current generation of transit operators is also the generation that introduced the last major innovation in transit, the motorbus.

The modern bus was widely introduced in this country between 1925 and 1936. However, a gestation period of some 10 to 15 years before that time set the pattern for the last 40 years of transit development. Had the, even then, currently prevailing forces of urban development been clearly seen by the transit industry, perhaps public transportation would have followed radically different lines of development. As it was, it was not technology that guided transit development but acquiescence to certain sociopolitical forces that guided technology. We want to avoid the same thing happening to the concept of computerized dial-a-bus as happened to many other transit innovations during the years.

As in any prosperous industry, transit tended to be quite conservative toward innovative practices at the beginning. Any departure from the standard or any new method of carrying passengers on a common-carrier basis was (and still is) viewed only as a threat to the existing infrastructure and not as a way to offer better or more desirable service to the public (and perhaps gain a larger share of the urban transportation market).

Prior to 1912, electric street and rapid transit railways were prosperous monopolies carrying almost all urban passenger trips. Per capita ridership on street railways rose faster than the urban population until the end of World War I; hence, investments in those days in street railway companies were extremely attractive. Most street railway operators anticipated that ridership and earnings would increase indefinitely as population grew; costs were expected to decline as utilization of their investments increased.

Given the absence of competition, there seemed to be no reason for operators to change practices. Franchise laws also prevented established operators from trying new types of service or equipment. For instance, most operators had to have new laws enacted simply to permit the introduction of motorbuses, or even to reduce the crew on streetcars from two men to one. Because fixed routes, a single standard of service, and generally inflexible fares are still part of the transit scene, we expect similar problems in the implementation of dial-a-bus beyond the federally sponsored demonstration stage.

Daniel Brand

Are there any historical precedents, for example, jitneys, for this gloomy prognosis?

Richard J. Solomon

The history of the jitney and other similar "nonestablished" carriers shows this. Jitneys have challenged traditional transit operations in one form or another to the present day, even though the industry often has pretended that it was regulated out of existence. The jitney is quite relevant to the dial-a-bus concept and is the basis for existing motorbus systems as we know them today.

The first jitneys were modified 5- or 6-passenger touring cars used for common-carrier service between some western American cities in 1910. They were essentially motorized stage coaches and were initially ignored by both the regulatory bodies and the railroads. An early urban operation was between central Los Angeles and several suburban towns in 1911. A 5-passenger Ford Model T would cruise along the route of a downtown trolley and, for a 5-cent fare, pick up passengers who were destined toward some suburban location such as Long Beach. A practice was made to deliver these passengers as close to their destinations as was deemed feasible without a major diversion for the other passengers—an intuitive premonition of the one-to-many dial-a-bus algorithm.

Instead of trying to compete by introducing better and more varied public transportation services, the transit industry's response to the new competition was to regulate it out of existence. Legislation in most cities by 1920 temporarily reestablished the public transportation monopoly position of the electric street railways. Almost every city had some form of restrictive anti-jitney bus ordinance, usually with franchise rules for fixed routes to be established according to the determination "of public convenience and necessity." These regulations still exist and may prove to be a major stumbling block to the implementation of new systems without major new legislation.

Daniel Brand

How did the street railways around 1920 perceive the automobile as possible competition?

Richard J. Solomon

When the street railway companies wrote their franchises, they could not conceive of any urban transportation technology becoming viable other than street railways. They even resisted electrification until the economics of horse-drawn vehicles began to overwhelm them and financial interests forced the issue.

Daniel Brand

What were the attributes of jitneys that made them so attractive so early as an urban transportation mode?

Richard J. Solomon

The main attributes were frequent service along corridors, seats for all, and occasionally door-to-door operation. Some say "personalized" transit. Jitneys had a resurgence during the 1930's. There were probably 2 major reasons for their reappearance. The first one was the same unemployment pressures that spiked the original jitney boom. In addition, urban travel was reorienting itself spatially, temporally, and quantitatively, and the conventional transit industry was not changing its routes and services rapidly enough to meet new demands.

Daniel Brand

What existing institutional problems now work to prevent the introduction of, specifically, dial-a-bus?

Richard J. Solomon

No matter what we think of dial-a-bus, and where it fits in the public transit spectrum, the industry will look at dial-a-bus as its competition and not as another tool to compete with the automobile. The regulator may look on dial-a-bus, though, as another form of transit but not the way we might think. Let us use a recent example of Monarch Associates that until recently leased minibuses for car pools in northern New Jersey and Rockland County, New York. They put the car pools together and then leased the vehicles making it very convenient to get into a car pool. If you changed your job or your residence (in their territory), they would attempt to put you in another car pool. By acting as an organizing agent, as well as a leasing agent, they managed to avoid many of the problems of car pooling. However, they were also in the public transportation business as innovators in a very real sense. For obscure reasons, they decided to go to the Interstate Commerce Commission to get permission to run their service. The ICC did not know what to do with them because the mode did not fit under the rules. The ICC suspected, however, that Monarch was doing something wrong and, therefore, said, "You can't do it." Monarch is appealing this in court. The first thing is that the court will have to decide what kind of "mode" Monarch has, and it will turn out to be a bus. If the court cannot think of anything else, then it will consider the mode a bus in terms of how it competes with bus lines and not how it fits into the total urban transportation picture. [Since this conference, that is exactly what the court ruled. Monarch was permitted to operate but only as a bus route with defined corridors. Monarch has since discontinued this business because of heavy losses incurred from the change of operating practices to a conventional system.]

Daniel Brand

A worthwhile project would be to differentiate in clear terms the service attributes of the various modes and submodes. In particular, we should differentiate how dial-a-bus separates itself from fixed-route and scheduled service and from taxis and private cars, i.e., where it falls into some heirarchy of modes.

Richard J. Solomon

We must not fall into the same trap as legislators, regulators, and operators. Legislators say, What kind of mode are we going to regulate today. Then they set up an agency like the ICC, which has jurisdiction over some limited set of modes. Then that agency assumes it has authority over everything, so as not to dilute its authority. Is that what we want from regulation? We want to encourage the lawmakers to think in terms of functions of service, reliability, and safety instead of the technological details by which we now name modes, i.e., bus.

Daniel Brand

Therefore, in addition to specifying the important attributes, we need somehow to name the modes and keep all the information together for purposes of identifying the mode. That is, the attribute values will really be mode (i.e., activity of riding on the mode) specific. We must not be so naive as to be completely abstract and use only service characteristics in our identification of modes. There are many instances where it is convenient if not necessary to know the technology involved.

Kenneth W. Heathington

We had a similar instance recently of overregulation in Lafayette, Indiana. A private travel agency purchased 3 or 4 limousines a few months ago to run a limousine service between Lafayette and the Indianapolis Airport. The limousines ran about 3 times a day for about a month, and then the agency suddenly found that it came under some existing regulations because the limousines were for-hire. The Greyhound Bus Company, which has no service whatsoever between the Indianapolis Airport and Lafayette, protested. The railway companies also protested, and they have almost no passenger service whatsoever. To our amazement, the airline companies also protested. So, the service was put out of business but not because of anything related to the system performance. When we look at dial-a-bus or for that matter any other transportation innovation, we must realize that the courts and the regulators are going to deal with these matters in strange and different ways.

Daniel Brand

It appears, therefore, that we need to bring some hard evidence to bear in such cases. But what kind of evidence? Perhaps we need to know how these innovative transportation modes differ in terms of their effect on the travel market. We need to be able to specify or isolate the different travel markets so that one can argue in court that these are different kinds of services. Before we can do that, however, we need to know a lot more about how the range of attributes affects users and nonusers.

IMPACTS ON NEIGHBORHOODS

Daniel Brand

Let us leave the government area and discuss another nonuser impact of interest, and that is the impact on neighborhoods. What would be some dial-a-bus attributes and their effects on persons who live on roadways having such service?

H. J. Bauer

My comment has to do with DATS vehicles in residential areas. I think this is one case where the nature of the vehicle is going to be a detriment to the whole concept. People build cul-de-sacs and pass local legislation to preclude through traffic. They even go so far as to build barricades across streets to restrict travelers to main arteries and prevent shortcuts. We must be very aware that people, users as well as nonusers, are going to be very sensitive to the running of these "commercial" vehicles in their neighborhoods where children are playing on streets and sidewalks. I would like to ask Harriet Curd if she remembers from our GM surveys the response to the question of how people feel about the various kinds of vehicles coming into residential neighborhoods.

Harriet N. Curd

In general, people liked a smaller bus and a stylish vehicle.

Daniel Brand

Did you also look at the problem of vehicle size and style from the standpoint of the user in these neighborhoods? One envisions conflicts between user and nonuser design requirements. That is, from the standpoint of the nonuser, the buses should be as unnoticeable as possible, and looking like automobiles might be the norm. From the standpoint of users, however, perhaps big conventional buses that stand out and are noticed by nonusers would lead to later increases in usage by these same people?

H. Norman Ketola

We have been concerned with small vehicle design for a number of applications, dial-a-bus being one. To date, our ideas call for a vehicle that is able to go into any residential area and be unobstrusive and accepted. We have spent a good deal of time with communities, with operators of transit systems, and with people who may be considered potential users of the systems. I think that they all definitely want a small vehicle, both exterior and interior. This is going to be extremely important in selling the dial-a-bus concept and other advanced concepts for bus transit in residential areas.

Daniel Brand

It appears there may be arguments for a vehicle that stands out and is a traveling advertisement for the service and that is also unobstrusive.

Arthur Schwartz

Regarding acceptance by local residents, there are 2 criteria that really have little to do with visual appearance. These are that the vehicle be small enough to operate in a residential area without having to back up twice to make turns or otherwise tie up traffic and that the vehicle be quiet. It should not shake all the houses as it comes down the street, and, when it accelerates, it should not produce large clouds of smoke.

Daniel D. Morrill

I know of a city that runs 45-passenger, GM buses on as many of the residential streets as can be negotiated. There have been no complaints to my knowledge from nonusers about the presence of the vehicles.

Arthur Schwartz

All of the attributes we have discussed are important and desirable, but here is one example where they have not been implemented and nobody has complained. We should remember that frequency of appearance is also important. If something happens once a day, people are not likely to complain. If something bothers them every 5 or 10 minutes, they are much more likely to complain than if it bothers them every hour or half hour.

Frank L. Ventura

I would like to list some attributes that would be of concern to the nonuser: noise, vibration, pollution, intrusion into the tranquility of the residential area, scale of the vehicle, safety, and speed. I feel that we would have a mild revolution in some residential areas if a Greyhound type of vehicle were to come pounding down the pavement every 15 minutes or even every hour or two. People have adjusted to the size of the car as being in scale with their own immediate environment. I think we have to get a vehicle more on that scale. In new developments, the lots on cul-de-sacs sell first and the lots on short loop streets sell next. Why? The residents do not want any traffic that does not belong there. Speed is also another safety consideration.

Daniel Brand

I have small children who sometimes run into the street. I am always mad when I see a car going by too fast.

H. J. Bauer

In fact, in some areas, there are bumps deliberately built into the streets near the corners to curb high speeds.

William T. Howard

Let me introduce one other dimension on the plus side. From experience, we know that, prior to 1967 in the Bay Ridges area of Toronto, homes could barely be given away. After the introduction of the GO transit rail service, the home values increased by as much as 50 percent. I think the nonusers of DATS in this area who might otherwise want to complain about the increased use of streets by dial-a-bus will think twice because I am quite sure they expect another 50 percent increase in their property values.

Karl Guenther

We experienced something quite the reverse of what some of you seem to be saying. The Woodland DATS vehicle is a different color from the rest of the city buses in Mansfield. It was immediately adopted by at least a portion of the residents as being their bus. This includes users and nonusers. We have had a lot of people walk up to the thing as it is sitting on the main downtown square and talk of it as being their bus.

William F. Kail

It appears that most complaints in residential areas come from women. I seriously doubt that men will complain. For one reason, they are not home all day, unless they are unemployed. For another reason, women are primarily concerned with safety for children. At home I get two complaints from my wife. One is the noise from the motorcycle that goes up the street, and the other is the speed of the contractor's trucks going up and down the road. She is concerned about noise and safety. It may be wise to take a look at what women think in regard to dial-a-bus vehicle design.

Kenneth W. Heathington

I would also like to share a few personal experiences with my neighbors. We live on a street on which one of the greater Lafayette (Indiana) buses travels. The buses were probably purchased in 1910. Although nobody, so far as I know, from the neighborhood goes out and complains to the city (who now owns the transit company), they still come to me and say, "Gee, look how dirty the thing is and how bad it looks. Can't they have a better looking design? Why does all this smoke have to come out of it?" There is an underlying theme to their complaints: There is something better that can be done. I do not think their dissatisfaction is at the point that we will see protesting and signs and things of this nature. However, we should not wait until people march on city hall or the bus company with signs of protest.

Joseph H. Stafford

This raises the point of the image of the conventional transit coach. It has not changed, and that carries over in the name "dial-a-bus." We might keep that in mind in the use of that name for the system.

Edwin H. Porter

One thing we sometimes miss when we talk about dial-a-bus is that it is not yet a system. It is more a concept. The flexibility of the concept does not get stressed enough. We tend to think of dial-a-bus as always being implemented on a massive scale—a many-to-many mode. Well, you can do that, but it is so flexible that you can cheaply change the route. If a neighborhood decided that it did not like it, you could say there are no subscribers in that area. Then, if someone wanted it, he could argue with his neighbors to let it come in. This relates also to the transit union's concerns. It is concerned that dial-a-bus will take away the line-haul, fixed-route bus business. It does not need to be. In fact, dial-a-bus could be used to test where line-haul buses ought to be established on the basis of demand for dial-a-bus. I think we should stress flexibility more. You need to know exactly where a railroad goes because after you have put it in you cannot change it. However, dial-a-bus is so flexible that for a relatively modest investment you can put it in service in a neighborhood.

Daniel Roos

When we talk about the impact of the vehicle on the neighborhood, we should also look at the reverse problem, What is the impact of the neighborhood on, not the vehicle, but the people in the vehicle? A typical situation in most cities is a poor neighborhood located next to a relatively affluent neighborhood. I think people choose to use or not to use transit partly because they know where they are going. For example, in Boston, I suspect very few people who boarded the transit vehicle in a $50,000 neighborhood would use the system if there was a strong probability they would find themselves in the middle of a ghetto. This will have considerable impact on whether people do or do not use the system.

Richard J. Solomon

I want to underline what Edwin Porter said. The flexibility we are introducing with dial-a-bus can change our concept of public transportation. Dial-a-bus can be fixed route, but it does not have to be fixed route. Jitnies were flexible until they got lumped into the categories of old mode names. Maybe if we emphasized flexibility, public utility commissions might change their regulations so they are functional and address the market, and not only from the suppliers point of view, i. e., the number of wheels, seats, or windows or other arbitrary rules.

Eugene T. Canty

Before we leave this topic, we should reemphasize the point that Frank Ventura made about safety. The operation of DATS vehicles through residential streets will be drastically different from that of conventional buses on fixed routes on arterial streets. There are a number of reasons: There are not necessarily markings on the roadways, there are more likely to be children playing on residential streets, and so on. I think this has a significant impact on desirable vehicle design, in particular, the amount of driver vision. Although the preferable design that we exhibited was called stylish, the primary attribute of this design was the large glass area, not just the above-belt line but in a wide area, vertical and horizontal, at the driver's position. At least a 270-degree horizontal and a large vertical aperture is important to be able to see the edge of the road, curves, children, toys, and what not on the roadside. I think also that the concept of pulling into people's driveways and backing out is a very bad and a dangerous tactic. A large number of child deaths are caused by automobiles in driveways now.

IMPACTS OF HIGHWAY CONGESTION, LAND VALUE, AND LAND DEVELOPMENT

Daniel Brand

A final area of nonuser impacts is the systems effects of dial-a-bus. Dial-a-bus cannot be viewed in isolation; it must be viewed in terms of its effects on users of the larger transportation system. Without getting into the attributes that affect demand directly, can we make any generalizations now as to the network effects of dial-a-bus? For example, will dial-a-bus relieve highway congestion? Is dial-a-bus the kind of congestion-relieving panacea that fixed-route and scheduled transit (e. g., rail transit) was once thought to be (or perhaps still is thought by many to be)?

Frank L. Ventura

In our study of the benefit that might be realized by our case study community with implementation of a D-J system, we discovered that the diversion of automobile rides to D-J was not high. The 2 or 3 percent of automobile passenger diversion would not provide substantial traffic congestion relief. As far as a decision-maker is concerned, his decision to go for this type of system should not be based on potential traffic congestion relief.

Daniel Brand

That is an excellent introduction to the problem and one with which I and perhaps others can agree. However, if what you say is true, how does dial-a-bus affect land development and land value? It does not seem to do this through changing the travel decisions of vast numbers of automobile users.

Daniel Roos

Regarding the question about the effect on development, I think one principle of dial-a-bus is that it does not affect development, it responds to land development. So often we planners and transportation engineers sit down and say it shall be this way and I will put a transit route in here and this marvelous thing will develop around it. I think people and things affect development. That seems to be what is occurring in society today. The problem is to provide transportation facilities for that type of development. For certain types of development, dial-a-bus is ideal, regardless of the final form of the development. Regarding the question about relief of automobile congestion, I agree very much with what was said by Frank Ventura. However, when we talked to people from planning organizations in larger cities, some of them referred fondly to their dream of banning automobiles from downtown. They thought that dial-a-bus offered the first hope that they might be able to do this. So given dial-a-bus, one could in fact legislate a decrease in congestion. I do not suspect that this will happen in the near future, but it is always a possibility.

Kenneth W. Heathington

In one preliminary study, we found that diversion to DATS would be one automobile per lane per hour. This indicates that we would not want to argue for dial-a-bus as offering relief of congestion on busy streets. I myself do not think this is a consideration. There are many good uses for dial-a-bus, but relieving congestion is not one of them.

Frank L. Ventura

In fact, it might add to congestion if the vehicle were permitted to stop at every corner along every thoroughfare. Because there is normally no provision in these kinds of roadways to stop without interfering with traffic, the frequent stops would reduce the effective capacity of that particular lane and result in added congestion, if any exists to begin with.

Fred Tumminia

Dial-a-bus is a functional vehicle that is useful for filling some gaps in providing efficient transit service. On the question of efficiency, I think dial-a-bus is going to succeed because it services certain travel needs in a more efficient and functional manner than other vehicles. On the question of institutional constraints, there should be federal support for removing constraints on the use of transportation vehicles by one regional operator. A regional operator should be able to operate every type of transit vehicle. The operator should be allowed to let efficiency dictate how he is going to meet the travel demands of the people. For example, if there are people who are not traveling because they do not have access to a private vehicle, they should be allowed to have access to a system that transports them in the time and at the price that would allow them to make their trip.

Daniel Brand

Perhaps, then, dial-a-bus is not going to affect land development by decreasing the time or cost of travel for large numbers of present automobile users. However, it may affect land value by offering a convenient and viable travel choice, for example, by increasing the availability and convenience of travel for "the wife and kids." Can we discuss the attributes of dial-a-bus in terms of this aspect of convenience of travel?

Arthur Schwartz

Yes, the principal effect of dial-a-bus on automobile travel will be to reduce somewhat the large number of automobile trips that are made for the purpose of getting a nondriver from here to there.

Daniel Brand

These are the serve-passenger trips.

Richard L. Smith

In new subdivisions or communities, one of the primary problems is the trips that the housewife has to make in shuttling children to and from school and making convenience shopping trips. Dial-a-bus service could fill a temporary need in a developing community where the density of trips is not great enough to justify scheduled service. The demand-actuated service could be instituted on a temporary basis to facilitate people moving out from boundaries of existing communities.

Daniel Brand

How did the developer of the new town of Columbia, Maryland, view transit service in general and dial-a-bus in particular? Did he have an expectation of additional payoff from transit in terms of selling houses more easily, for example?

Richard L. Smith

Generally, the developer of Columbia considers transit service necessary for drawing people to the community. People should be given the opportunity to use bus service if they do not have a car for convenience purposes or if they are teen-agers or nondrivers. However, the development of the new community demands a more efficient transit service in the future than dial-a-bus.

Robert D. Stevens

The initial planning of Columbia called for a scheduled bus system on an exclusive right-of-way. This has been used in the selling of houses in Columbia. Real estate salesmen display pictures of minibuses in advertising houses. There was quite a problem with possible misrepresentation of what the bus system was going to do and where it would be located in the neighborhoods. The expected bus service was greater than what was really there. I think they have resolved that problem. There was bus service but it was not really clear to the people whether it was only on the right-of-way or whether it would go into the neighborhoods. The original intention was just for service on the fixed right-of-way. However, the bus service had been advertised, and people were told they would only need one car. Some people actually sold their cars when they moved to Columbia. They have since brought another car, going back to a 2-car family.

Daniel Brand

Therefore, the presence of good transit service could affect the total cost of living in a new community by reducing the need for a second car. The resulting savings could be capitalized in the additional value of housing. People might pay more for a house or be more apt to pay the same price for a house, given the savings on a second car.

William T. Howard

The real estate ads in the particular area of Toronto served by the GO transit trial have gone one step further. They say now you do not need to own an automobile at all!

H. J. Bauer

In Columbia, the notion of the village concept was ordained initially to reduce the need for people to use anything other than their legs to get from home to the convenience shopping. Every village has a small general store. Walkways were designed to be separated from all vehicular traffic. One of the developer's ideas was to vitiate the need for a vehicular transportation system, as far as the daily lives of housewives and children are concerned.

Robert D. Stevens

An elaborate walking system was designed for Columbia to serve both the neighborhood and village centers. However, there still are, probably more than expected, a large number of short automobile trips to neighborhood stores. The parking demand at both the neighborhood center and the village center was greatly underestimated. The assumption was that people would walk, but people are not walking. They are driving.

Daniel Brand

The achievement for a true walking-scale community is going to require much higher densities than those currently planned for Columbia!

H. J. Bauer

And a lot of brainwashing!

Daniel Brand

We have spoken already about the longer run "travel" decisions related to car and residence purchases. Are there any other possible longer run consequences of dial-a-bus?

Eugene T. Canty

There are decisions in plant and shopping center location and layout that would be affected by increasing transit service by dial-a-bus. With increased transit service, employers can minimize parking requirements and locate their plants to be more accessible to people not owning or having access to an automobile. Regarding the potential increase in accessibility to shopping centers, it is possible to consider a subsidy of dial-a-bus operation by shopping center proprietors.

Frank L. Ventura

The relatively low land consumption by dial-a-bus could be of significant importance to cities that are hardpressed for vacant developable land. The relatively low land requirements of dial-a-bus could mean that there would be little or no displacement of families. There is also an economic impact in the sense that the community's tax is not decreased by the amount of land required for the system.

Eugene T. Canty

Another impact on neighborhoods is that dial-a-bus may allow for more heterogeneous neighborhoods. We found in some of our in-depth interviews substantiation of the notion that older people move from houses to apartments to a large extent because of mobility. I think mixing people of different economic and age levels in a community has positive value.

ATTRIBUTES OF SYSTEM OPERATION AFFECTING USAGE

Daniel Brand

Let us shift over now into the area of user impacts. Are there any hypotheses or results about operating procedures or performance of dial-a-bus that affect use of the system. For example, in the Northeast Corridor study it was found that standard operating procedures relating to business purchase of air tickets was an important determinant of intercity modal split. Are there hypotheses or results relating attributes of system operation to usage of dial-a-bus?

Kenneth W. Heathington

The length of time the system is in operation is one. We must have a system that is not just an 18-month demonstration. It must be something that users will consider to run for a long while. I think this has substantial impact on the long-run decisions people make regarding housing purchases, which in turn affect system usage. In my experience with the North Shore area of Chicago, I observed that buying a house along the railway was very important, particularly if one worked in town. Farther away from the railway, one had to pay for an extra automobile to get to the train station. Dial-a-bus feeder, on the other hand, on a long-run basis will allow families to purchase houses away from the stations at less additional cost. In other words, they would be more apt to take the money that would be used for extra transportation and put it into housing or land. The funds would be redistributed so it may not be as important to live as close to the station as before. I think we may see these considerable changes, and they are not short-term changes. They are going to evolve over time. We are going to have to have demand-actuated transit systems that are reliable and permanent, insofar as anything is permanent.

Frank L. Ventura

Another long-run benefit will be that those now without cars who are forced to live in the inner city where transit systems now exist will be able to live in suburban, lower density areas without fear of being without transportation. They will have greater housing opportunities.

Fred Tumminia

There could be more use of institutions because of the availability of dial-a-bus to gather people together. For example, when the mayor found that the Wax Museum in Philadelphia was foundering, he asked his transportation people to do something about it. I found the way that worked successfully was to go to the neighborhoods that had bus service and talk up the idea of the Wax Museum to women's clubs. We gave them the idea of going in groups, and we arranged car pools and special buses. This met the mayor's needs and aspirations for the Wax Museum.

Daniel Roos

Dial-a-bus is the one new transportation concept that involves new technology and that might be implemented in, say, a couple of years. Depending on how well or how badly we implement the first systems, we are going to lend credibility to the idea that innovation in transportation is possible, or we are going to set it back a good number of years.

Daniel Brand

In the New York area, which attributes of transit seem to affect people's choices of travel mode and travel routing decisions in a transit network?

Arthur Schwartz

An important problem not confined only to the New York area is economically providing feeder bus service with conventional buses to outlying commuter railways. We had several experiments in the New York area where we tried to provide a conventional feeder bus system in an area of good ridership potential, e.g., one having a rather high bridge toll. It did not work because, when there are 2 infrequently running services that have to be scheduled to meet each other, people are not willing to risk missing the connection. The person who arrives at 8:43 at a train connection that runs relatively infrequently cares very much if he missed the train that left at 8:40. I think that a flexibly designed dial-a-bus system can provide feeder service to such line-haul facilities. In addition, we find ourselves in a situation where the demand for transit service in the suburbs and smaller cities cannot be viably supplied with fixed-route vehicles. It is not a large demand. It is also not a demand that if not accommodated would cause the areas to fold up overnight. It is that the conventional bus transit service has dried up.

Daniel Brand

What are some of the characteristics of those markets?

Arthur Schwartz

One market is the station-to-home trip that is now made by calling up someone and saying, "Joe, come get me." There is a lot of this in a suburb of Trenton, where I live. If someone comes in on the train after the bus service has quit around 6:00 p.m., he can use a cab or he can call up one of his neighbors and have him come and pick him up.

Fred Tumminia

You would replace dial-a-neighbor with dial-a-bus!

Kenneth W. Heathington

We might see some behavioral changes in trip-making characteristics over a longer range period. A high-reliability vehicle coming to the door would allow putting a child on at the door and allowing him to be dropped off where and when he is supposed to be. He does not have to go to a bus stop and get on and off by himself. In this way, serve-passenger trips, such as parents carrying children to school, music lessons, and things of this sort, would be reduced or converted to single person trips.

ATTRIBUTES AFFECTING DEMAND

Daniel Brand

Let us switch finally and firmly into the area of attributes and their impact on demand. What are some additional results and hypotheses as to how attributes of dial-a-bus affect demand for the system?

Joseph H. Stafford

From the urban transportation planning surveys in the M. I. T. CARS study, about 15 to 20 percent of total automobile trips are serve-passenger trips. These trips serve people who for some reason are not driving an automobile. In most cities, an average modal split of 3 to 5 percent makes up the total bus system market. At the same time, perhaps 5 times as many trips are served by somebody else driving the automobile. Tapping this serve-passenger market may radically alter the break-even position of a bus company. What does it take to tap that market? We can look at this from the same perspective as other consumer expenditures. A whole host of convenience items like dishwashers, prepared foods, and wash and wear fabrics are a normal part of the consumer budget. Dial-a-bus is a convenience item in relation to this serve-passenger market. We can cast the demand for it in the framework of what we are willing to pay to let our wives stay home and do what they want to do instead of being chauffeurs. What are we willing to pay to save their time? The time in question is not just the value of time of the person who wants to go somewhere but also the value of time for the person who is going to have to drive him there, drop him off, go back home, and then go down later, pick him up, and bring him back—or go down and wait for the person! We can use the value of time-consumer choice framework to look at the serve-passenger trip as a separate segment of the market.

One other thing I want to suggest is disaggregating the different components of time. That is, we should calculate willingness to pay for minutes of time spent walking exposed to the elements differently from minutes of time spent standing at the curb waiting for a bus. This should be done in the context of willingness to pay for the opportunity to use the time in a different way. The Mansfield dial-a-bus experiment has been a unique opportunity to test the usefulness of this disaggregation. By looking at which households are walking to the bus and which are choosing to pay the extra 15 cents for door-stop service when all the other characteristics of the service are equal, we have a nicely controlled experiment. The average distance of door-stop users was about 800 ft from the fixed routes. There seemed to be a threshold of about 300 ft. That is, if residents (not domestics coming into the area) were within 300 ft of the fixed route, they did not use the door-stop service. This makes it possible to put things into some sort of cents per minute framework. I believe that they are paying 5 to 10 cents a minute to avoid time outside in the elements. There are limitations as to what could be inferred because we did not know the maximum waiting time, but the results check out with Lambe's figures of about 5 cents a minute. It also checks out with Lisco, Lave, and Quarmby's figures that the willingness to save time is on the order of 40 percent of the wage rate for time spent at home and $00 percent of the wage rate for time spent at home rather than in walking. In summary, people are willing to pay quite a bit for a higher quality service that prevents their having to be out in the elements or to stand at a stop, even if it is close by!

Arthur Schwartz

I must object slightly to your assumption of equal availability to 2 classes of service. There will be an incentive to use the new service because the introduction of the dial-a-bus feature means the times of arrival of the bus at fixed-route locations are not as exact as they were before the dial-a-bus service. There will be 5- or 10-minute variations on the fixed-route arrivals. A rider must now walk to the regular stop to arrive at the earliest time the bus could possibly come, with the expectation of having to wait a few minutes.

Joseph H. Stafford

I quite agree, although there was some variation in the arrival time before. Nonetheless, making allowances for this, we concluded that roughly 5 cents a minute is what people are paying in this Mansfield neighborhood for not walking and waiting out in the elements.

Daniel Brand

What do the Mansfield results indicate about how dial-a-bus diverts riders from transit relative to diversion from automobiles? Also, do you have anything on induced (new) trips from the Mansfield results?

Joseph H. Stafford

The data we were working with are for households rather than for trip-makers, so we must be very careful about what we conclude. Karl Guenther has also recently worked with these data. There appear to be no new households using transit. In other words, in the dial-a-bus experiment in Mansfield, almost no households using the Woodland route with dial-a-bus were not using it before. The increases in usage were from members of households that were using transit before, buying the extra service, and taking additional trips.

H. J. Bauer

Were they making entirely new trips?

Joseph H. Stafford

We do not have suitable data on that. We were only trying to discriminate between the households who were using the service and those who were not. We do not have trip-making data per se. However, another significant result was that the residents (and not those who were commuting to the area) were using the service relatively infrequently, 2 or 3 times a week at the most and often only 2 or 3 times a month. These households were all classified as users of transit. To look at the results in a meaningful way, we have to start looking at data in terms of travel decisions over some relatively long period, such as a year rather than at the typical cross-sectional data of what they did yesterday. The latter data are what we get in the typical home interview surveys.

Daniel Brand

Are there results relating the attribute "distance from the fixed route" to demand for the new dial-a-bus service in Mansfield?

Joseph H. Stafford

In discriminating between the group of users who walk to or from the bus and those who get door-stop service, we found the only significant variable to be distance from the fixed route. In distinguishing between the households who used some sort of transit and those who did not, we found the most significant discriminators to be the age of head of household and educational attainment. However, in that neighborhood the latter is so highly correlated with age of head of household that the differentiation is probably not meaningful.

Daniel Brand

Do you suspect there will be seasonal variation in these results?

Joseph H. Stafford

Most of the household data were collected by Ford and the county planning commission before the dial-a-bus service started in December. The start of service was followed with a small early spring survey and a follow-up survey in early summer. We tried to look at seasonal or weather variations, and there does appear to be a weather effect. Statistically, we cannot yet say there is.

Daniel Brand

Are there any more recent Mansfield results?

Karl Guenther

There are many new results. We may have to cover some of the same topics that Joseph Stafford covered. New and induced trip-making was only significant among nonresidents and amounted to over 10 percent of nonresident trips. This derives from a survey question that indicates they were taking a trip they would not have taken if the service had not been available. However, as Joseph Stafford said, these represent existing transit riders making more trips.

Daniel Brand

What groups were in your sample universe?

Karl Guenther

We sampled the total transit user population and have broken the survey results down into 4 categories: nonresidents who use dial-a-ride, nonresidents who do not, residents who use dial-a-ride, and residents who do not. The important result is that nonresidents did take more trips. The number of residents who would not have made the trips was insignificant, about 1 percent.

Daniel Brand

That does not necessarily mean that the residents would not make more trips or that there might not be any induced travel by these people. It can mean that they simply have an alternative more available in the short run (a car) for their trips.

Karl Guenther

Along this line, there is a very important finding that a large number of people use the service very infrequently. We had a 100 percent sample of the households who had ever telephoned and requested door-stop drop off. We recorded every address and went back to that particular household and asked: "You used it once or twice; why did you quit?" The answers were not dissatisfaction answers. Our consensus is that people were satisfied with the attributes of the service. We gave them the option to comment freely in writing on their gripes. They had almost nothing that they wanted to complain about. We also gave them the option of checking specific boxes for things that they might not like (e.g., the driver or the vehicle). We got almost no response on this.

Daniel Brand

What were the reasons for the infrequent use of the service?

Karl Guenther

All the normal kinds of things that fell into a category we called personal circumstances: Somebody was on vacation and had taken the second car out of town; a son was home on leave from the service; the second car was laid up for repairs temporarily; or someone took a part-time job downtown for a few months. It appears that there is a market that will view dial-a-bus as a temporary convenience and use it that way.

Daniel Brand

We can characterize this as a short-run response to a short-term or new service. The longer run adjustments to the new service (selling the second car or not replacing it when it wears out) take a long time.

William T. Howard

One of the interesting things that turned up in our Toronto DATS operation was that we consistently carried more people home in the evening than we brought in on dial-a-bus in the morning. This leads us to believe that the attribute of waiting time at the residence leads a lot of people to divert to kiss-and-ride or car pool in the mornings but to remain with dial-a-bus in the evenings.

Richard J. Solomon

On that point, the experience of the Washington, D.C., transit people is that more people use cabs in the evenings to get home from the Silver Spring transit terminal than come by cab in the mornings. They attribute this to calling home at 5:00 p.m. when the wife says, "The kids are screaming, get a cab."

Arthur Schwartz

We have just the opposite in New York where the feeder transit peaks are higher in the morning. The absolute volume, though larger in the evening, is spread out. New York is one city that does not close down at 5:00 p.m. However, in southern New Jersey, the traffic is heavier and more concentrated in the afternoon. Philadelphia, therefore, does close down at 5:00 p.m.

Daniel Brand

Let us highlight a very interesting difference between some of the Mansfield findings and the GM findings presented yesterday. The Mansfield findings show dial-a-bus riders to be mostly diverted from the existing transit service, with some induced travel from nonresident households. The GM case study findings are that relatively few trips are diverted from the existing, admittedly very poor, transit service. They either were diverted from automobile travel or were induced trips by members of automobile-owning households. Might this have been caused by the survey method? If you describe the concept of dial-a-bus to people who are not familiar with it, are you in effect selling a product in competition with the "old" product, i.e., the automobile?

H. J. Bauer

Responding to part of your question, you say that Mansfield ridership consisted mostly of diversion from transit. I wonder if that is the right way to look at it because the new service is an adjunct to a fixed-schedule system. People are not so much diverting from transit as they are taking advantage of the additional convenience and facility that are offered by the dial-a-ride doorstep transit service. There are not many new riders evidently. So it is not really a diversion.

Joseph H. Stafford

I would agree with that. The other difference is that Mansfield already had pretty good fixed-route service in that it still went downtown.

H. J. Bauer

There was also one line in Mansfield to begin with. There is no diversion from any other radial line, is there?

Karl Guenther

That is right. There is no diversion from the fixed-route Lexington Avenue bus line that runs parallel to the Woodland neighborhood.

Daniel Brand

Would you, therefore, go so far as to say that dial-a-bus is not going to cut into the automobile market any more than good, or perhaps very good, fixed-route and scheduled transit service?

H. J. Bauer

My statement was merely relative to your comments about Mansfield. I wanted to clear that point up.

Joseph H. Stafford

We should bring out the fact that, in Mansfield, dial-a-bus essentially served only a few zone pairs. In another city (Manchester, New Hampshire) where we have done a small paper study, the overall modal split to transit is about 3 percent. However, the modal split between zones that have a direct or nontransfer type of transit service is up to about 7 or 8 percent. A many-to-many dial-a-bus system would give direct nontransfer service between all zone pairs. So this distinction between type of service must be kept in mind when these experiments are looked at.

Daniel Brand

Before concluding that modal split will be similarly increased by many-to-many dial-a-bus service, we must also keep in mind that the 7 to 8 percent Manchester modal split is to destination zones having unusual private automobile attributes like congestion and parking charges. To switch the subject somewhat, I was interested that the most important of the 32 attributes GM had on its questionnaire was arriving when planned. Was this just a reaction to the bad taxi service in that city? Also, does this attribute have some explicit and "modelable" relationship with speed or travel time?

Harriet N. Curd

People did place a very high value on time. We concluded from the study that people want good service, they want to arrive at the time they expect to, and they do not want to wait for the bus. Also, they will pay a little more for the good service.

Daniel Brand

What fare difference do you think they had in mind when you asked the question? Are they thinking in terms of a 5- or 10-cent difference, or a 50- or 80-cent difference?

Harriet N. Curd

In this questionnaire, we did not quote specific fares at all. They were forced to make a choice between 2 attributes as to which was more important to them, for example, arriving on time or a lower fare.

Daniel Brand

Can you elaborate on the relationship between arriving at a fixed time and duration of travel time? Did asking about arriving when planned cause travel time or speed to be lower in the importance groupings of 8 or 19 attributes, or were travel time and speed not very important in absolute terms?

Eugene T. Canty

Arriving when planned was essentially a reliability factor, separate from travel time and speed.

Daniel Brand

This is consistent with the Maryland study results on the same subject.

Richard L. Gustafson

I could say something about some of the ratings and the particular characteristics you are talking about. The reason we lumped the eight characteristics together was that they were not significantly different from one another. The three that were rated separately were a significant distance above the other characteristics. Arriving when planned was far above. In making paired comparisons, we used zero as the low value. Stylish vehicle was the lowest. Each of the other characteristics is rated relative to every other characteristic within the scale. Arriving when planned received a rating of greater than 1.8, and being assured a seat on the vehicle was second with 1.65. I do not know whether these numbers mean anything because the relative difference is the important factor. No transfer was third. On top of the next group of eight is being able to call the system and arrange for a pickup without being delayed. I think this is important for the same reason as that in Mansfield; namely, in Mansfield, there was a problem that people found the telephone busy and were deterred from using the system. People are also concerned with dependability and would trade off extra time in order to be able to plan exactly when they are going to arrive at their destinations. If one is going to the doctor's office, one wants to be there at 10:30 for the appointment instead of 10:20 or 10:40.

Daniel Brand

Were there any speed or travel time factors other than those you have mentioned?

Richard L. Gustafson

Our alternative questionnaire also had some interesting results. We traded off various travel times by saying that, if it took you 10 minutes by car, would you accept a 15-minute dial-a-ride trip or a 30-minute dial-a-ride trip. So we input our travel time ratios at 1.5, 2.0, and 3.0. We found that the size of the ratio was only of marginal importance. The important thing was the absolute extra time involved in traffic. That is, a 15-minute dial-a-ride trip for a 5-minute automobile trip was about as acceptable as a 20-minute dial-a-ride trip for a 10-minute automobile trip. Both involved the absolute difference or extra time of 10 minutes. Of course, between the trips with the two 10-minute differences, the one with the better time ratio was preferred, but again the major difference was explainable by the absolute time difference.

Daniel Brand

A waiting time of 15 or 25 minutes as reported in your paper seems rather high?

Richard L. Gustafson

One of the reasons that waiting time was set at those levels was the size of the case study community. Within a 6-mile by 6-mile area, vehicles dispatched in the morning from the central part of the city will take at least 15 minutes to reach a demand on the periphery. Therefore, a guarantee of less than 15 minutes may not be possible to meet.

Daniel Brand

Why put all vehicles in the center?

Richard L. Gustafson

They could be dispatched from all over, but that was not part of our simulation.

Eugene T. Canty

If you can guarantee a 15-minute pickup, you increase the number of vehicles that can be considered as possible pickup vehicles, and you can get a slightly better optimum utilization of vehicles. However, that is a different kind of a trade-off.

Kenneth W. Heathington

There are also some other things that were interesting in the GM questionnaire. We found in this survey that things experimented with in Peoria rated a very low priority as far as dial-a-ride is concerned. Coffee on board and magazines were of very little importance. Use of credit cards also had very low importance. These results go directly opposite to some of the marketing thinking as to what characteristics or attributes a system should have in order to induce people to use it. People are more concerned with travel time, waiting time, and availability of seats.

REFERENCE

1. Solomon, R. J., and Saltzman, A. History of Transit and Innovative Systems. Urban Systems Laboratory, M.I.T., Cambridge, Paper USL-70-16, 1970.

SEMINAR ON SIMULATION

INTRODUCTORY COMMENTS

J. F. Nunamaker

The comment has been made that what we really need is a design theory for demand-actuated transportation systems (DATS). The following approach is suggested as one way of viewing the DATS design problem.

The DATS design process has a number of similarities to any physical design process, such as a production plant or a bridge. In each case there must be an initial recognition of a need. Next, preliminary studies are conducted in which major alternatives are considered, the technical feasibility is determined, and costs of alternatives are estimated. If a decision to proceed is made, the requirements must be stated in sufficient detail for designing the system. The design phase consists of preparing a set of specifications (blueprints) that are detailed enough for the construction phase.

The major functional activities are decision points in the design process of DATS are shown in Figure 1. After the requirements have been documented, the systems designers consider the equipment available (or equipment desired) and any constraints (such as the existing system) on the design activity. The design phase consists of producing the specifications for the 3 major parts of the system: transit equipment (characteristics and type of vehicles); transit facilities (loading and unloading facilities); and system scheduler.

The specifications must be detailed enough to verify feasibility and to evaluate the performance of the proposed system but only detailed enough to specify construction because producing specifications that are too detailed is costly; and they may have to be changed in any case. In addition, specifications that are too detailed tend to bind the design unnecessarily at too early a stage with negative payoff.

An important aspect of this formulation of the DATS design problem is that it should include an explicit statement of the performance criterion by which performance of the system is measured. A consequence of including performance measures is that the emphasis is focused on the overall performance of the system rather than on any one part. DATS design is defined as the process of producing design specifications necessary for the construction of the system from a problem statement and knowledge of the capability of the components of the system.

Simulation is one way of evaluating alternative designs. It should be kept in mind that simulation is the least desirable solution technique; however, it has the greatest applicability. The major classifications of solution techniques from most desirable to least desirable are as follows: analytical, iterative (mathematical programming), branch and bound, enumeration, heuristic, and simulation.

Simulation is, however, the most applicable solution technique available for handling large unstructured problems. Because we are concerned with simulation models, it is necessary that sensitivity analysis be discussed with respect to the various models. It is not uncommon for the systems designer as decision-maker to be presented with point estimates of the uncertain parameters to be used in his analysis. Sensitivity analysis

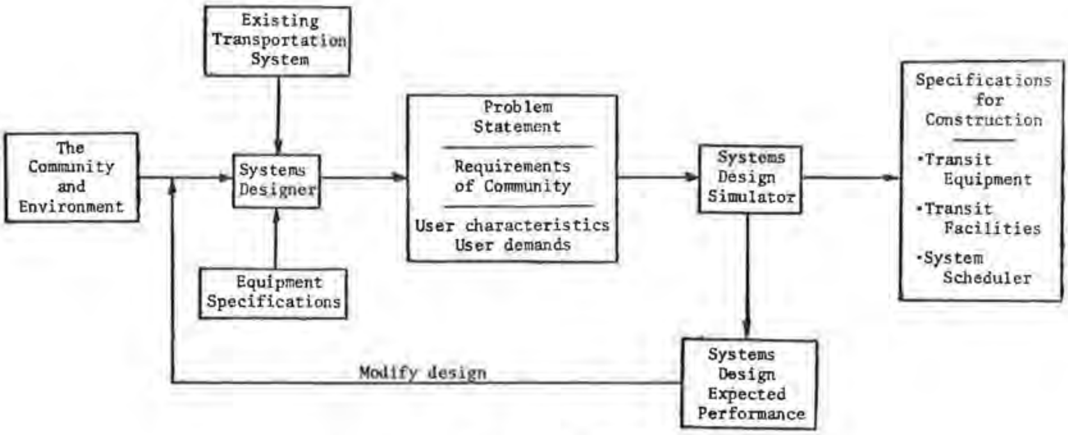


Figure 1. The DATS design process.

is one method of demonstrating the effects of unknown variances in these uncertain data and of identifying their most crucial elements.

The purpose of sensitivity analysis (or parametric analysis) is to show how the results of an analysis can change when either the data change or when the assumptions imposed on an analysis or model are altered. Treating the parameters in this way is a meaningful method of expressing uncertainty to the decision-maker.

Therefore, when reporting on simulation models, one should comment on the extent to which sensitivity analysis was used, the validity, and the testing of the models. In addition, one should indicate the decision-making structure of the models as described by (a) specification of the inputs and outputs, (b) specification of decision variables and determination of feasible alternatives, (c) selection of an objective function, (d) expression of objectives as a function of decision variables, (e) explicit statement of constraints that limit the value of the decision variable, and (f) solution, i. e., determination of the values of the decision variables.

There are other questions and topics that should be discussed. Was a data management language used for the analysis of survey data? Because of extensive questionnaire analysis, we are confronted with a large data base problem. To aid in the handling of large data bases, data management language has been developed during the past 8 years (1, 2, 3). A data management language is quite useful in situations where one is not sure what questions will be asked about the data. What computer configuration was used to run the simulation model? What language was used to program the model? Describe the scheduling algorithms. Discuss the implementation problems with respect to the scheduling algorithms. What thought has gone into the problem of selecting a computer for the implementation of DATS?

The selection of the "right" computer configuration is itself a very difficult problem in well-structured problems such as routine business data processing. There are the additional problems of selecting a computer that a community can afford for a real-time DATS. The DATS could be well designed for a community, but the entire system might fail because of the selection of the wrong computer. The first discussion is of a DATS simulation model developed by General Motors and described in a number of reports (4, 5, 6).

GENERAL MOTORS DATS SIMULATION MODEL

Larry Howson

The General Motors DATS simulation was displayed on an IBM Model 2550 Model 3 graphic terminal connected to an IBM 360/67 time-shared computer. A list of items such as number of buses in the system, number of seats on a bus, the velocity of buses in the various networks, and sizes of the zones in the simulation can be modified at the display terminal. In addition, the algorithms for routing and keeping track of buses can be modified at the display terminal. The number of demands per hour can also be displayed. A scale model of the area in which the bus is being routed is displayed on an upper corner of the scope. The route of one bus is on display continuously while the simulation is in progress, and the provisional tour is displayed and changed. A flashing or flickering occurs on the screen to indicate that a customer has been accommodated. The customer has been either picked up or delivered at his destination. Some additional numbers are also displayed to indicate the time and the number of vehicles in the system. The simulation can be interrupted at any point, and all of the tours can be observed. The tours of all the buses currently in the system can be displayed on a point-by-point basis. The points are labeled with P's and D's to indicate either a pickup point or a delivery point. The systems designer has the option of observing the tour of a single bus or the tours of all buses in the system. The system designer also can "dump" out data on each of the buses and analyze who is going where and why. In addition, he can check the constraints for each rider on each bus.

The display starts to get messy when approximately 10 or 11 buses are displayed in the system. However, you can get a mental picture of what a manual dispatcher might be looking at if he were trying to schedule all of the buses.

There are 5 IBM 2550 graphic terminals being supported on the IBM 360/67 plus a background partition. Therefore, the simulation does not run as fast as we would like, but it is not too slow for our purpose. The simulation with 100 demands to be satisfied required approximately 80 seconds of CPU time and required about 7 minutes of real time. The simulated time for this example was 1 hour of operation.

Karl Guenther

Do you need the ability to pull out the history of one vehicle and look at what it has done for the previous hour?

Larry Howson

We have not done that. We are preparing to punch a set of cards every time a demand is served so that at the end of the simulation we can evaluate the bus route. One of the ideas we have for demonstrating feasibility is to take one bus route from the simulation and drive a real bus along that route. In this way we can see whether the route is feasible and whether it indeed can do what we had proposed.

Karl Guenther

Did you present the same problem to a manual bus dispatcher and let him generate routes? Did you attempt to compare the computer-generated routes with manually generated routes?

Larry Howson

We have not done that at this time.

Eugene T. Canty

We analyzed one approach to manual dispatching for the simulation that was based on a particular case study involving 36 square miles. For a low demand, we had a few buses spread over a large area. We looked at the 3 closest buses to a customer, and that is the way we determined our cost based on somewhat inefficient scheduling. From this case study, it was determined that more buses were needed to meet the same requirements.

Larry Howson

There are essentially 2 ways that this scheduling problem could be structured. We could use the objective function technique that is similar in many respects to what has been done at M. I. T. The other approach is to use a technique similar to one that was developed at Northwestern University and that essentially looks at the closest bus. We said, "How might a manual system operate?" and we concluded that it might operate more like the Northwestern simulation rather than like the M. I. T. As a result it was proposed that we might be able to do somewhat a better job by looking at the first 2 or 3 closest buses and evaluating the first few positions in their tours. This was thought to be an enhancement of the approach to looking at the closest bus. This approach is very similar to the selection of routes by using strings and pins. The next step is to choose from the 2 or 3 closest buses 1 bus that looks best from the customers' constraints. In effect, we simulated a manual system in that respect. For certain dimensions of the problem, this approach was almost as good as a complete analysis of the objective function. Potentially it may be cheaper because fewer buses are scanned by the program.

J. F. Nunamaker

How long does it take to make the next decision on a route?

Larry Howson

That depends, of course, on the size of the system and how many buses we have to scan to make the decision. Some typical numbers are 56 to 60 milliseconds to scan a bus. If we have about 100 buses in the system, it would take several seconds to make a decision. If there are only 10 buses in the system, the time is considerably less. This seems to be a straight line function and seems to support the notion that there is no change of scale.

J. F. Nunamaker

What scheduling techniques are used in the simulation?

Larry Howson

The objective function of the scheduling model considers both waiting time and travel time. The scheduler evaluates the waiting time and travel time of customers who have requested service and who have not been assigned as well as the waiting time and travel time of those customers who have been assigned. In addition, the scheduler also considers the waiting time of those people who have been assigned but not picked up and customers who have been assigned and picked up but may be delayed. Weights are assigned to each of these parameters. The weights can be varied, and we can determine whether there is some combination of weights that gives a better system and a better solution for a set of input parameters.

The scheduling algorithms consist of the Northwestern system and the modified Northwestern system. The Northwestern system assigns the closest bus, and that is the only thing the scheduler considers. The modified Northwestern system evaluates the closest N buses, where N is less than the number of buses in the system, and then looks at the first j points in a tour of each of the buses, where j is less than the number of points on the tour of the bus. Part or all of the objective function can be used to determine which of that subset of buses would be the best bus to assign. That is the range of the assignment technique used in the General Motors simulation.

J. F. Nunamaker

What is the language for the DATS simulation model?

Larry Howson

The model is written in PL/1. This particular version of PL/1 is run under IPSS, an interim operating system for the IBM 360/67. PL/1 was not found to be as efficient as FORTRAN. The execution time for PL/1 was 5 times as long as the execution time for FORTRAN (with full optimization) for the minimum path algorithm. PL/1 is probably not the best language for our particular needs. However, we had little choice in the selection of a language because the systems we were working with only supported PL/1. This was not necessarily a bad situation because the graphics systems we used were only supported by PL/1. In some areas PL/1 was found to be very valuable. For example, PL/1 is very good in the area of address retrieval and data manipulation.

J. F. Nunamaker

Can you discuss components and structure of the objective function?

Larry Howson

The components considered in the objective function are the user-related attributes of the system. Weighting factors or values are assigned to the attributes, and the model is essentially a linear utility model. The model is formulated as a minimization problem. The model has the interpretation of minimizing the social and political costs of transportation of the customers in the system. The customers in the system include customers on board a bus and those called in or waiting for a bus. In that sense, there is a total correlation between the decision-making processes in the simulation model and the problem of minimizing the social cost of people involved in the transportation system.

Karl Guenther

In your objective function approach, did you find that specific coefficients used in the utility model vary over a extremely wide range? If not, then did a narrow range of coefficients make it possible for you to handle a large variety of different situations such as number of vehicles and demand rates?

Larry Howson

We have not done any sensitivity analysis on the parameters. The simulation program was completed in February 1970, and shortly thereafter the project was slowed down considerably. The inputs necessary for the economic analysis could not be obtained, and the simulation model was checked out with weights of unity. We have not had the opportunity to go back and to see what happens if we change the weights and to observe how sensitive the various weights are to changes in operating conditions. We would like to determine the full range of the parameters that can be used in the operation.

J. F. Nunamaker

What additional work is planned for the DATS simulation model?

Larry Howson

We intend to perform a sensitivity analysis and to investigate the efficiency of the program. We would like to reduce the cost of running the program.

J. F. Nunamaker

What are some of the reasons for the high cost?

Larry Howson

I am sure part of the problem is the language we are using and part is possibly due to inefficient programming.

Kenneth W. Heathington

Can the travel time constraint or any other service constraints be violated? Can you lose a customer in the system so that he ends up waiting 30 minutes for service when you guaranteed him a 15-minute pickup?

Larry Howson

It is impossible to miss a guarantee.

Nigel Wilson

How do you achieve that guarantee?

Larry Howson

If a guarantee is approached as customers are assigned a vehicle, each customer's projected arrival time is updated and the slack time is decreased and approaches zero. At this point the system goes critical for this one individual, and he is delivered. We have not looked at the possibility of something unexpected happening like a vehicle breakdown. It is assumed that the system operates perfectly at all times.

Nigel Wilson

Such an ambition, though laudable, is unattainable simply because the unexpected does happen. In addition, the GM simulation model assumes an unrealistically large supply of vehicles.

Kenneth W. Heathington

The problem of breakdown can be scheduled within a simulation; however, the only effect is to create a larger supply of vehicles with which to serve the demand. It is most important to recognize the fact that if one did not meet the service guarantees the system is in trouble. Some people on the DATS project felt that if we met the guarantees 95 percent of the time that would be sufficient. However, how do you keep that 5 percent that is not satisfied from shifting to another system? In addition, how do you keep from losing customers over a period of a couple of years? What does that do to the public's confidence in the system? It is not hard as far as scheduling algorithms go to meet all constraints with no one getting lost in the system and everyone being delivered on time. The question is, Can we afford to not meet the constraints that we have guaranteed?

Nigel Wilson

If on a very snowy day the demand is 3 times larger than the expected demand, how would you handle the situation?

Kenneth W. Heathington

We would propose that when a person calls in we would communicate with him and at that time give him a guaranteed time. This would be done only on days with adverse weather conditions. In both the Northwestern and General Motors studies, the time for pickup is fixed. The maximum waiting time is 15 minutes, and the delivery time is fixed. However, it is realized that in bad weather or as a result of breakdowns some problems will occur. It is not so detrimental to the overall concept of dial-a-bus to wait in adverse situations. However, on a bright sunny day in July it is upsetting to wait 45 minutes for a bus instead of the anticipated 5 minutes, and this becomes a very critical situation.

Nigel Wilson

There are 2 very different situations involved: whether a general system policy guarantee on waiting time and travel time may be violated (a) when adverse weather conditions are experienced or (b) when unexpected demand is experienced. As I understand the proposed system, at the time of the service request, the customer is notified of the service expectation and is given the option of saying, "I don't want to be picked up." This is a feasible way of operating, and it is probably the only feasible way of operating. The other approach is to have guarantees that one hopes the system never violates, and this is not a feasible approach.

Eugene T. Canty

We want to distinguish between the malfunctions in the system itself and the routing and scheduling. It is important to establish whether the system can pick up and deliver people on time if there are no acts of nature. The objective is to determine whether these assurances can be met with a computerized system and to determine whether the computerized system can do the job and a manual system cannot. The other aspect of the question is concerned with the extent to which failures and abnormal events can be accommodated, i.e., vehicle failure, traffic jams, and inclement weather.

Nigel Wilson

There is no great mystery about satisfying service guarantees. It is simply a question of how many vehicles are available to cover a specified demand in a given number of square miles. There is no way of satisfying guarantees if the system was designed with the wrong number of vehicles for a given number of demands.

Eugene T. Canty

The argument should be focused on whether the system is 100 percent responsive to the customer demands with everything else being fixed. In addition, the system can then be evaluated to determine if it is adaptive to the exogenous forces such as weather and bus breakdown. In the next set of simulations, it would be desirable to input these external forces as well as customer demands and to observe how well the system can adapt. Then it will be possible to calculate the frequency of occurrence in which the system did not meet its guarantees.

Joseph H. Stafford

None of us has done a crucial piece of work on this problem from the behavioral or customers' point of view. What is the trade-off? What are people willing to pay for increased reliability? Let me suggest an approach to the problem, if we had the time and energy to do it this way. What customers will do if the system is unreliable is to simply allow more time for the trip. If they are 95 percent confident of meeting their appointments at the doctors' offices, then they will begin to make the appropriate allowances for the trip. The customer will have enough experience with the system if he is using it at all to know or to have a "feel" for the trip time probability distribution. Then we can start asking the following question: What is a customer willing to pay to reduce the amount of safety time he has to allocate to a trip? To date, we have not done a complete analysis on that problem. It is necessary that we start thinking of the problem in terms of a confidence interval for travel time, i.e., the amount of time a customer must allow to be 90 to 95 percent sure of meeting appointments. This also suggests that travel time reliability may be rather different for a trip originating at home and for a trip ending at home. The problem of arriving home 15 minutes late is quite different from being 15 minutes late for work or 15 minutes late for an appointment.

Kenneth W. Heathington

One point we have not investigated concerns determining the exact size of the system required to hold to system guarantees. I am not convinced that it requires a large number of extra buses; maybe it does not require any, maybe one. I do not know of anyone that has investigated this problem.

M. I. T. SIMULATION MODEL

Nigel Wilson

At M. I. T., we have been involved in a project similar to the GM project. We have developed a series of algorithms for operation in the many-to-many problem or in the many-to-one problem (7, 8). These algorithms have been tested in a simulation model to determine how suitable they are for the operation of a DATS and to provide data for economic analysis of the system on which cost figures have been based. The simulation model was operational in March 1969, and since that time considerable testing has been done. Formulas have been developed for relating the number of vehicles to an area, demand level, and level of service (8). This formula is a result of a great deal of parametric work that was done to make it possible for comparisons to be made of the M. I. T. and General Motors results. It was realized about 15 months ago that, in order to get a "good" intuitive feel for how well the scheduling algorithm is doing compared with human logic, we really needed a graphic capability. As a result, a display system was implemented on the ARDS terminal. The ARDS is a much less expensive storage tube version of the IBM 2250 display scope. The display scope really increased our confidence in two respects: (a) that the algorithm had been programmed correctly and (b) that the logic of the algorithm was also correct. Human intuition did not indicate that we had a poor set of computer decision rules. The scope was found to be a very important aid in explaining to someone that was not familiar with the concept of dial-a-bus what it is all about. It is possible to demonstrate on the scope the type of service a customer might expect to receive. The ability to interrupt the simulation and to input new requests for service to the screen through a light pen was found to be very useful. With this type of device it is possible to specify an origin and destination on the screen and to let the computer algorithm specify alternative assignment of a customer to several vehicles. The customer is then given a first, second, and third choice, and then the customer (or analyst) can decide which choice is best and compare it with the computer's choice of which assignment is best. This was found to be a very useful approach to evaluating the scheduling algorithm.

In terms of the other questions raised in the introduction, we do specify constraints and an objective function that can be used in the way Larry Howson and Kenneth Heathington mentioned. One constraint is concerned with whether a request is acceptable or unacceptable. For instance, an option within the program permits the analyst to specify those constraints as firm constraints or soft constraints. Therefore, if there is no feasible way to service a new request and satisfy the service guarantee, the analyst can reject service for that customer. Whenever this situation occurs, the customer is notified of the best available service. This is clearly where the objective function comes in. The objective function is to maximize the satisfaction of all users or the social welfare of the system. The objective function considers everyone who is currently on the system, whether they have been picked up or whether they are still waiting. It also attempts to take into consideration potential customers who are not yet in the system and who will undoubtedly request service; i. e., it is necessary to keep a measure of slack to preserve service for those potential customers who will enter the system in a future time period.

The simulation was programmed in FORTRAN and is as a result operational on many computers. Most of the work has been done on the IBM 360/67, which has worked out very well with respect to the graphic capability. Some work has also been done on the Sigma 7.

J. F. Nunamaker

Can you comment on the details of the scheduling algorithms and on the practicality of the algorithms for an operational system?

Nigel Wilson

A result of the simulation work is the development of a primitive operational system. This primitive system is operational on the IBM 360/67, and in this version of the model the simulation environment has been removed from the software and replaced with external stimuli, i. e., an analyst seated at a console typing in a request from a person in terms of an origin (street address) and a destination. These street addresses are translated into coordinates that are put into the algorithm that exists in the same form as it exists in the simulation model. The instructions are printed on another console that represents the printout for a vehicle in an operational system. From that point of view, we have come a very long way toward having an operational system. Considerable testing has been done on the operational version, and we have reached the point where we have stopped finding elementary "bugs." There are no doubt a lot of other bugs in the system, and if it were put into a field environment we would find out the hard way. However, we would like to test the system in a field environment.

J. F. Nunamaker

Can you represent an existing street network, or do you use a rectilinear grid to approximate the street network?

Nigel Wilson

We can represent an actual street network. The operational system was programmed for Cambridge, Massachusetts. All the streets in a 4 square mile area are represented by a hash code and then translated into a grid map that is fed into the algorithm.

J. F. Nunamaker

Have you considered the selection of a computer for the implementation of an operational dial-a-bus system?

Nigel Wilson

That problem has been given considerable thought, and I would say we virtually have an operational system already, or we are very close to it. Naturally, there are some reservations about the system because it would be clearly a very experimental system. It would probably be prone to failures because it was designed from the simulation model, and as a result we patched various parts of the simulation model together to build the operational system. At present, it does not incorporate good systems design techniques (file design techniques) to make it a "good" operational system. Another drawback is that the system is tied to a fairly large computer because of the size of the program and the fact that data were stored redundantly to make it possible for someone not involved in the design of the program to modify it easily. This work was done in an academic environment, and the person who wrote the program for his master's thesis graduated. Since that time, everyone has been running it and modifying it, and it had to be very easy to modify and change. One of the initial design criteria was that the program must be written so that it could be easily modified.

J. F. Nunamaker

What are the minimum core requirements for the system as implemented on the IBM 360/67?

Nigel Wilson

The minimum core requirements exclusive of graphics is approximately 150,000 bytes. The model fits into one partition on the IBM 360/67 without any difficulty. The core requirement including graphics is approximately 200,000 bytes. We have considered using a mini-computer for implementing an operational system. This would necessitate developing the software from scratch, although basically the same scheduling algorithms could be used. The aim is to generate a system for a small computer very quickly. It is necessary to program it for speed of execution and to minimize the storage requirements. Whether we take this approach or not is undecided at this time.

J. F. Nunamaker

Do you have any particular mini-computer system that you are considering?

Nigel Wilson

There are several mini-computers on the market; possibly something like a VARIAN 620 is one that has been considered. There are many machines available; some can probably do the job, and others cannot do the job.

J. F. Nunamaker

The problem is that at the present time we know very little about the capability of these small computers.

Daniel Roos

That is true. One thing is certain: The system will have to be programmed in an assembly language rather than in a higher level language such as FORTRAN. This is necessary from the point of view of being able to fit the system into the memory available. Clearly that would have implications in terms of transferability, and one could imagine a proliferation of many dial-a-bus systems on small computers. The other approach would be to go to a medium- or large-scale computer where one is not so constrained as going in the FORTRAN route.

J. F. Nunamaker

Very few cities could afford to go the route of the medium- or large-sized computer for scheduling of a transportation system. Do you see a problem in having to customize the mini-computer dial-a-bus system for each city that would use the system?

Daniel Roos

There is a certain amount of customizing one has to do whether it be a small, medium, or large computer.

J. F. Nunamaker

But it is harder to make the changes in assembly language.

Daniel Ross

I agree that as one gets smaller and smaller machines one is faced with more and more customizing. However, for any system, the minimum amount of customizing involves modifying the street networks for each city.

Kenneth W. Heathington

Did you make an economic evaluation of using a large time-sharing system as opposed to using a dedicated smaller machine? Can you obtain the priority required for a DATS on a time-sharing system?

Daniel Roos

The one thing that bothered us about time-sharing was not so much the question of priority, because at least in the tests we ran the model needed a relatively small amount of the total computer, but the question of competition from the other users in terms of reliability. The fact is that when you are running with 23 other users and 1 of those 23 happens to "bomb" out the system you are down. That was our main reservation about time-sharing, and I do not think we ran into many problems actually getting into the system. At times during the day, when the load was very heavy, we did encounter some problems. In the environment we run under at M. I. T., one can set the number of users and set the priority, and problems can usually be worked out if one is willing to negotiate.

Kenneth W. Heathington

I realize that you can pay a premium and get top priority, but can you afford to do that 24 hours a day in order to meet all your schedules? However, the time-sharing costs seem to be decreasing all the time, and we now can have access to large capabilities at relatively low cost.

Nigel Wilson

To elaborate on a point made by Daniel Roos, I would say the amount of reprogramming that must be done for each new city will probably be quite small. The algorithms developed by M. I. T. and General Motors are very much independent of the demand distribution for an area. The grid network representation is also independent. Most of the software would not have to be reworked. However, the street address coordinate translation schemes would have to be reworked.

Kenneth W. Heathington

If, for example, people in Dayton, Ohio, want to conduct a feasibility study to estimate the number of vehicles required for a given demand, can they take the M. I. T. program and run it on a comparable machine in Dayton without needing the help of the people from M. I. T. ?

Daniel Roos

We developed the simulation model at M. I. T. primarily for our own use. That was the extent of our initial grant application. As further work, we extended the system so that we hope we can use the system for that very purpose. We hope that a community could use the system to test out the feasibility of dial-a-bus analysis. How effective the model is for that purpose we will just have to wait and see.

Kenneth W. Heathington

Is M. I. T. attempting to market the system?

Daniel Roos

No, it is the property of the Urban Mass Transportation Administration.

Larry Howson

As far as General Motors is concerned, a community could try to use the system for a feasibility study. However, I have always experienced difficulty getting a program running that was developed elsewhere. This seems to be the case even with good documentation. Even if the installations are similar, there is usually some strange thing that is a bit different and that causes problems. The General Motors DATS simulation leans heavily on specialized software for the IBM 360/67. This implies that anyone wishing to use our model would have to do a lot of rewriting on the graphics part of the system.

Kenneth W. Heathington

Would you perform a feasibility analysis for a community if it provided the description of the existing street system.

J. F. Nunamaker

The consensus from representatives from both M. I. T. and GM is that they are quite willing to perform a feasibility study for a community or city. Did either M. I. T. or General Motors investigate the vehicle scheduling system (VSP) package available through IBM?

Nigel Wilson

We have looked at VSP and found it to have somewhat limited capabilities. The vehicle scheduling area has tremendous potential for many types of transportation systems.

Larry Howson

We have not really had an opportunity to evaluate the VSP package. The original intent was to use VSP as an adjunct to the dynamic scheduler. Vehicle scheduling looks like a great area for development work.

Nigel Wilson

In addition to the dynamic scheduling problem, we are doing some work on the pre-scheduling problem for work trips that are repeated day after day. There is a great potential for a more sophisticated vehicle scheduler that can be run off line and not in real time. This type of scheduler could be run once a week or once a month, whenever it is necessary. This approach gives tentative routes for vehicles that can be updated in real time with a less sophisticated algorithm to modify the schedule for day-to-day variations in demand. The basic system then might consist of a set of standing requests for service that could be overridden by a phone call on any particular day. Combining these 2 approaches to vehicle scheduling appears to be a good area for algorithm development.

Eugene T. Canty

I would like to comment on something Nigel Wilson said earlier because it has important implications. He was talking about the fact that when an operational computer program is developed in one community there is a minimal amount of change necessary to adapt it to another community. The key change centers around the characteristics of the local community, i.e., the street network. It is important that we have new transportation systems that have a steep learning curve. If the system is proved successful and operational for one community, then it is relatively easy to implement it into a second, third, and fourth community. It is important to have that learning curve both with regard to the hardware and the software. A dial-a-bus system is one that should have a very steep learning curve. It is different from a moving sidewalk where there is a very high level of architectural and engineering content and a very shallow learning curve. Almost as much architectural and engineering time is expended on the hundredth system as on the first system; however, the learning curve for the system is shallow. Dial-a-bus is different. With regard to hardware, software, communication system, and vehicle, it should be rather easy to standardize on those components. This is important to the community because if the federal government sponsors the development of components for the first community then the other communities around the country profit from the experience of the first community. This should also hold with respect to software. Intuition indicates to me that a computer routed and scheduled vehicle program will be more adaptable to a second city. The automated routing system has perhaps a steeper learning curve than a manually routed system. For that reason, I think it would have been better to go the manual scheduling route at first rather than start with computerized routing.

J. F. Nunamaker

It is obvious that we have a good start on the simulation of DATS. However, much work remains to be done with respect to sensitivity analysis, development of more powerful and sophisticated schedulers, and implementation problems in the community.

REFERENCES

1. CODASYL Systems Committee. A Survey of Generalized Data Base Management Systems. Assn. for Computing Machinery, May 1969.
2. Data Management Software. Diebold Research Program, Document T24, Sept. 1969.

3. Dixon, P. J., and Sable, J. DM-1: A Generalized Data Management System. Proc. Joint Computer Conf., May 1967.
4. Bauer, H. J. A Case Study of a Demand-Responsive Transportation System. General Motors Corporation, Res. Pub. GMR-1034, Sept. 10, 1970.
5. Howson, L. L., and Heathington, K. W. Algorithms for Routing and Scheduling in Demand-Responsive Transportation Systems. Highway Research Record 318, 1970, pp. 40-49.
6. Vitt, J. E., Bauer, H. J., Canty, E. T., Golob, T. F., and Heathington, K. W. Determining the Importance fo User-Related Attributes for a Demand-Responsive System. Highway Research Record 318, 1970, pp. 50-65.
7. Roos, D. Dial-A-Bus System Feasibility. Paper presented at Conf. on Demand-Actuated Transportation Systems and published in this Special Report.
8. Wilson, N. H. M., Sussman, J. M., Higonnet, B. T., and Goodman, L. A. Simulation of a Computer-Aided Routing System (CARS). Highway Research Record 318, 1970, pp. 66-76.

SEMINAR ON PRICING AND ECONOMIC EVALUATION

Robert A. Meyer, Jr.
Department of Economics, Purdue University, Lafayette, Indiana

Two of the important economic aspects associated with demand-actuated transportation systems (DATS) are the methods of pricing the service (and the attendant implications for operating revenues) and the methods of evaluating the desirability (from an economic point of view) of introducing DATS in a particular situation. The following summary groups the contributions of the various discussants under these 2 broad areas that are in fact closely interrelated because of the effect the method of pricing has on factors such as total revenue and distribution of benefit.

ALTERNATIVE VIEWS OF PRICING

As an introduction to the problems of pricing of a transportation service, it may be useful to review some of the well-known pricing schemes employed by public utilities. These may be grouped roughly as uniform pricing, two-part tariffs, and block tariffs.

A uniform tariff is a single price method where the same price applies to all individuals, to all quantities purchased by a given individual, and at all points in time; no intertemporal price discrimination is employed.

The first step away from the uniform scheme is a two-part tariff that consists of a fixed-charge portion (perhaps per month) and a uniform variable portion that must be paid for each unit of the commodity consumed. A gas tariff consisting of a monthly charge for being hooked up plus a uniform rate per 100 cubic feet of gas consumed is an example.

A yet more refined pricing scheme is the block tariff that in the form of zone-to-zone fare schedules appears to have received wider usage in the transportation field. Basically, a block tariff consists of uniform prices that apply to a specified quantity of the service consumed. For example, one might pay one rate for the first 100 kilowatt-hours, a second (usually lower) rate for the next "block" of kilowatt-hours, and then the rate may be still lower for a block further on. There are, of course, alternative ways of interpreting a block tariff to the one given here.

DATS Demand Studies

As with any production and marketing problem, one is confronted with the problem of estimating the demand for DATS. This information then becomes the raw material for the evaluation of pricing plans, investment policy, and scheduling requirements. DATS typically will share the demand characteristic of intertemporal peaking that is so crucial in areas such as electricity supply.

Discussion has brought out 3 aspects of work on demand studies: the "new product" problem, a maximum willingness to pay approach, and the defects of data gathered from survey questionnaires. With respect to the new product problem, which is common to all areas of marketing, little can be said except that DATS suffers from an acute form of the malady. For commodities that potentially have very close substitutes, information on demand for these can be useful; but in the case of a markedly different service such as DATS, one is literally without a satisfactory reference point from current market data.

To offset the data deficiency, 2 approaches have been discussed in connection with DATS. The first concentrates on estimating the maximum, or at least an upper bound, on the willingness to pay as reflected by alternative modes of transportation. If one assumes that some transport service will be used and the only question is which one, then the alternative cost approach can be useful. Some of the suggested reference points for costing include taxi fares, fixed-route bus fares, cost of owning a second automobile, and parking fees. An integral part of the alternative cost method is the valuation of time component that is essential to provide comparability among modes.

The principal defect of the alternative cost method is that, although it can be applied to both core and noncore transportation, it ignores the amount of off-peak use to which DATS can be put and is of prime usefulness in evaluation of trunk-line and connecting service to core areas during peak periods.

As an alternative to indirect estimates of the demand schedule, one can use surveys or questionnaires or both. Although the principal benefit from a survey seems to be confined to preferences as to characteristics of the service and the economic-demographic characteristics of potential users, relatively little seems to have been done with respect to pricing. Questions have been asked only about uniform prices and not necessarily for a range of values. At best one gets information—a priori, not revealed choice—on one or a few points on a hypothetical demand schedule under only a single type of pricing scheme.

The dubious nature of demand estimates from survey data suggests that a far preferable method would be to utilize revealed preference data developed during demonstration field tests. The primary drawback to experimentation with a variety of pricing schemes is likely to be the lack of automation that may cause most of the tasks to be performed manually.

A Marketing Viewpoint

In contrast to the emphasis on the monetary pricing schemes, a marketing approach centers attention on convenience, habit, and nonmonetary pricing aspects. The main contention seems to be that casual observation over a wide range of consumer products suggests a definite drift toward convenience-oriented rather than cost-minimizing consumption patterns. In addition, although the implied prices of "convenience" characteristics seem to be several times those of conventional products, they gain considerable market acceptance. Such observations would imply that the upper bounds to price gained through evaluation of alternative modes of travel are not really upper bounds at all if one can introduce convenience aspects that are simply not present in alternative methods. From a marketing viewpoint, the presence of noncomparable characteristics has the further desirable (?) property that other modes may not really be viewed by consumers as substitutes.

A second point is related to the habit portion of a consumer's purchasing decisions. Habit aspects could come about both with respect to habit of using (and, therefore, price-insensitive behavior) or through habit of paying a certain price. If one were considering what pricing scheme to introduce or at what level to set prices and the habit element was felt to be quite strong, one could begin with relatively low prices and gradually raise them over a period of a year or so to the level required for DATS to be self-supporting.

Nonmonetary pricing aspects cover a wide gamut. Items such as the availability of reading material and coffee and the choice as to waiting times and transport time all fall under this heading. Snags occur when one attempts to obtain information on the association of these and other characteristics with alternative charges for the service. If adequate data were available, the implied willingness to pay for each of these characteristics could be unscrambled from the data.

Other Alternatives

Most of the discussion has centered around DATS rather than alternative transport systems. A notable exception was the mention of a study by SRI on a "public car," which is a proposal based on a local rent-a-car plan for an urban area with designated pickup and drop-off points for the vehicles.

An integral part of the pricing scheme employed for any commodity is the method of billing. For DATS, automation may be feasible both for billing and scheduling uses. The use of even a small computer makes almost any pricing scheme feasible computationally; this might be accomplished by user insertion of a plastic commutation card in a meter on boarding and departing from the vehicle.

ECONOMIC EVALUATION OF DATS

Before the evaluation and special problems of DATS are discussed, it seems worthwhile to recap the basic methods of evaluating investment projects, some, all, or even none of which may be applicable here. These methods can be grouped roughly as a present value approach, the cost-effectiveness method, and the cost-benefit analysis.

The most conventional of methods for evaluating the desirability of an investment is the present value approach. In its simplest form, this consists of specifying the outlays, both capital and operating, that will be needed at each point in time over the life of the investment and arraying against these costs the gross revenues that are expected at each point and then discounting these back to the present. Despite its apparent simplicity, it suffers several defects: (a) Costs and revenues are not known with deterministic accuracy; (b) the "life of an investment" is not a constant but is itself one of the economic variables of the problem; and (c) estimates are required of one or more interest rates or desired rates of return before one can determine the discount factors.

A second method that has gained a degree of popularity for government investment projects is the cost-benefit approach. In the special case where one had adequate demand estimates, this comes close to a consumer surplus approach. As one might expect, there is a stigma to be overcome when this method is employed because of the precarious nature of "benefits" and the methods one might use to estimate them. It is usually, but not always, the case that costs of a proposed project enjoy a higher degree of accuracy and currentness while benefits frequently accrue in the future, and it is by no means clear to whom they accrue. Dorfman in his report, Measuring Benefits of Government Investment, gives several examples of this approach.

The last technique is the result of a skeptical, if not condescending, attitude toward the cost-benefit approach and is frequently used in defense project analysis. The method is referred to as cost-effectiveness analysis. Instead of an attempt to evaluate the benefits associated with projects, the problem is phrased as a cost minimization one in which one seeks the least cost method of achieving specified objectives. This approach has been popularized by Hitch and McKean.

Although no specific details were available on overall evaluation procedure and profitability, 2 related issues were brought out: (a) concern over DATS as a labor intensive or, at least, fixed labor-capital ratio system and (b) municipal versus private ownership operated with or without subsidies.

DATS retains one of the chief operating characteristics of bus and taxi modes; the capital (carrying capacity) to labor (one driver) ratio is fixed. The major advantages claimed for DATS is a carrying capacity larger than a taxi and a retention of some of the personal service elements of a taxi through the avoidance of fixed routes. The chief criticisms appear to center around dispatching and the use of a high and fixed labor use in an environment where increasing labor cost is certain to be a chief factor. The dispatching factor is largely mitigated by use of an on-line computer; however, short of mechanically guided control, there is no clear answer to the labor cost argument. In addition, short of going to larger vehicles, there is no way to increase labor productivity; and, thus, wage increases imply rising real input cost per unit of output.

In the earlier pricing discussions, no mention was made of the type of ownership envisaged for DATS. Several alternatives can be mentioned: (a) municipal or (b) ownership by taxi or bus firms currently in the transport field, either with or without subsidies. When one considers pricing policies and the associated investment programs, one cannot divorce these from the nature of the entity operating DATS. It hardly seems realistic to think of a governmental unit operating DATS with the same objectives in mind that a private firm might employ. Pricing and investment policies for DATS in a community have both political and economic facets. It is quite conceivable that a governmental unit might run DATS at a loss to subsidize certain areas such as an urban ghetto or specifically seek to use DATS to provide greater employment opportunity within an area.

The basic issue revolves around what objectives are to be achieved by a transport system. If certain objectives, either political or social or both, are sought that conflict with the profitability requirements of a private firm, then either operation must be relinquished or a subsidy must be sought.

Subsidies to transportation modes is certainly not new. Such subsidies can take the form of special tax treatment of financial instruments or special depreciation and tax credit policies or simply direct cash subsidies for operation. What objectives a private firm may be compelled to pursue under the franchise umbrella of a municipality cannot be evaluated in purely economic terms. The only direct statement that can be made is that, if a firm operating under a franchise that creates monopoly powers is not able to find any pricing scheme such that total revenue at least covers total costs, then ipso facto the aggregate valuation placed on the service by the public does not exceed its total cost and it should not be provided. If such a pricing scheme does exist but for other reasons is not employed, there is little that can be said except that the pursuit of alternative policies have embedded in them some element of implied income distribution that lies outside the purview of economics.

SEMINAR ON SYSTEM EVALUATION

Clark Henderson
Transportation and Logistics Department, Stanford Research Institute, Menlo Park, California

Demand-actuated urban public transportation services currently are supplied by taxis and, in some places, by airport limousines, school buses, and jitneys. The possibility of developing new systems employing radio-dispatched minibuses was recognized at least as early as 1963 when the city of Menlo Park, California, conducted a limited experiment with an improvised system called dial-a-bus and filed a grant application with the U. S. Housing and Home Finance Agency.

During a recent period—about 4 years—the concept has had considerable attention from the community of professional research analysts and the Urban Mass Transportation Administration. There are small-scale demonstrations in Haddonfield, New Jersey, and Rochester, New York, and a valuable demonstration has been undertaken by the Government of Ontario in Toronto, Canada.

The degree of interest that is being shown by researchers and civil servants is not necessarily a good indication of the value of the dial-a-bus system. Therefore, in this seminar an effort was made to consider the value of the system from the viewpoints of several other groups who must lend support if the system is to enjoy significant success. A number of evaluation-oriented questions were considered from the viewpoints of operators, owners, patrons, and labor.

OPERATOR VIEWS

How Can Dial-a-Bus Be Used?

A considerable variety of operating patterns and services have been discussed. Among these are the following:

1. Flexibly routed, scheduled buses (Mansfield, Ohio);
2. Many-to-one service coordinated with scheduled commuter trains (Toronto, Canada);
3. Many-to-one service for rail rapid transit (Haddonfield, New Jersey);
4. Many-to-many service providing area-wide coverage (M.I.T., GM, and WABCO studies); and
5. Many-to-many service especially for nondrivers and local travel (one member of the Stanford Research Institute family of "future urban transportation systems").

The first three of these patterns and services are attainable currently but offer the potential for only a relatively small-scale contribution to the solution of urban public transportation problems. The fourth is attainable now also and offers the potential for large-scale contributions as will be shown later. The fifth pattern depends on the existence of a number of other advanced systems that have not been developed yet and, therefore, is only a long term possibility.

What Is the Possible National Potential for Dial-a-Bus?

It may be useful to develop some rough estimates of the possible national scale of dial-a-bus service over the next 10 to 15 years. During that period, dial-a-bus would face little or no competition from other new modes and, because it makes only limited use of fixed facilities, dial-a-bus could be introduced quickly and expanded rapidly in many communities.

Work at M.I.T. has suggested, tentatively, that dial-a-bus operations may be economical and attractive for areas with population densities of 2,000 persons per square mile and may remain attractive, in comparison with scheduled buses, for higher densities up to 6,000 persons per square mile. In the United States, approximately 60 million people will reside in areas within that range of densities 15 years hence.

Possible demands for dial-a-bus service were estimated in the same rough fashion. Using data from the case study described by GM staff members, we estimate that dial-a-bus service may be suitable for about one trip per day per person in the area served. Also, we estimate that dial-a-bus patronage may be in the range of 3.6 to 14.9 percent depending on fares and service quality.

These estimates, considered together, suggest that the national potential of dial-a-bus may be quite large. Areas populated by 60 million persons might be served; 60 million trips per day might be candidates for dial-a-bus service; and 2,150,000 to 9,000,000 trips per day might be taken on dial-a-bus vehicles. If the cost of providing service averaged $1, the total national outlays for dial-a-bus services would fall in the range of $650 million to $2,700 million per year. To help put these numbers in perspective, we note that total outlays in 1967 for all modes of urban public transportation—including taxis and school buses—was about $3,400 million.

What Kind of Service Can Be Offered?

The services of dial-a-bus can be tailored over a wide range. The descriptors used by GM are the maximum delay (i. e., waiting time between calling for service and boarding the vehicle) and the speed of dial-a-bus expressed as a multiple of the travel time that would be required by a private automobile. Their case study treated 15- and 25-minute delays and travel times 2 and 3 times as long as automobile travel time. M.I.T. researchers have combined the 2 factors and expressed the entire trip time by dial-a-bus as a multiple of automobile travel time. It is evident that the cost of providing service will increase as the system operator takes measures to reduce delays and travel times. A spokesman for M.I.T. suggested that providing service becomes expensive if the trip time is shorter than 2.5 multiples of automobile trip time. Clearly, there is no need for the operator to offer just one service; for example, he could offer priority service with a short trip time and a high fare and service with a lower priority with longer trip times and lower fares.

Do Operators Recognize Problems in Dial-a-Bus?

There is no large body of operator experience, and prospective operators have little understanding of the system or of its problems. However, the limited evidence available suggests that prospective operators will be concerned about matters such as use of computers, ability of customers to use the phone to order service, lack of predictable routes and work patterns for drivers, inability to maintain control over drivers via radio, and maintenance of services on snow-covered streets. However, transit operators informed about dial-a-bus have expressed a moderately optimistic view of the potential of the system to provide new services and growth for their industry.

OWNER VIEWS

Who Will Own Dial-a-Bus Systems?

Resolution of the question of private versus public ownership is expected to depend on whether dial-a-bus will be a self-sustaining operation. If fares and other business revenues are sufficient to cover costs and recover capital with a profit, private ownership would be feasible; however, if subsidies must be paid by government, public ownership would be likely. The costs of providing dial-a-bus service will be influenced considerably by rates of pay for labor, and these will vary among geographical areas. Therefore, private ownership may be a realistic goal in some areas and not in others.

Are There Any New Conditions Favoring Private Ownership?

The basic elements of a dial-a-bus system—small buses and radio dispatching—have been available for many years but have not been exploited by private business. Is it possible that recent developments—technical or nontechnical—may provide the last required elements for action by entrepreneurs? Many private businesses have tried to establish new types of demand-actuated urban public transportation service—over a period of 50 or 60 years—but few if any have prospered. The reasons for failures are not understood. It seems possible that the impacts of recent development have not yet been assessed by entrepreneurs. It is encouraging that interest in dial-a-bus is being shown by some of the remaining private bus operators and by taxi operators as well.

Do the Changes Favor Public Ownership?

The same opportunities for innovation have existed for public transportation agencies and, for reasons poorly understood, the innovations have not occurred. The public policy shifts that have caused government agencies to enter the field of urban public transportation may produce the conditions required for large-scale use of dial-a-bus. At the federal level, the Urban Mass Transportation Administration has supported research and development programs that were beyond the capabilities (or the willingness to pay) of industry and will also conduct demonstrations. The large capital grants program of the federal government can be regarded as confirmation of the analyst's claim that urban public transportation provides benefits worthy of taxpayers' support. Agencies at the state, regional, and local levels are becoming increasingly involved in financing and operating urban public transportation systems and are finding that the demands for service do not match capabilities of available systems. Therefore, it is possible that public agencies will soon recognize dial-a-bus as a new and valuable tool and begin its use.

What About Costs and Fares?

If ownership were private, it would be necessary for fares and other revenues (possibly from businesses served) to cover operating costs plus capital recovery and a return on investment. According to M.I.T. researchers, fares might be 80 cents; however, the GM case study, for a different and perhaps especially difficult situation, found that fares would need to be $1.25.

With public ownership, fares can be low—possibly no more than the 30 to 50 cents commonly paid for bus and rapid transit service. Deficits of the public agency would have to be covered by tax-based subsidies. The case study by GM showed that the patronage of of its demand-jitney system would vary depending on fares and service, and the influence of fares was quite significant. Profitable operation by a private organization appeared possible in only one case when fares were high ($1.25) and patronage was at the lowest level (3.6 percent). Maximum use (14.9 percent) occurred when fares were low (50 cents). In that case the traveler paid only about half of the cost of service, and presumably a subsidy of about 50 cents would be required. The proponents of subsidies argue convincingly that the use of transit as well as the increased use of transit induced by lower fares benefits society in many ways that cannot be converted directly to revenue for the operator. Will the public (or public transit agencies) prefer the higher patronage and its benefits along with lower fares and subsidies? This question may have to be answered, specifically, in dozens of communities if dial-a-bus is to have a significant large-scale application.

PATRONAGE VIEWS

Who Will Ride the System?

It is a common practice to view urban public transportation as an alternate to the private automobile and sometimes to cast the public and private modes as competitors. That view neglects the great differences in availability of travel services to various groups of travelers.

In 1967 there were about 156 million people (excluding children under age 10, persons in institutions, and persons overseas) in the United States requiring individual mobility and about half as many automobiles and small trucks. Also, there were about 1.2 licensed drivers per vehicle. Thus, half of the individuals were drivers with first claim to a vehicle. This class has essentially full mobility and would have little or no need for the services of dial-a-bus. Another 17 million individuals (11 percent) had drivers licenses but had only second or lower claim to a vehicle. This group suffers some degree of limited mobility and would have at least occasional need and perhaps regular need for dial-a-bus service. About 19 million children between the ages of 10 and 16 and about 12 million older children and adults (comprising 20 percent of the travelers) do not have drivers licenses but live in households having one or more vehicles. These people are often served as passengers by other family members but would make considerable use of dial-a-bus. Finally there were about 30 million persons (19 percent) living in households without automobiles who would probably depend heavily on dial-a-bus.

It appears that the benefits to society from dial-a-bus (as well as other public modes of travel) will be valuable when service is provided to the limited mobility groups, and especially to those individuals with severe limitations who are found in greatest numbers in the low-income districts of cities. Middle-class communities offer favorable settings for early tests and small-scale demonstrations of dial-a-bus; but ultimately the value of the system will need to be determined in more difficult environments.

Employment of dial-a-bus need not be focused entirely on any group or area. Dial-a-bus will need to be marketed, and its image should be developed to appeal to everyone requiring service rather than to certain market groups. A similar image will be desirable when a dial-a-bus program must obtain the approval of voters.

LABOR VIEWS

Will labor unions favor dial-a-bus? A favorable evaluation of dial-a-bus by organized labor may be one of the most essential factors in determining whether the system will succeed. It would appear that the labor-intensive character as well as the wide applicability of dial-a-bus (in comparison with scheduled buses and rail rapid transit) would be appealing because of the new jobs that would be created. However, dial-a-bus will present some new labor-management problems. For example, close disciplinary control will be required to make efficient use of vehicles and to avoid deterioration of service. Drivers will be required to follow instructions more closely than is necessary for either taxi or bus operation. Also, in a highly automated system vehicle movements can be monitored closely and, if desired, can be reviewed at a later time. Responses of labor, thus far, have been highly favorable to the dial-a-bus concept.

FUTURE DEMONSTRATION PROJECTS

During the course of the conference, Joseph Silien of the Urban Mass Transportation Administration made a few brief statements on proposed dial-a-bus experiments to be funded by that agency. He spoke primarily of the Haddonfield, New Jersey, project that is a manually scheduled operation and primarily a many-to-one system. He further stated that the project was in cooperation with the New Jersey Department of Transportation and that the contractor had not been selected for the project. He indicated that there were no immediate plans for UMTA to sponsor a computer-scheduled dial-a-bus system. He felt that there would be no further dial-a-bus experiments in UMTA until the 18-month Haddonfield project had been fully evaluated. The discussion during a question and answer period that followed his remarks has been reproduced in edited form here. Although this particular session was not originally scheduled, it is felt that most of the material discussed would be of benefit to those working with demand-actuated transportation systems. The remarks have been edited only enough to help clarify some of the questions and responses.

Kenneth W. Heathington

Question

Can you give us a very brief description of Haddonfield?

Answer

The borough of Haddonfield is a community of $2\frac{1}{2}$ sq mi with 15,000 people and 5,000 households. It has a rather dense core for a small community. There is a central business district of sorts. The nature of the CBD has changed from one of convenience stores to one of boutiques and little restaurants. It is a fairly affluent middle-class community. Most of the people work in Philadelphia and use the Lindenwold Line to go to and from the city. We do not believe that our service areas will be confined to the $2\frac{1}{2}$ sq mi because obviously with buses in $2\frac{1}{2}$ sq mi you can do almost anything. So we want to go beyond that to back up the various residential communities, probably a major shopping center at Cherry Hill, which is 5 miles away, and serve that kind of demand. However, the basic area is just $2\frac{1}{2}$ sq mi.

I should say something about bus service and taxi service. Public Service Coordinated Transport, a line-haul service through Haddonfield to Philadelphia, is essentially competing with the Lindenwold Line. Almost nobody rides these buses at the present time, and there is almost no local bus service. There are 10 taxis owned locally. The parking at the Haddonfield station of the Lindenwold Line is filled to capacity. The surrounding streets handle some of the overflow of the parking much to the dismay of the citizens. We feel sure we can, at least, carry some people to and from the station.

Question

When do you expect to have this project under way?

Answer

Service should start early in 1971.

Question

How do you plan to proceed with dial-a-bus demonstration projects?

Answer

Our plans now are to take it one step at a time. The budget simply does not permit us to do more than that. The entire research, development, and demonstration budget for this year is $20 million, and $1½ million is a good portion to put into one area. Unless we get additional funding, we have to do these one at a time rather cautiously, unfortunately. We would like to be a little bit more bold, but we just cannot. If this is successful, and we have every reason to think that it will be, we then have political ammunition and hard data to justifying our need for more money. Perhaps we will want to run a parallel demonstration at another site if that field proves not to be expandable; but there will not be a whole series of these projects under our jurisdiction; at least that is our present thinking. They will be one at a time.

Question

Will there be no further demonstrations within this fiscal year of dial-a-bus?

Answer

Right.

Question

Do you have a projected fare for the Haddonfield system? How much are the taxis?

Answer

Taxis now are either 75 cents or a dollar for any trip. We have not established a fare structure; that will await the results of the survey that will attempt to determine what people are willing to pay. The Lindenwold Line charges 60 cents each way to and from Philadelphia. There is no discount of any sort available. PATCO, operators of Lindenwold, have a standing offer to refund 7½ cents to every passenger who passes through its turnstiles and who was delivered by the public transportation system. We fully intend to take advantage of that and perhaps boost that subsidy so that the fare does not become exorbitant. We fully expect that the system will not operate in the best profit-making way for the first go-around.

Question

UMTA has spent a lot of money on dial-a-bus research, and so has GM and Ford. How much of the results are you using in the Haddonfield project? What parts are you using?

Answer

That is a hard question to answer. Not much of the research is applicable to the kind of system we are going to run. Almost all of it will be applicable to the computerized system that will result from this. I think that is really about all that can be said. The problems that were addressed by M.I.T., the Institute for Public Administration, and some of the other people involved in the system study all look toward starting out with a large or fairly large computerized, highly sophisticated system that we think is the way it has to go. It has to get there; but to start with, we want to put a toe in the water and test the market. A year from now I think all of this research that has been done will be focused on the next step in the system.

Question

Is it economically feasible to employ a manually scheduled system?

Answer

That is one of the things we are going to find out. It is likely that a manual system is economical, quite feasible, and quite efficient for 10 vehicles. It certainly works for 5 vehicles on a many-to-one basis. If a computer is not necessary for some installations, then why not do it manually? One of the things we will test in Haddonfield is the limit of efficiency with a manual system. We will then have, as a result of this, a reliable backup for the computer when we computerize it. We have to have some kind of backup, and it has to be developed one way or another. So instead of starting with a computer and then developing the backup, we can do it the other way around. However, there is no illusion on our part that a manual system is the be-all and end-all of dial-a-bus. It has to be computerized. It seems to us that there is a lower order of things that might work very well manually, but we do not know.

Question

There has been a great deal of expertise developed, good work done, and knowledge gained by the various groups developing algorithms, scheduling techniques, and things of this nature. Do we lose the expertise that we have gained by delaying a computer-scheduled dial-a-bus system? Are we taking a chance of losing all that we have put in?

Answer

All of the research that has been done is available to Ford, to General Motors, and to all private forces that see a future in this, as well as to ourselves. We plan to make use of it. By starting and developing a backup system that has to be developed anyway, I do not think we are setting back anything. We are as concerned as anyone about the image of service. We are very concerned about what it is that we are going to learn from this and what it is we are going to prove. If something does not-work out, we want to pinpoint the reasons why it did not so that we do not call the whole thing off for extraneous reasons. We are being cautious; we admit it. There are bolder approaches that could be taken, but the administrator has decided that this is the soundest way to pursue this.

Question

Is there not another dimension here that we are missing, and that is that much of this research has been done and is publicly available to anyone who wants to go out and try something. A slow, cautiously paced approach to things by UMTA or by any organization may mean that there will be many uncontrolled, quickly patched together projects out in the field within the next 18 months. We may fail to take full advantage of what goes on out there. It seems to me there may be a much greater kind of danger here than simply putting off a computerized demonstration. I am assuming a computerized demonstration is going to happen. Then the question is, Are we really going to be able to learn from the computerized demonstration?

Statement

There are no plans that will retain the information and expertise that these groups have attained. We cannot expect someone uninitiated to take the published reports and attain the same expertise that these groups now have. It is just impossible.

Question

Suppose the Haddonfield project turns out to be a flop, and it sets dial-a-bus back about 4 years? How do your propose to determine whether the failure was a function of the manual scheduling system? What criteria are you going to use to measure success or failure?

Answer

Judging from the success that GO transit in Toronto is having with 5 mini-buses and one operation, I do not think we are going to have a flop because of the dispatching mechanism.

Question

You are talking about a many-to-many, not many-to-one?

Answer

We are going to try many-to-one; the primary function of the system will be many-to-one. We do not really know how many many-to-many trips will be involved, and we will not know until we take the survey and until we get some buses on the highway.

Question

Is it, therefore, primarily many-to-one?

Answer

Primarily, although we want to try many-to-many. We will never know what we can do until we try.

Statement

We seem to be getting into an unfortunate situation where a sort of binary condition is implied to exist, i.e., simple, inexpensive, manual systems and complex, costly automated systems. It should be understood that there is a whole range of automated systems that one can speak of. A system with 50 to 200 vehicles has to be viewed, particularly if digital communication is involved, as sort of the far end of the spectrum in terms of a complex automated system. However, there are far simpler, automated systems. We have developed an operational computer program that is geared to a 20- or 30-vehicle system and that can be run economically, possibly even less expensively than many manual systems, for it would not require a great deal of additional research and development or implementation work. A computer today may cost \$3,000, \$20,000, \$50,000, or \$3 million. We cannot lump this concept of automated systems and get one image of it. In terms of the dial-a-bus program, it is not appropriate that we start off initially with a super-complex, highly sophisticated, highly expensive automated system; and it certainly is possible to start off more conservatively and less expensive. Therefore, we should be aware of what the options are and what the evolution is that takes us from an initial system and allows us to get more and more sophisticated. A problem in deciding on an automated system is whether it can be implemented in one community for 50 vehicles or in a variety of communities. Can it be run under a different set of operating conditions, on various computer systems, or one computer system? Can you start with 20 vehicles and go to 50 or 100? These are some of the critical issues for which we need clarification as to what the evolution is going to be. It is important to try to get answers to these questions before we spend a lot of money and possibly arrive at either wrong answers or decisions to spend 4 or 10 times as much in the long run because we did not face the issues initially.

Statement

Automation need not be as elaborate as people think. When one talks about computerization and automation, most people think about great monitor systems. What worries me more is the question of vehicle design. Do you use a Ford Courier, or a "monkeyed-up" General Motors vehicle, or something else? I am worried that we will go into these things in a hurry and in a fashion that will mar the image and the public response to a demand-responsive jitney. I would be more inclined to wait until we can go into it well because I feel that, if the image is marred by doing the job badly or doing it with a poor piece of equipment or with poor service, the whole attitude of the public or the potential ridership is going to be "just another one of those things." Even though 6 or 8 or 10 months later, we come up with a well-developed system, an effective vehicle, and excellent service, it is going to be too late. This has happened to us in the automobile industry when one year one manufacturer goofs and puts out a bad vehicle. It may take 10 years to recover; even though next year's vehicle objectively and scientifically is a good vehicle, the memory lingers on. A great deal of caution should be taken in approaching the systems so that they are not just "half-baked" because they will reflect on where we want to go. If a system flops somewhere the first time, then it is bound to be an expensive flop. It is going to sour all the potential, and I feel strongly that it has a potential and that it can serve in many different ways. I would hope that we do not goof it up the first time around.

Statement

I agree with anyone who would not want to go into anything half-baked, but I would ask you to be a little more specific about what you think the development time will be or should be on getting a qualified system operated. I do not think that 18 months of demonstration of an operation that has already taken place in Canada is anymore worthwhile than spending large quantities of money on research and development in high-speed operations that may already be operational in other countries. I do not agree that the steps that are being taken by UMTA in its research and development at this point are the correct steps based on what we have already learned. We are taking two big steps backward and then taking a very small step forward.

Statement

We certainly are not going to take two steps backward. We have a lot of technology at our disposal at the present time. We would not want to let that get dusty upon the shelf. As far as implementation time is concerned, to have a vehicle especially designed for operation with a service will require about 3 years under ordinary circumstances, including items such as normal production, research and development, and engineering. However, these things can be speeded up, and one can proceed on an interim basis. The only concern that I have is that the interim vehicle might not be an appropriate vehicle. We have heard people talk about using station wagons for this kind of service or using the airport limousine type of vehicles because they can count the number of seats in these vehicles and say, "Well, that's all you need." That sort of approach might not be an acceptable equivalent. Obviously GO transit in Toronto has done very well with the Ford vehicle.

Question

I attended a meeting this summer in which one of the topics was transportation. Some of the things that were brought out by various people with fairly good expertise and experience within the transportation area is that there is a substantial amount of moving into the transportation field by people that have perhaps lost government subsidies in other areas, particularly the space industry. We have seen a lot of bidding on transportation projects by groups not previously transportation oriented. What criteria do you use to determine who should actually perform one of these dial-a-bus demonstrations? Who should run it, control it, or do the implementation? What criteria do you use to evaluate an individual's background, expertise, knowledge, or whatever you want to call it?

Answer

There are no set criteria because there have not been any dial-a-bus experiments run to base a decision on. We look at proposals. We look at the people involved and their backgrounds.

Question

What do you look at when you look at an individual's background?

Answer

It depends on the project. Is he in transportation? Has he thought about the problem involved? Does he have a solution in mind that is appropriate? There are no set criteria.

Question

You have nothing that you generally use as guidelines?

Answer

In an area like this, there really is nothing to base them on. When we have been in it for awhile, then we will see. We are going to advertise very soon in Commerce Business Daily for systems management capabilities in all aspects of the UMTA program. In order to evaluate these, there will be criteria established.

Question

I sort of have the feeling listening to the conversation here that either we are awfully tired from eating or there are an awful lot of people who are very disappointed in what they are hearing. I think that probably the latter is more true than the former. It seems to me that there is a feeling around that maybe we were getting kind of close together in a certain particular direction in regard to some near-term implementation of transportation systems, and tonight we hear that the effort is no greater than, maybe even less than, it has been during the course of the past few years. The question that I have is, Is that true? Are we talking about a lesser effort in this area in the next 2, 3, or 4 years than we have talked about during the last 2 or 3 years. If we are, I think we have headed in a bad direction.

Answer

I do not believe we are. I think that we are proceeding on the basis of what has been done, and we are proceeding in a very logical way. We are going to start with a small system, test something that has not been tested (many-to-many), and computerize it if it is successful. We are certainly not going to go in with a 50-vehicle system somewhere.

Statement

We have developed a lot of expertise in this area, and in the Haddonfield project we are seemingly starting from scratch as though nobody in the world has ever done anything like this before. There has been a fair amount of expertise developed; that is particularly evident from the sessions of this conference. This expertise or knowledge should be put into use. Otherwise, why throw away all that research money? If we have developed something, then I feel we should implement it and use some of the concepts. Otherwise, we have wasted our money. (Responses such as "amen" and "I'll agree to that" followed this statement.)

Question

Many communities are getting wound up and ready to go with these kinds of programs. I think the direction of UMTA could be more diversified than this singular effort indicates.

Answer

It is difficult to do that with the budget that we have. There is not just a bus program budget, but a budget for bus, railroads, planning and support, employment facilitation, and everything else for the United States. We cannot spend all our money on dial-a-bus. I wish we could. I personally would like to see a much more elaborate project undertaken quickly. However, I think that this approach is very sound.

Question

What part of the budget last year was carried over?

Answer

$13,000,000.

Question

Does this mean that $33,000,000 is available this year?

Answer

The $13,000,000 was obligated money, but it was carried over. It was not expended, but it was obligated.

Question

Because many of us are very interested in other areas of innovation, would it be appropriate to ask if you have made any kind of allocation for the rest of this $18½ million for this year?

Answer

All of it has been allocated. Of the $33 million, roughly $10 million each is for bus, rail, and new systems, with slightly less in the new systems, and the remainder is for support of the planning efforts.

Question

Can you give us a few of the major projects?

Answer

I do not want to get into a discussion of the UMTA program right now. The UMTA program (the research and development and demonstration program) will be described in depth at the ATA meeting in Boston. The administrator, Mr. Hemmes, and people from the bus program, the rail program, and the new systems program will be there to describe the budget allocation and the projects that are going to be undertaken.

Question

I know of several programs, Dayton's being one, where model cities areas in connection with technical studies grants that were performed on transportation needs have been completed. Recommendations have been made for implementing a demand-actuated system or a dial-a-ride system. These areas are in the process of implementing these with model cities projects. At this point, does UMTA plan to become involved financially or technically in monitoring these programs. If so, what is the rationale behind merely becoming involved in one particular project?

Answer

We do not see the Haddonfield Project as being an end in itself. We see it as a beginning for building more refined and more sophisticated systems. We have to start somewhere. The model cities programs are not really within our jurisdiction. We have no control over the experimental designs that are set up for whatever it is that they are doing or proving. They are primarily designed to serve a specific local transportation need and to solve a problem in a given area rather than to prove a concept or to tell us what the next step should be.

Question

How can you move from a successful set of experiments that have been made by you and the Department of Transportation in application to 10, 20, or 30 cities through your program? Once the demonstration is over, what do you do?

Answer

The primary aim of the Research and Development Demonstration Office is to deliver a project to the capital grants people. This means something that cities can afford to pay for on a one-third local, two-thirds federal basis. It seems to us that dial-a-bus is one of the few transportation innovations on the horizon that cities can afford to pay for. We all talk a lot about very sophisticated guide systems, and then we stop to think about it. Our job is to deliver a project to capital grants that people can afford, and one wonders how many cities in the United States can afford many of the sophisticated systems we talked about. Dial-a-bus is something that is quite reasonable by these kinds of standards; so we have no difficulty in seeing how the systems will be proliferated.

Statement

This raises the overall question of whether the present situation of having capital grants is adequate for something like this. These sort of start-up grants are between capital and operating subsidies, and this, in my opinion, is unfortunate. Eventually, public transportation is going to require government assistance and the sooner we face up to it, the better.

Question

You mentioned that the aim is to deliver an end product to the capital grants program. Under the present capital grants program, I know that one can buy a piece of equipment to wash a transit bus and one can buy a transit bus, and I believe it has been established that one can buy a two-way radio. Are there in the kind of dial-a-ride systems that we are likely to be putting together with cities during the next 18 months other potential ingredients that qualify under the capital grants program?

Answer

I fully expect that, of all the cities that we have received inquiries from, at least one of them will not be willing to sit still for 18 months and to wait to see what happens. I am anticipating that there will be some action.

Question

I am anticipating that there will be some federal grant-capital grant applications made, and I would be interested in your comments on what ground rules might be used.

Answer

What other components are you thinking of? Computers? Software?

Question

Computer, software, and digital communications systems, if and when they become available?

Answer

I really would not like to speak for them on that.

Question

Would your office be called in to advise if such a grant application were received through the capital grants program?

Answer

It is likely that we would be. Our position is that we are funding as far as components and operation only one at a time. If someone else wants to fund the operating part of it and can prove beyond a question that the components they are asking for are working, acceptable, and fully tested, then I think capital grants would act favorably on it. However, whether that can be done, I do not know.

Question

Is there a reasonably well-established criteria for what "proved and established" is?

Answer

No.

Statement

Everybody is missing one of our real problems, and that is that the transit industry has not picked this up. You are talking about developing new techniques by using university people. Nobody in the transit industry gets involved; possibly a few people in the space industry do. Then you wonder what you do when your program runs dry so that you cannot keep it going and when nothing has happened regarding application to the transit industry. The M.I.T. people have plenty of clients and do not have to worry about the federal government research program. We cannot do anything about it, and we are not responsible for the transit industry; but there is a resource problem.

Answer

In the Haddonfield experiment, the transit industry will be involved. Public service will be very much involved in the experiment. There are very few companies that can afford to do anything in public transit.

Statement

That is not true. If the transit industry can afford to lose money and go out of business, it can afford to spend some money and stay in business. If I am a business man and if I am losing money, I had better put out another dollar and try to recoup rather than just let my last dollar go past another loss and then finally cash my remaining chip in and say, "OK, I'm going home now." If I am going out of business, I will make a last effort to stay in business.

Answer

The traditional approach to that has been not to innovate but to cut back and cut back and cut back. There are people who have innovated and still are in business.

Statement

Right, a few.

Answer

Mansfield is one of them.

Statement

I have talked extensively to various transit agencies around the country, and their main and frequent retort is, "We don't have any money. We can't try anything new. We are going to have to ask for a subsidy of $10 million this year because we're having a deficit operation. How can you expect us to go out and have a new program when we can't even pay for what we're doing already?" I think there is a problem on both sides, and I do not know the answer to it.

Statement

I want to ask an honest question to any and everybody in this room. If you had some management capability and some innovative capability, would you go into the transit industry and try to move that bunch of boneheads? Do you think any innovative capability ever develops in the transit industry? If so, it immediately leaves.

Statement

Well, the risk capital (and I do not mean just money risk capital but political risk capital) is obvious. You know it is obvious just by talking around in the room. Is anybody going to go into the transit industry and innovate? Yes, some people are! Some are literally beating down our door just because we played a silly game in Mansfield. Some system will be put in. There have been reports that model cities agencies, cab companies, and many others are going to start firing up shared taxi service, and there will be some of these things. Nobody in this room or anybody else can control this thing. I do not think anybody can sit here and expect to control it in that environment even for the next 18 months. I surely agree that there is a risk-capital void; UMTA has publicly stated that the cautious, $1½ million approach is the one that it has elected to take. It is obvious what is going to happen. I just do not see that there is any other way for this system to get diffused. It will become implemented. In 18 months, there will be more than one dial-a-bus system in the United States. Some of them will be very bitter fisacoes.

Question

I understand that there was a report published by M.I.T. in connection with the work done there. I understand that the federal government will make these available to other areas. Do you have any idea what the status of this particular report is?

Answer

We have all but one of the reports submitted for review. They are being reviewed right now, and within a matter of a couple of weeks we should have our comments back to M.I.T. They can then be printed. The reports go to the National Technical Information Service because we have no real mechanism for distributing hard copies. Orders should be placed with that agency.

PARTICIPANTS

George J. Bacalis, Bendix Corporation
H. J. Bauer, General Motors Research Laboratories
Daniel Brand, Harvard University
Glenn F. Brehm, Vogt, Sage and Pflum Consultants

Eugene T. Canty, General Motors Research Laboratories
Leon M. Cole, University of Texas at Austin
Kenneth Cook, Highway Research Board
Harriet N. Curd, General Motors Research Laboratories

Peter M. Dalton, Department of Highways, Ontario

Raymond H. Ellis, Peat, Marwick, Mitchell and Company

W. Donald Goodrich, Sr., United Aircraft Research Laboratories
William L. Grecco, Purdue University
R. J. Grosh, Purdue University
Karl Guenther, Ford Motor Company
Richard L. Gustafson, General Motors Research Laboratories

William Hamilton, Social Systems Department, General Research Corporation
Kenneth W. Heathington, Purdue University
Clark Henderson, Stanford Research Institute
Charles S. Henry, Tri-State Transportation Commission
William T. Howard, Department of Highways, Ontario
Larry Howson, General Motors Research Laboratories

William F. Kail, General Electric Company
Edward J. Kennel, Purdue University
H. Norman Ketola, Rensselaer Research Corporation

Robert J. Maxman, Schimpler-Schuette Associates
Douglas Medville, MITRE Corporation
Rajendra K. Mehta, General Motors Research Laboratories
R. A. Meyer, Jr., Purdue University
Daniel D. Morrill, Montgomery County Transit Planner, Dayton, Ohio
Tom Mulinazzi, Schimpler-Schuette Associates

J. F. Nunamaker, Purdue University

Edwin H. Porter, Jr., Massachusetts Institute of Technology

Wilfred J. Roesler, Applied Physics Laboratory, Johns Hopkins University
Daniel Roos, Massachusetts Institute of Technology

Gilbert T. Satterly, Purdue University
Arthur Schwartz, New Jersey Department of Transportation
James A. Scott, Highway Research Board

Joseph S. Silien, Urban Mass Transportation Administration
Anthony U. Simpson, Dave Systems, Inc.
Richard L. Smith, Bendix Corporation
Richard J. Solomon, Massachusetts Institute of Technology
Joseph H. Stafford, Massachusetts Institute of Technology
Robert D. Stevens, Bendix Corporation

Fred Tumminia, Southeast Michigan Transporation Authority

Thomas Urbanik, Purdue University

Robert A. Vaughan, Dayton Transportation Study
Frank L. Ventura, Sr., General Motors Research Laboratories
Robert S. Vogt, Vogt, Sage and Pflum Consultants

Glenn E. Wanttaja, Sr., General Motors Research Laboratories
Nigel Wilson, Massachusetts Institute of Technology

Marcel J. Zobrak, MITRE Corporation

SPONSORING COMMITTEE

Committee on New Transportation Systems and Technology

Leon M. Cole, chairman

William H. Avery, Robert U. Ayres, George J. Bacalis, Eugene T. Canty, Donald Friedman, William F. Hamilton, II, Kenneth W. Heathington, William S. Jewell, Harold W. Merritt, Theodore F. Morf, C. Kenneth Orski, Daniel Roos, Albert J. Sobey, and Foster L. Weldon.

James A. Scott, Highway Research Board staff

THE NATIONAL ACADEMY OF SCIENCES is a private, honorary organization of more than 700 scientists and engineers elected on the basis of outstanding contributions to knowledge. Established by a Congressional Act of Incorporation signed by Abraham Lincoln on March 3, 1863, and supported by private and public funds, the Academy works to further science and its use for the general welfare by bringing together the most qualified individuals to deal with scientific and technological problems of broad significance.

Under the terms of its Congressional charter, the Academy is also called upon to act as an official—yet independent—adviser to the Federal Government in any matter of science and technology. This provision accounts for the close ties that have always existed between the Academy and the Government, although the Academy is not a governmental agency and its activities are not limited to those on behalf of the Government.

The NATIONAL ACADEMY OF ENGINEERING was established on December 5, 1964. On that date the Council of the National Academy of Sciences, under the authority of its Act of Incorporation, adopted Articles of Organization bringing the National Academy of Engineering into being, independent and autonomous in its organization and the election of its members, and closely coordinated with the National Academy of Sciences in its advisory activities. The two Academies join in the furtherance of science and engineering and share the responsibility of advising the Federal Government, upon request, on any subject of science or technology.

The NATIONAL RESEARCH COUNCIL was organized as an agency of the National Academy of Sciences in 1916, at the request of President Wilson, to enable the broad community of U.S. scientists and engineers to associate their efforts with the limited membership of the Academy in service to science and the nation. Its members, who receive their appointments from the President of the National Academy of Sciences, are drawn from academic, industrial, and government organizations throughout the country. The National Research Council serves both Academies in the discharge of their responsibilities.

Supported by private and public contributions, grants, and contracts, and voluntary contributions of time and effort by several thousand of the nation's leading scientists and engineers, the Academies and their Research Council thus work to serve the national interest, to foster the sound development of science and engineering, and to promote their effective application for the benefit of society.

The DIVISION OF ENGINEERING is one of the eight major Divisions into which the National Research Council is organized for the conduct of its work. Its membership includes representatives of the nation's leading technical societies as well as a number of members-at-large.

The HIGHWAY RESEARCH BOARD, an agency of the Division of Engineering, was established November 11, 1920, as a cooperative organization of the highway technologists of America operating under the auspices of the National Research Council and with the support of the several highway departments, the Bureau of Public Roads, and many other organizations interested in the development of transportation. The purpose of the Board is to advance knowledge concerning the nature and performance of transportation systems, through the stimulation of research and dissemination of information derived therefrom.