Technique For Selecting Operating Characteristics of Demand-Actuated Bus Systems

William C. Taylor, Michigan State University; and
Tapan K. Datta, Wayne State University

As the number of applications of demand-actuated public transit systems increases, careful consideration must be given to the selection of operating policies. It is not sufficient to merely determine that a demand-actuated system is better than a fixed-time operation. We should also attempt to select those operating characteristics that result in the optimal benefit to the user, operator, and community. In this paper, we explore the effect of several variables on the economic and service characteristics of demand-actuated systems. Comparative tables and charts describe a process for selecting the "best" system for prescribed service areas and potential demand. The variables include scheduling dynamics and routing dynamics. The selection criteria include user statistics such as ride time and waiting time and operator statistics such as total capital cost, operating-hours, and vehicle productivity. The selection of a system will necessitate a trade-off between service and operating costs, and techniques for formalizing these decisions and results of applying these techniques are presented.

The term "demand responsive" has many meanings. In a sense, bus systems in major cities are demand responsive. That is, as the demand has decreased through the years, the frequency of service and route coverage has responded to that demand.

If we want to more accurately characterize demand-responsive systems, we would define attributes to which they respond: average ridership and the response period, probably measured in years. This type of system provides good service if demand is relatively high and requires frequent service if both short- and long-term variations in demand are small. This may result in short periods of crowded buses and then periods of underuse of buses, but probably not to the extent that changes in operating policies are warranted.

However, as the average demand decreases, continued use of these attributes for scheduling and routing leads to either infrequent service or low bus use. The former means poor service as viewed by the user, and the latter results in an uneconomic operation.

To overcome this dichotomy in the face of decreasing patronage, analytical and empirical studies have been conducted. These studies use instantaneous or short-term demands for scheduling and routing as opposed to long-term averages. In this way, they avoid the long wait time associated with bus systems responding to long-term averages and yet maintain a higher level of bus use. As the demand increases or the variation in demand decreases, these advantages decrease. Since the cost is inherently greater for managing demand systems than for managing the existing system, we must understand the precise level of demand that warrants one or the other of these systems.

Because there are policy variations in the operation of demand-actuated systems, the question is one not of defining a single point but of defining a family of curves describing optimal operating policies ranging from instantaneous response to the "fixed-time" response of the existing systems. If we use cost in a general sense to include some combination of user costs and operating costs, this family of curves may appear as shown in Figure 1.

The purpose of this study was to develop and operate a model on a common set of data to produce this family of curves. A second objective was to illustrate the application of this concept for various definitions of cost and to test the sensitivity of these curves to various system parameters.

DEFINITIONS

At the outset, we had to define the characteristics of the various systems to be tested and evaluated.

Table 1 gives a list of demand-actuated public transportation systems. The characteristics of those used in this study are given below. The dynamic system was not tested in this study.

1. The fixed-headway and fixed-route system is based on multiple-passenger vehicles traveling on predetermined routes at prescheduled headways for passenger pickup and delivery. The route and headways for such operations are predetermined from past demand experiences. This type of system now exists in most urban areas.

2. The variable-headway and fixed-route system also uses multiple-passenger vehicles traveling on predetermined routes, but the schedule depends on dispatching criteria. For this study, we used 2 independent criteria: total demands or a specified wait time, whichever occurred first.

3. The fixed-headway and variable-route system is similar to the route-deviation service offered in Mansfield, Ohio. An optimal routing technique is necessary for system operation. To increase the efficiency in computing the optimal routing strategies, high-speed digital computers are necessary.

4. The variable-headway and variable-route (nondynamic) system is the traditional dial-a-ride service. The demands are recorded and analyzed according to their time of calls and spatial locations, and routes and schedules are selected based on the input criteria. The same set of dispatch criteria were used in this case.

SIMULATION MODEL

The simulation model was developed with the capability of replicating the operations of bus systems under various system strategies and collecting the data required for statistical summaries of system performance parameters.

The model is initiated by generating strings of demands (collection and distribution) for each specific area of operation. There is no limit with regard to the size of an area. For larger areas, the model can handle sectoring or splitting of the entire area in segments and can operate the simulated bus systems concurrently in each segment.

The model assumes a central pool of buses from which vehicles are dispatched to any sector on demand. (Different pooling policies are investigated in the sensitivity analysis portions in the study.)

For fixed-route systems, the routes of bus operation are specified; for variable-route systems, the shortest path is used by the model.

The simulation program develops a point-to-point travel distance matrix for the given area under investigation. The distance matrix is then converted to a travel-time matrix by using link travel speeds. The speed of travel can either be used as an average speed or as a function of other parameters.

Input variables include these specific speed parameters, number of sectors to be serviced, pooling policy, fixed headways, dispatch logic, vehicle capacity, and number of available buses.

A demand is considered as a call for service and can consist of either single or multiple passengers; the number of passengers is generated from probability functions with assigned probabilities for 1 passenger, 2 passengers, and so on.

The available buses in the bus pool are serially numbered, and the simulation model always searches for lowest numbered buses for use and will not call for a new bus (though available from the system constraints) so long as there is a bus in the pool that has been used before. Thus, maximum use of each bus is accomplished, and the number of buses required may be determined by specifying large bus pools. That strategy was used in this study.

The capacity of vehicles used in the simulation is an input parameter and must be specified. Capacity is treated as a constraint in making the decision regarding vehicle

and passenger service.

The zone number for identification of the activity center is also an input parameter. Thus, multiple-activity centers for various trip purposes are possible.

The mean arrival rate for the area under study is an input. The generation subroutine computes the rider demand on the basis of a preassigned probability distribution. The frequency of collections and distributions is also computed according to probability functions. Thus, the generation of rider demand is completely random (Poisson or any other probability distribution) and is computed for any specified length of time in the model.

The delay at any stop for a bus is a function of the number of passengers involved and whether they are loading or unloading. The model includes separate delay functions for evaluation of travel times. For a given bus stop, the delay is computed on the basis of the number of passengers entering and leaving at that location. This function is set up as a default option in the absence of specific input.

The model requires specific inputs regarding minimum number of passenger demands to warrant dispatching a bus or maximum headway of buses if the specified demand is not registered. These are predetermined in the definition of the system.

The maximum tolerable waiting time for a passenger is also an input to this model. This parameter signifies to some extent the level of service provided to the riders. It also is used to define the limit at which potential riders switch to other means of transportation and are lost in this study. We used 30 minutes as the maximum wait time, after which the call was erased from the demand list.

The general flow chart for the model is shown in Figure 2. The function of each subroutine is described below.

1. The "generate" subroutine generates passenger demands (collection and distribution) with necessary identification information such as origin zone, destination zone, number of passengers in each demand, and absolute clock time of generation.

2. The passenger demand is then separated by sectors and arranged in increasing order of generation time.

3. The model then examines the demand list of each sector at a specified interval of time (5, 10, 15, 20, 30 seconds) and tests the maximum headway constraint and dispatch logic. If neither of the above 2 dispatch triggers is satisfied, the model moves to the next increment of time and tests again. This operation is done concurrently in all sectors. When a dispatch criterion is satisfied, a bus is dispatched with the demand list for the specified sector being serviced.

4. The bus-pool subroutine is activated by 1 of the 2 triggers and searches for a bus with the lowest serial number and sends it to the sector identified.

5. The time of bus dispatch is noted, and a time clock is advanced in each bus to keep a record of tour time. This time clock considers point-to-point travel time from the generated travel-time matrix and also accumulates embarkation and disembarkation times at each service point. This module summarizes bus operating times and bus use statistics.

6. A separate test module keeps track of individual passenger generation time, wait time, riding time, and total travel time. This module summarizes passenger service data after each bus tour and also compiles summary statistics.

The system simulation is performed by the model, and all pertinent statistics of the riders are accumulated. The waiting time at the point of demand, riding time, and total travel time are accumulated by the model and printed for each bus trip. The origin and destination of the riders, their time of generation, waiting time, riding time, and total travel time are printed for each bus trip and also for each segment of the service area as shown in Figure 3.

The mean, maximum, and frequency over a specified limit are accumulated and printed for all statistics. This enables the analyst to take a closer look at the system attributes.

The bus occupancy, the trip time, and the bus utilization are accumulated for the entire simulation period. The first set of printouts consists of a table for each vehicle indicating each tour, number of passengers collected and distributed, and total

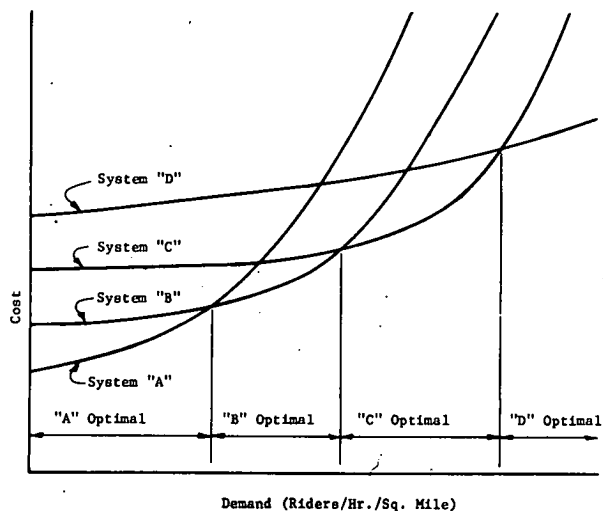**Figure 1. Optimal regions for alternative systems.**

Table 1. Performance criteria levels in hierarchy of demand-actuated bus systems.

System Number	Dispatch Logic	Response to Demand	Route
1	Fixed route and fixed headway (general purpose)	Nonresponsive	Fixed
2	Variable headway and fixed route	Semiresponsive to fixed route	Fixed
3	Fixed headway and variable route	Semiresponsive	Traveling salesman
4	Variable route and variable headway, nondynamic	Fully responsive	Traveling salesman
5	Variable route and variable headway, dynamic	Fully responsive to address	Traveling salesman

Figure 2. Simulation model.

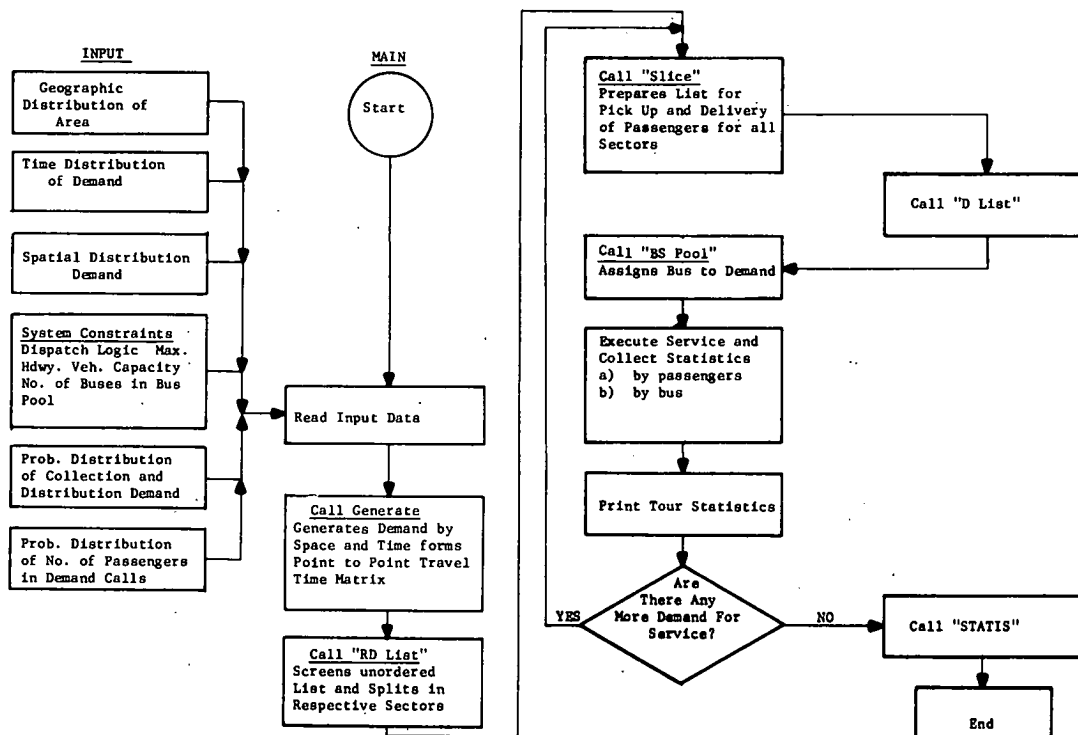**Figure 3. Model output of user statistics.**

```
    SECTCR  2          PES NUMBER  1          LEFT A.C. @    4.09 MINUTES          RETURNED @   23.02 MIN
TOUR COMPLETION TIME:   18.25                    BUS DISTRIBUTED . 0 PASS. COLLECTED  5 PASS. IN THE FCLLOW
```

DEMAND #	DESTI-NATION	ORIGIN	NUMBER PASS.	TIME GEN.	WAIT TIME	RIDE TIME	PASS. TOT. TRAV. TIME
1		33.	1.	C.41	5.76	16.86	22.62
2		73.	2.	3.78	15.37	23.11	38.48
3		139.	2.	0.26	34.62	10.91	45.52

```
BUS NUMBER  1 EXECUTED  8 TOURS INVCLVING   37 PASSENGERS
TOTAL TIME IN USE = 163.98 MINUTES
```

TOUR NUMBER	# PASS. DISTRB.	# PASS. CCLLCT.	TOTAL TOUR TIME
1	0	5	19.24
2	2	3	19.54
3	1	3	20.25
4	4	1	20.89
5	1	3	21.41
6	0	5	20.04
7	3	2	21.81
8	3	1	20.80

PASSENGER "WAIT-TIME" STATISTICS,

SEGMENTING IS DONE EVERY 60 MINUTES BASED ON GEN.-TIME

	SECTOR #1			SECTOR #2			SECTCR #3		
SEG. #	MEAN	MAX.	OVER 15 MIN.	MEAN	MAX.	OVER 15 MIN.	MEAN	MAX.	OVER 15 MIN.
1	10.37	30.82	7	13.05	27.17	9	14.41	30.12	12
2	9.59	23.53	6	13.53	31.39	12	13.72	28.35	6
3	7.43	24.25	3	9.85	16.79	3	8.45	30.10	4
4	0.0	0.0	0	0.0	0.0	0	0.0	0.0	0

PASSENGER "RIDE-TIME" STATISTICS,
SEGMENTING IS DONE EVERY 60 MINUTES BASED ON GEN.-TIME

	SECTOR #1			SECTCR #2			SECTCR #3		
SEG. #	MEAN	MAX.	OVER 15. MIN.	MEAN	MAX.	OVER 15 MIN.	MEAN	MAX.	OVER 15 MIN.
1	12.55	20.42	10	1C.95	17.82	3	10.5C	21.22	8
2	8.84	18.17	3	10.05	17.68	5	9.09	17.29	4
3	9.39	17.16	3	9.11	20.55	2	9.92	18.13	4
4	0.0	0.0	0	0.0	0.0	0	0.0	0.0	0

tour time.

The summary statistics for the buses shown in Figure 4 consist of one table for each time segment indicating the number of tours performed by each bus, number of passengers collected and distributed, total tour time, mean tour time, and bus use.

TEST SYSTEM

The street network used in this study was composed of 3 sectors with a common activity center. Each sector is 1 mile square and contains 225 passenger-generation points.

The variable-route system has access to each generation point through a grid network. The fixed-route system, which follows a pattern as shown in Figure 5, makes 20 stops to pick up or drop off passengers. The generated riders walk to the nearest stop for service, and the walking time is included in their waiting time.

Passengers were generated at each of the 225 generation points-sectors by a random generator. Poisson distribution was used to distribute passenger arrivals at each point; the mean value was one of the variables tested.

Before analysis is made of the differences in system performance characteristics produced by the models, the model results must be validated. To do this, we compared the model results over a range of demand densities with actual field experience, as shown in Figure 6. As expected, the existing systems perform better than fixed-time and fixed-route systems, but not so well as an optimally routed demand-actuated system. Figure 6 also shows that the advantages of demand activation decrease with increasing demand.

SYSTEM PERFORMANCE CHARACTERISTICS

Each of the 4 systems was used as the basis for simulation on a fixed data set representing 3 hours of operation at each of several levels of demand. The demand levels tested in the anslysis were 10, 20, 30, 40, 60, 80, and 100 demands per hour per sector.

Both user and operator summary statistics were collected and compared as a method of establishing system performance. These statistics include waiting time, riding time, number of vehicles required, and vehicle productivity.

Figure 7 shows the average wait time per passenger versus the demand per hour per sector for each system. The variable-headway and variable-route system provides the lowest wait time for a demand level below 75/hour/sector. Beyond this level, the fixed-route and variable-headway system has the lowest waiting time, although the variable-headway and variable-route system is quite close. At demand levels beyond 60/hour/sector, the fixed-route and fixed-headway system has almost the same wait-time characteristics as those of the variable-route and variable-headway system. The variable-route and fixed-headway system is clearly not comparable, for it results in a much higher waiting time than that of any other system.

Figure 8 shows the ride-time characteristics of each system. The variable-route and variable-headway system can reduce riding time in the network for all levels of demand tested. Both fixed-route systems yielded very high ride times.

No single system provides the optimal value of each characteristic at all demand levels. However, if the 2 recorded times are added to obtain total travel time, the variable-route and variable-headway system yields the lowest total travel time at all tested levels of demand.

Figure 9 shows that the variable-route and fixed-headway system yields the highest vehicle productivity for all levels of demand. The variable-route and variable-headway system produces a higher productivity than either one of the fixed-route systems for demand levels below 80/hour. Beyond this point, the fixed-route and fixed-headway system shows higher productivity.

Figure 4. Model output of bus statistics.

```
SEGMENT NUMBER  1          TIME FROM    0.0 MIN. TO    59.99 MIN.
```

BUS #	NUMBER TOURS	NUMBER PASS. DISTRB	NUMBER PASS. COLLCT	TOTAL PASS. SERVED	TOTAL TOUR TIME	MEAN TOUR TIME	BUS UTILI-ZATION
1	3	2	11	13	50.01	16.67	0.83
2	3	4	5	9	49.18	16.39	0.82
3	2	4	6	10	46.92	23.46	0.78
4	2	6	4	10	46.66	23.33	0.78
5	2	2	7	9	40.75	20.37	0.68
6	2	0	4	4	19.98	9.99	0.33
7	1	3	2	5	21.81	21.81	0.36
8	0	0	0	0	0.0	0.0	0.0

Figure 5. Fixed-route system.
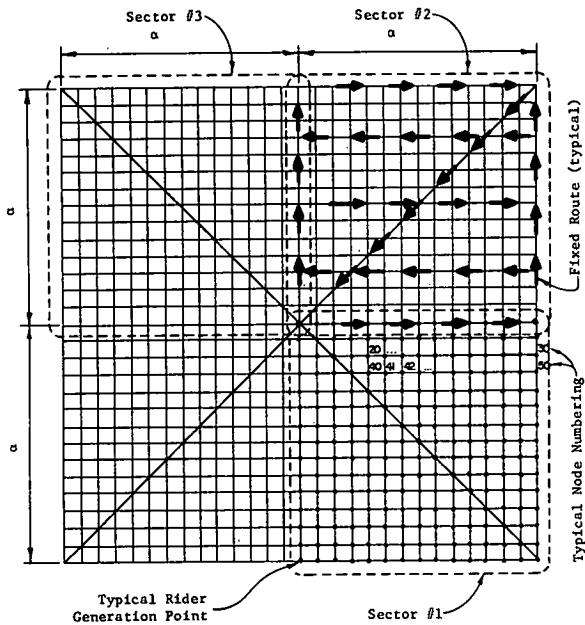
Figure 6. Comparison of productivity of simulated and operating systems.
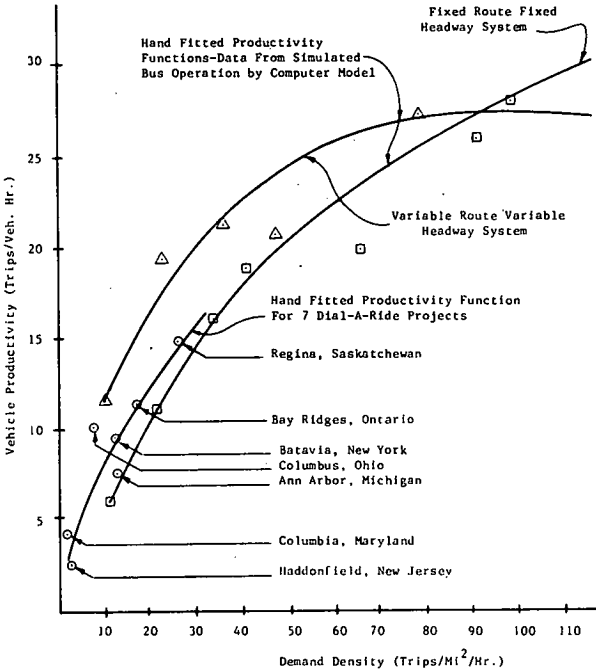
Figure 7. Wait times of 4 systems.

Figure 7. Wait times of 4 systems.

Figure 8. Ride times of 4 systems.

Figure 8. Ride times of 4 systems.
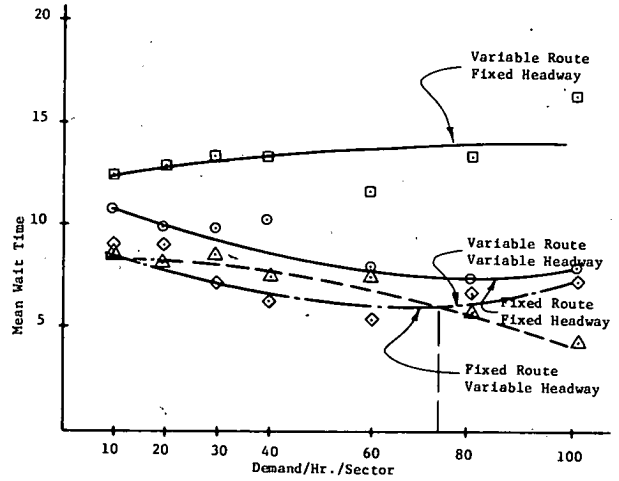
Figure 9. Vehicle productivity of 4 systems.
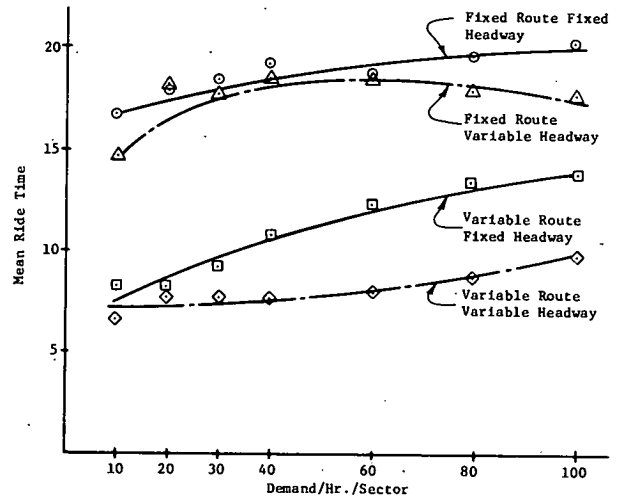
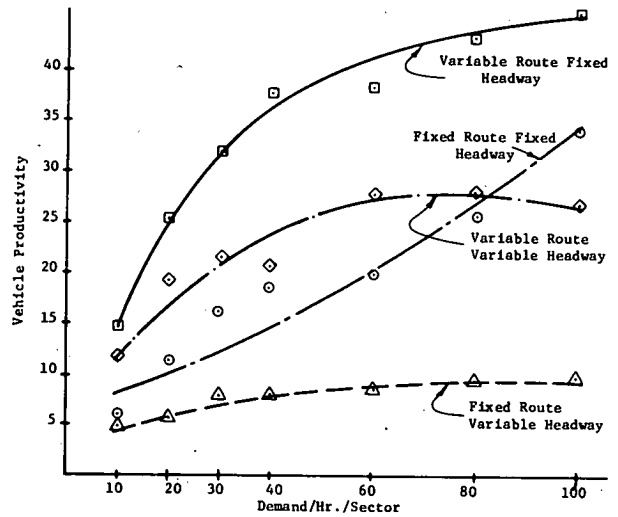
Figure 9. Vehicle productivity of 4 systems.

Figure 10 shows the total number of buses required for each system. Because this measure is inversely related to productivity, the variable-route and fixed-headway system has the lowest vehicle requirement for all levels of demand. A similar result is shown in Figure 11 for driver-hours. Again, the variable-route and fixed-headway system results in the lowest driver-hour requirements for all levels of demand. The variable route and variable-headway system has a driver requirement lower than the fixed-route and fixed-headway system in the low-demand sector, but the 2 systems become nearly coincident in the high-demand sector.

Figure 12 shows vehicle-hours of operation. The variable-route and fixed-headway system produces the lowest vehicle-hours of operation among the systems. The variable-route and variable-headway system has a lower vehicle-hour requirement than the fixed-time and fixed-route system up to the demand of 65/hour/sector. These curves and those for driver-hours cross at different demand levels because the variable-route and variable-headway system is a more efficient system when measured by bus use. Therefore, there are fewer idle hours for the bus driver while waiting for the run to start.

SYSTEM EVALUATION AND SELECTION

The primary objective of this study was to generate data to assist in the selection of demand-actuated bus system alternatives. If one were to make the very simple assumption that demand, service, and operating costs are all nonelastic, then the curves shown in the preceding section would suffice. The bus manager who wants to operate a bus system for profit could survey the demand and select the system with the lowest product of vehicle operating time multiplied by cost per hour and capital costs of required buses amortized over their life span. The cost for this bus service could then be compared with a feasible fare.

Similarly, if public transportation were being considered as a public service, a specified level of service as measured by waiting time and ride time could be established, and the system that met these criteria for the projected demand could be selected. The appropriation required for the service could be determined from the bus statistics, and a decision reached by the appropriating body.

There is sufficient evidence, however, to reject this assumption of a nonelastic market. The structure of existing trip-generation and modal-split models used in transportation planning includes a dependent relation among demand, service, and cost. Thus, the problem is not that simple, even if the data are known.

Obviously a trade-off must be made between the user's performance characteristics (wait time, ride time, total travel time) and the transit operating characteristics (number of buses, vehicle-hours of operation, vehicle productivity, bus use). The use of constant unit cost figures for each of these characteristics is unrealistic, for they vary with location and in many cases are quite subjective.

The value of these system attributes depends largely on the goals and policies of the community for which the transit system is being planned. In economic analysis, where the trade-off between intangible and tangible costs needs to be established, the common practice is to use a value scale for both items. This value scale varies depending on the goals of the environment and is often referred to as a utility scale; system alternatives are selected on the basis of their score or utility function. Whether the simple benefit-cost anslysis or the more complex utility analysis is preferred by the analyst, there are 2 common factors in all evaluation techniques:

1. A scaling factor representing the "value" of an incremental change in each of the significant measures of performance, V_i; and
2. A quantitative representation of the change in the magnitude, x_i.

The evaluation models can combine these factors in an additive, multiplicative, or exponential manner. They can be linear or nonlinear, independent or interdependent, and time independent or time dependent.
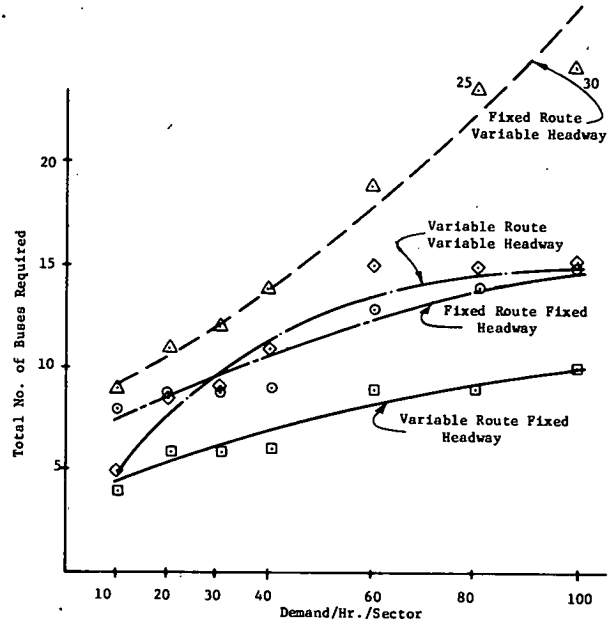
Figure 10. Bus requirements of 4 systems.

Figure 11. Driver-hour requirements of 4 systems.
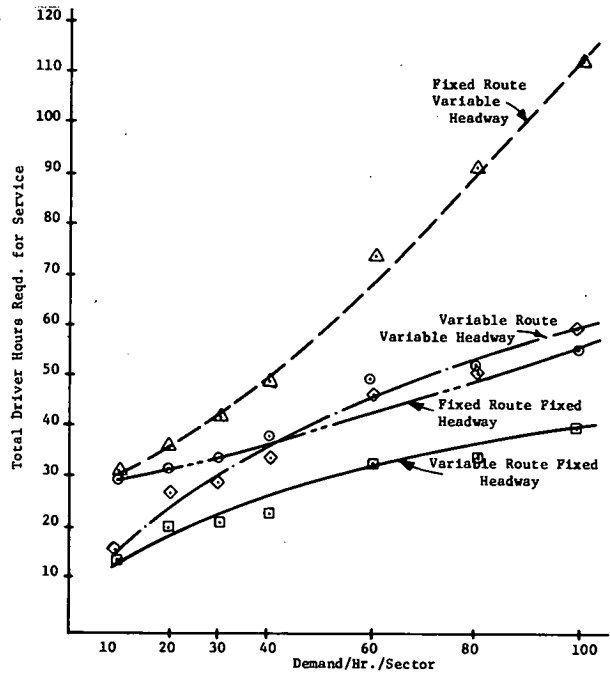
64

Figure 12. Vehicle-hours of operation of 4 systems.
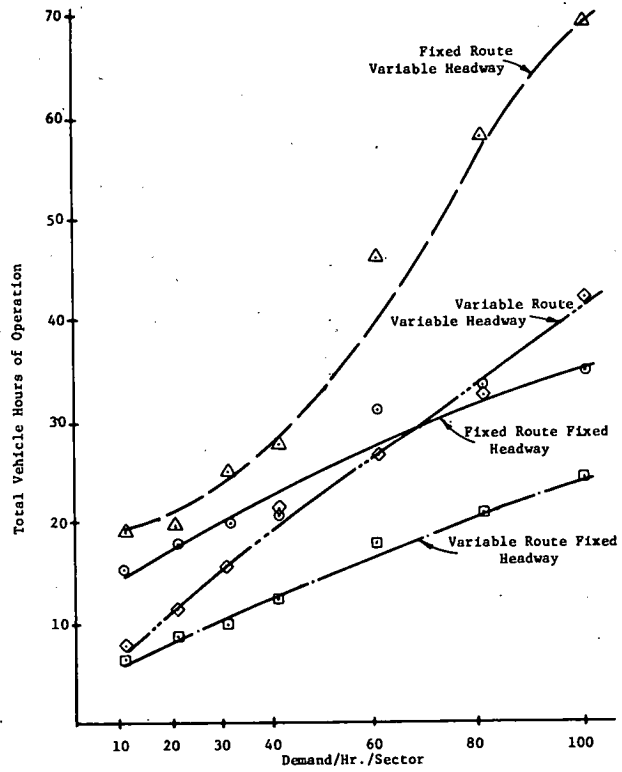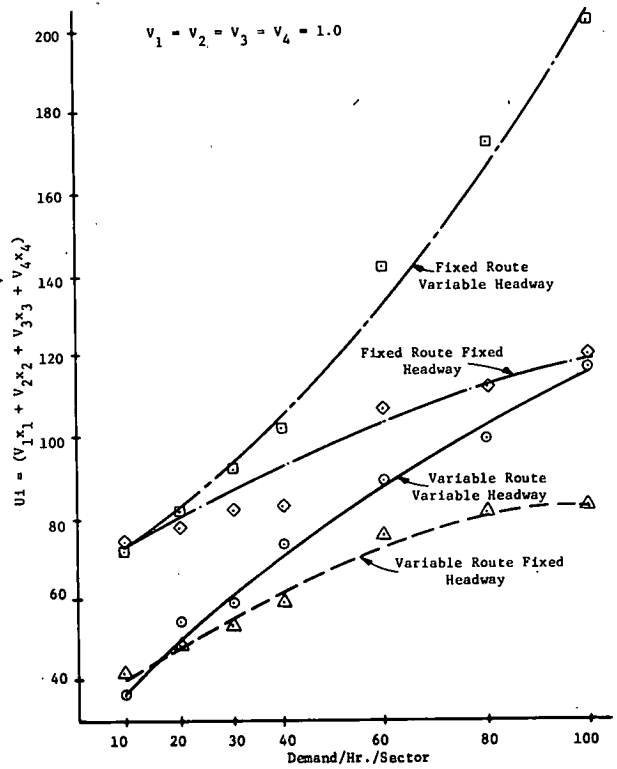

Figure 13. Utility cost functions for all coefficients = 1.

This modeling represents an entire area of study and is beyond the scope of this paper. However, for the purpose of demonstrating the applicability of these model outputs to the evaluation process, a simple additive, linear model is assumed. The scaling factors, V_i, are also assumed, but variations in these values are tested to demonstrate user-oriented, operator-oriented, and system-oriented assumptions. The model structure used is

$$(U_j) = f \text{ (system performance data, policies)}$$

$$U_j = V_1x_1 + V_2x_2 + V_3x_3 + \ldots + V_nx_n$$

where

U_j = utility,
x_i = score of a selected system performance parameter, and
V_i = value coefficient selected in accordance with the goals and policies.

The following variables have been selected to demonstrate the applicability of the methodology of utility cost functions for system alternatives in the selection procedure:

x_1 = mean wait time/passenger,
x_2 = mean ride time/passenger,
x_3 = driver-hours required for service,
x_4 = total vehicle-hours of operation,
V_1 = value coefficient for mean wait time,
V_2 = value coefficient for mean ride time,
V_3 = value coefficient for driver-hours required
      for service, and
V_4 = value coefficient for vehicle-hours.

Because these parameters all become increasingly undesirable with increasing scores, this model defines the disutility or utility cost, $U_j = V_1x_1 + V_2x_2 + V_3x_3 + V_4x_4$, of each system.

Selection of high-value coefficients for variables x_1 and x_2 (i.e., mean wait and ride time) will result in the selection of a service-oriented operation where passenger service criteria are quite stringent and the nonmonetary benefits of public transportation are given high weights compared to the monetary costs of operation. High-value coefficients for variables x_3 and x_4 (i.e., driver-hours required and vehicle-hours of operation) will lead to the selection of a low-cost operation with greater emphasis on tangible costs than on user benefits. The methodology presented here does not suggest any specific values for these coefficients, but merely demonstrates a procedure that could be used in evaluating alternative systems.

Figure 13 shows the utility cost versus demand density for all 4 systems where the utility coefficients are all equal to 1.0, or there is no bias between user values and operator values. At a very low-demand density (10/hour), the variable-route and variable-headway system results in the lowest utility cost. As the demand increases, the variable-route and fixed-headway operation results in the lowest cost system for demand of more than 20/hour. The fixed-route and fixed-headway system, which results in a high cost at low demand, approaches the variable-route and variable-headway system at approximately 100/hour demand. For low-demand situations characteristic of Columbia, Maryland, or Haddonfield, New Jersey, the variable-route and variable-headway system should be selected if the user and the operator characteristics are considered to be equally important.

Figure 14 shows the utility cost function for coefficients V_1 and V_2 equal to 1 and V_3 and V_4 equal to 3.0. This might be representative of a system with a limited subsidy. In this case, some increase in user costs would be accepted in return for lower operating costs. As a result of this change in the weighting functions, the total user time increased from 15.6 to 20.4 minutes at a demand level of 10/hour, and vehicle-

Figure 14. Utility cost functions for V_1 and $V_2 = 1$ and V_3 and $V_4 = 3$.
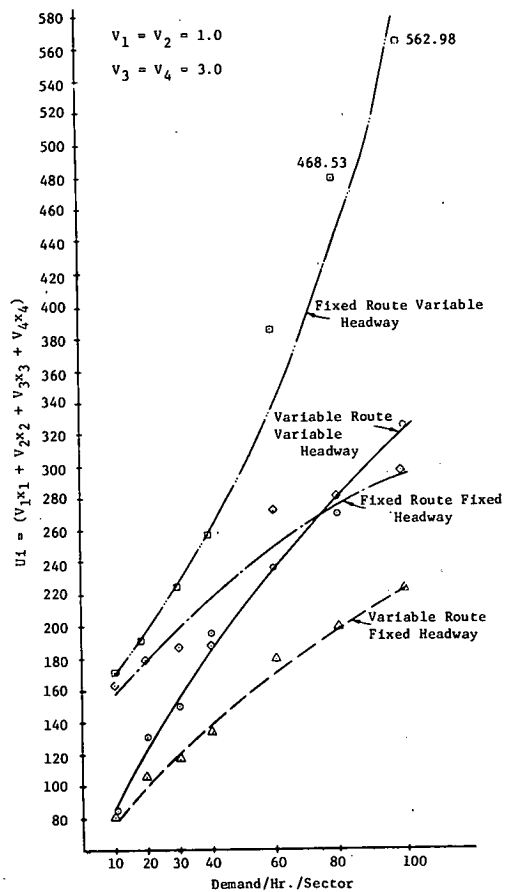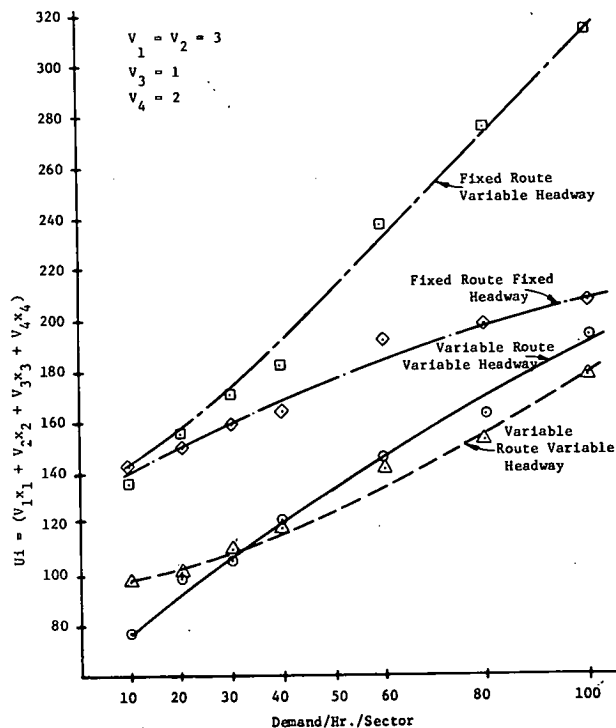

Figure 15. Utility cost functions for V_1 and $V_2 = 3$, $V_3 = 1$, and $V_4 = 2$.

hours of operation was reduced by 18.6 percent, from 7.76 to 6.31 hours. We are equating this 5 minutes of extra travel time to a $\frac{1}{2}$-hour reduction in bus-hours.

At the other extreme, Figure 15 shows a case in which the user characteristics are weighted very heavily. This might be characteristic of a highly subsidized service for a Model Cities neighborhood, in which service is the important factor to be considered. The operating characteristics of the variable-route and variable-headway system are far superior to those of any other system at all levels of demand. In comparison with the normal operation (fixed route and fixed headway) at a demand level of 100/hour, savings in total travel time is 51 percent and the penalty is 17 percent in operating hours.

In addition to system-selection policies, the analyst is also faced with the task of recommending operating policies. In this study, we looked at variations in system characteristics and utility costs as they are implemented by different bus-pooling policies, vehicle-to-sector assignment policies, sector size and network accessibility factors, and variations in demand over time. Time does not permit a discussion of each of these in this paper. However, an example was prepared to demonstrate the effect of matching the system with the demand over time.

Because the demand for bus transit ridership in any area varies with time, such variations in demand must be considered in the system selection process. As we have shown previously, the demand at which any system becomes "better" than other systems depends on the value coefficients. Thus, different systems can be optimal at different times during a typical day's bus operation. The effect of changes in operating system alternatives was demonstrated by a hypothetical passenger demand distribution (Fig. 16). The same decision variables—wait time, ride time, vehicles-hours of operation, and driver-hours required—were used and the value coefficient shown in Figure 14—$V_1 = V_2 = 1.0$ and $V_3 = V_4 = 3.0$—and the utility cost versus demand density were plotted to construct the utility costs of the variable-route and variable-headway system and the fixed-route and fixed-headway system for hourly variations in demand. Table 2 gives the time of demand, demand rate, and utility cost. This information was used to compare 3 alternative operating strategies: variable-route and variable-headway system for the entire period, fixed-route and fixed-headway system for the entire period, and a combination of those 2 systems to achieve minimum total cost. Table 3 gives the results.

This example serves only to illustrate how the results of this study might be used. The difference in cost saving or magnitude of system efficiency can be quite significant in some cases. This depends on the value coefficients selected for evaluation purposes (which really reflect the goals and policies of the community) and the magnitude of the variations in demand.

Other policies, like bus pooling, sector selection, guaranteed pickup time, dispatching logic, and level of service provided, will also influence these numbers. The approach used in this study provides the tools necessary to assess each of these and to bring rationale in the system-selection process.

ACKNOWLEDGMENTS

REFERENCES

1. Mason, F. J., and Mumford, J. R. Computer Models for Designing Dial-A-Ride Systems. SAE Automotive Engineering Congress, Detroit, 1972.
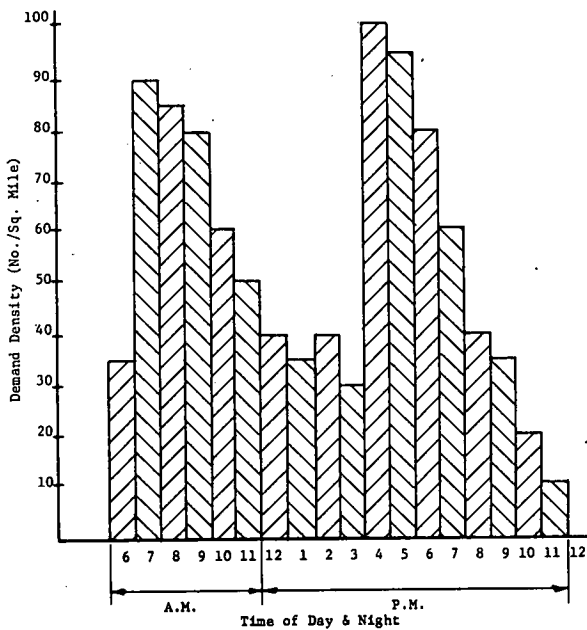
Figure 16. Typical distribution of rider demand.

Table 2. Utility costs of alternative systems.

Time	Demand Rate (riders/sq mi)	Variable-Route and Variable-Headway System	Fixed-Route and Fixed-Headway System
6 to 7 a.m.	35	170*	208
7 to 8	90	298	282*
8 to 9	85	284	275*
9 to 10	80	276	272*
10 to 11	60	232*	248
11 to 12	50	210*	233
12 to 1 p.m.	40	182*	217
1 to 2	35	170*	208
2 to 3	40	182*	217
3 to 4	30	155*	198
4 to 5	100	318	292*
5 to 6	95	308	282*
6 to 7	80	376	272*
7 to 8	60	232*	248
8 to 9	40	182*	217
9 to 10	35	170*	208
10 to 11	20	121*	178
11 to 12	10	83*	163

ªOptimal system for that hour.

Table 3. Cost and efficiency of systems.

System	Cost	Inefficient (percent)
Variable route and variable headway	3,849	3
Fixed route and fixed headway	4,218	12
Combination of 2 systems	3,754	

2. Wilson, N. H. M., Sussman, J. M., Migonnet, B. T., and Goodman, L. A. Simulation of a Computer-Aided Routing System (Cars). Highway Research Record 318, 1970, pp. 66-76.
3. 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.
4. Bruggeman, J. M., and Heathington, K. W. Sensitivity to Various Parameters of a Demand-Scheduled Bus System Computer Simulation Model. Highway Research Record 293, 1969, pp. 117-125.
5. Roos, D. Dial-A-Bus Feasibility. HRB Spec. Rept. 124, 1971, pp. 40-49.
6. Heathington, K. W., et al. Computer Simulation of a Demand-Scheduled Bus System Offering Door-to-Door Service. Highway Research Record 251, 1968, pp. 26-40.
7. Guenther, K. W. Ford Motor Company's Role in Dial-A-Ride Development: 1972 and Beyond. HRB Spec. Rept. 136, 1973, pp. 80-84.
8. Bauer, H. J. Case Study of a Demand-Responsive Transportation System. HRB Spec. Rept. 124, 1971, pp. 14-39.

Dial-A-Ride:
Opportunity for Managerial Control

Gordon J. Fielding and David R. Shilling,
Orange County Transit District, California

Competent management requires the ability to perceive problems, the ability to conceptualize solutions, and the skill to communicate both the problem and the solution to those responsible for carrying out management directives. It also requires that managers infuse the issue with a sense of urgency so that the solution is implemented. For the most part, public transit has not been managed by these objectives. Rather transit management has been totally absorbed with service, maintenance, and escalating costs. Policy decisions in public transit are often based on inadequate, outdated, or incomplete information or have come too late to reverse system inefficiency. Costs rise, the level of service falls, and patronage drops to levels so low that many operations are in desperate financial situations. And yet transit systems continue to be managed by heirarchical control. Effective management through the control of information flow will reverse this trend. Dial-a-ride transit, with its capability of providing real-time information about system status, is an ideal medium in which innovative management techniques can be tested. This paper explores the opportunities dial-a-ride offers for developing innovative systems for the management, control, and interpretation of information and outlines information flow techniques that can be useful in the optimization of system efficiency.

Dial-a-ride, dial-a-bus, telebus, call-a-bus, demand jitney, computer-aided-routing system, call-a-ride—these are all names for demand-responsive bus systems (1).