OPERATIONAL PLANNING OF FIXED-ROUTE AND DEMAND-RESPONSIVE BUS SYSTEMS IN THE GREATER LAFAYETTE, INDIANA, AREA

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ABRIDGMENT

Many small urban areas in the United States are evaluating implementation of a demand-responsive transportation system in addition to the conventional bus system. This paper suggests the proper combination of the two modes, fixed-route and demand-responsive systems, that best serves the demand at a level of service required by the customer. The greater Lafayette area is used as a case study. A simplified procedure was developed to design the fixed route of the bus system of the greater Lafayette area. The level of service was measured by the total time the users spend on the bus system. Computer simulation was used to duplicate the operations of the demand-responsive system in the real world. The system operates on a many-to-many basis, i.e., many origins to many destinations, and is dispatched by computer. Cost comparisons of the two systems provided the feasible operation of the two bus modes for various demand levels under the same level of service. The results show that the fixed-route system best serves the high demand, i.e., more than 90 persons per hour. The demand-responsive system best serves the lower demand. No generalization of the results could be reached at this point in time, except for small urban areas similar in size and in structure to the greater Lafayette area.

•MANY small urban areas in the United States are trying to revive bus transportation by implementing, in addition to the conventional fixed-route, fixed-schedule bus system, a demand-responsive transportation (DRT) system, which has attributes similar to those of the automobile. This paper addresses the combination of the fixed-route and demand-responsive systems that best serves the various demand levels in the greater Lafayette, Indiana, area at a level of service required by the customer.

Combined, the two modes, fixed-route and DRT, provide a feasible alternative for bus public transportation in small urban areas. They serve different demand levels. For a defined service area the demand level for public transportation varies at different times of the day. It increases sharply at certain times, usually during the home-to-work and work-to-home travel periods, and it decreases and levels off at other periods. The proper application of each of the two modes to best serve the various demand levels remains a problem to the transit planners. No real analysis and experimentation have been done to determine the proper combination of the two modes. Most of the DRT experiments have been done in service areas that did not include a fixed-route bus system, or the DRT has been implemented to serve part of an area that is already covered by a fixed-route bus system. This study investigated the application of a fixed-route bus system during the peak periods and the many-to-many DRT system during the off-peak periods in the greater Lafayette area. The number of vehicles required by each mode to operate at a certain level of service was determined. Consequently, the cost analysis of the two systems determined the feasibility of their operation.

FIXED-ROUTE SYSTEM

The routes for the fixed-route system were designed to provide 30-min headways on the entire system. The route coverage was such that no part of the entire area was more than $\frac{1}{4}$ mile (0.4 km) from a bus route. Average operating speed of the buses was assumed to be 12 mph (19 km/h). Fifteen buses were required to provide the service.

The level of service provided by the bus system was defined as equal to total service time divided by direct travel time by automobile. Total service time for the bus system is composed of bus travel time and user waiting and walking time.

The value of the level of service offered by the selected fixed-route bus system was 2.35.

DEMAND-RESPONSIVE TRANSPORTATION SYSTEM

Real-world operation of a DRT system was computer simulated. The system was designed on a many-to-many basis, i.e., many origins to many destinations, and vehicles were computer dispatched. The objective of the simulation was to estimate the number of vehicles required for specific operating conditions and quality of service. The results were used in a cost comparison of the DRT and fixed-route systems, which led to a decision on the utility of the DRT system. The input variables were the number of vehicles and the demand level. The level of service was output based on these two parameters.

Specifically, we isolated the effect of each of these three parameters on the performance of the system by conducting a series of computer simulations to study the effect of

1. The number of vehicles on the level of service with the demand level held constant,
2. The demand level on the level of service with the number of vehicles held constant, and
3. The demand level on number of vehicles with the level of service held constant (this was achieved after conducting a number of experiments with different combinations of demand level and number of vehicles).

COST ANALYSIS

The cost analysis determined the feasibility of operating the two modes under different demand levels at a required level of service. The mean level-of-service value that was considered acceptable to the public is 2.2 to 2.5 times the mean direct automobile travel time. The cost analysis of the different operations was investigated at this level of service, but the measure of service for the two systems is not quite the same except in terms of time consumption. The DRT system offers door-to-door service, comfortable waiting times, and no walking. It offers a better service than fixed-route bus system even when the time spent by the users on both systems is the same. However, the value of walking to the bus stop and waiting on the street is a qualitative measure and is difficult to include in the calculation of the measure of service. Therefore, this research considered only the total time spent by the users on the system in comparing the levels of service offered by the two modes.

The cost of a bus system depends mainly on the number of buses in operation. Drivers' wages and the operating cost of the vehicles constitute the major component of the total system cost. In the case of DRT systems, the cost of dispatching and the cost of computer assignment add another component to the total cost. Before the cost of the two systems can be compared, the number of buses required to serve the various demand levels must be determined.

The design of the two systems revealed the number of buses needed to serve the various demand levels at a certain level of service. The results are given below for a 2.2 to 2.5 mean level of service.

System	Demand (passengers per hour)	Number of Vehicles
Fixed-route	151 to 750	15
DRT	150	14
DRT	120	12
DRT	90	10
DRT	60	8
DRT	30	5

These figures show that, for a demand greater than 150 persons per hour, the fixed-route bus system requires fewer buses than the DRT to provide the same level of service. Consequently, it will cost less than the DRT because of its less sophisticated control systems. The high demands—greater than 150 persons per hour—occur during the peak hours of the day in the greater Lafayette area. Therefore, the fixed-route system provides a better alternative during these hours.

For a demand of fewer than 150 persons per hour, the DRT system requires fewer than 15 buses to provide the same level of service. However the total system cost could be less than, equal to, or greater than that of the fixed-route system, depending on the number of DRT vehicles in operation. This is mainly due to the additional administrative and operative cost required by the DRT system. The cost analysis investigated the break-even point between the cost of the two systems, that is, the number of DRT vehicles in operation that would produce the same total cost as the 15 buses in the fixed-route system. Below that number of vehicles the DRT system would provide a better alternative than the fixed-route system.

Hence, the cost analysis investigated the operating cost per hour of the following systems:

1. A 15-bus system operating on the developed fixed routes of the greater Lafayette area and
2. A number of DRT vehicles that would be equivalent in cost to the fixed-route system.

The cost analysis indicated that 10 DRT vehicles would produce the equivalent cost of 15 fixed-route buses. The demand served by 10 DRT vehicles would be equal to 90 calls per hour for the required level of service. Therefore the DRT system would be better for demands less than or equal to 90 calls per hour.

CONCLUSIONS

The results of this study identify the best operation in the greater Lafayette area for the two transit modes, the fixed-route bus and the DRT, for the different demand levels at a required level of service. These results for the prescribed level of service are as follows:

Demand (passengers per hour)	Number of Vehicles	Type of System
91 to 750	15	Fixed-route
90	10	DRT
60	8	DRT
30	5	DRT

From these results it can be concluded that the fixed-route system is better for high demands, and DRT offers a better and less costly service for low demands. This conclusion is valid only when the concept of level of service as defined is used as a yardstick for comparison of the two systems, that is, if the time spent by the users on the bus system compared to their automobile travel time is used as the criterion.

The results are applicable specifically to the greater Lafayette area. However, in areas that have the same size and structure as greater Lafayette, the results might be used.

The study has confined its analysis to the many-to-many DRT system with computer dispatching.

REFERENCE

1. A. G. Hobeika. Operational Planning of Fixed-Route and Demand-Responsive Bus Systems in Greater Lafayette Area. Purdue Univ., Joint Highway Research Project Rept. 22, Sept. 1973.

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