Abridgment

Evaluation of Pupil Transportation Routing Procedures

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The process of choosing a method for reviewing and designing the route structure of pupil transportation systems for rural and suburban areas was investigated. The available techniques for school bus routing were reviewed and divided into three general categories: (a) manual procedures, (b) computer-assisted manual design methods, and (c) computerized design programs. An evaluation framework is presented for application by school districts in selecting the most appropriate school bus routing procedure to use in their areas. The application of the evaluation model in a selected school district is described. The study results indicate that the computer-assisted methods are best suited for the majority of school districts, except for only the very large and very small areas. Future work should be directed to improving on these interactive computer-assisted methods.

This paper addresses a problem that rural and suburban school districts face in the early stages of reviewing the route structure of their school bus system--that of selecting a particular technique to use in studying their transportation system. The options available are reviewed and a strategy is developed whereby districts can rationally select a method best suited to their particular needs and resources. A case study is shown for Albemarle County, Virginia.

CATEGORIES OF ROUTING METHODS

School bus routing methods are ways of determining the sequence of stops school buses make in picking up and delivering students to their respective schools. A wide variety of techniques is available for school bus routing that may be divided into three general categories:

1. Manual procedures,
2. Computer-assisted manual design methods, and
3. Computerized design programs.

For comparative purposes, a subclassification is made for methods that use computers to design the routes: (a) methods that are implemented and used by the school district and (b) methods that are provided by consulting services and purchased yearly by the school districts.

Manual methods are those that use only pencil, paper, maps, and, perhaps, handheld calculators to develop school bus routes. As a class, manual methods are used in all but a small minority of school districts today. Usually no formal procedural steps are followed; routes are typically developed by intuition and experience.

As a category, the manual methods offer the potential advantage of allowing for consideration of a variety of local conditions that are often unquantifiable and undocumented. To be effective, however, the manual methods can be extremely tedious and time consuming. As a result, most manual routing efforts consider only minor modifications to historically derived routes rather than systemwide evaluations.

Computer-assisted manual school bus routing methods use computer programs to assist in the manual design of routes. The computer programs are used to generate performance statistics for the routes that are manually designed. These measures typically include disaggregate and summary statistics on travel time, passenger volume, and mileage. Examples of the computer programs include (a) the Urban Mass Transportation Administration (UMTA) Urban Transportation Planning System (UTPS), (b) statistical package for the social sciences (SPSS), and (c) a variety of specially written computer-program-assisted manual methods (1-3).

The primary advantage of the computer-assisted methods over the manual methods is that they provide individual route and system statistics quickly and easily. This feature facilitates the examination of different routing configurations and the implications of different policy options, an operation that is virtually impossible by the use of a completely manual method.

Computerized school bus routing methods are those that use computer algorithms or programs in the actual design of school bus routes. The major difference between the methods and the computer-assisted manual methods is that they use a computer algorithm for route design but the latter rely on individual judgment.

The algorithms and programs that were developed to design school bus routes are based on one of the following approaches:

1. The traveling salesman approach (4,5);
2. The vehicle delivery or, as its solution became known as, the savings approach (6-9); and
3. The random approach (10).

All require a systematic documentation of (a) the street network in terms of links, nodes, and travel times or distances between nodes; (b) the bus stop locations and their respective numbers of students that correspond to each school; and (c) parameters for constraints, such as bus fleet size and capacities (11).

In the United States today, a relatively small number of districts have fully computerized their school bus routing process. Some have tried and have since abandoned the computer method and returned to manually developed school bus routes. The reasons for abandonment vary, though they are generally a combination of the following: (a) insufficient manpower on the local level to accurately gather all data, (b) lack of commitment of local school officials and transportation supervisors, (c) inadequate memory and calculating power on the computers used, (d) high turnover rate and lack of experience of computer staff, (e) discontinued interest of several firms that had formerly provided school bus routing consulting service, and (f) dissatisfaction with the results.

Those districts that have successful computer systems are very enthusiastic about them. They cite the relative ease in updating the various data files and in using the computerized systems to develop routes for their districts each year after implementation as primary benefits of the method.

Computer school bus methods, however, are not recommended for all school districts. Because of the high initial costs, they are generally more suited for large school districts where potential savings in the pupil transportation systems would more likely equal or exceed the implementation costs.

FRAMEWORK FOR SELECTING ROUTING METHOD

The evaluation framework for selecting a routing method developed here is a two-step procedure. The first step involves an assessment of the pupil

transportation needs and resources of the community followed by the evaluation and selection of the general category of school bus routing method that best matches these needs and resources. In the second step, specific methods that are available in each of the general categories are examined.

To evaluate the categories of methods and the methods within each category, several sets of criteria or measures of effectiveness were developed. In each case, they were designed to reflect the various resource requirements and capabilities of the different approaches. Nine basic measures of effectiveness were developed for comparing the general categories of methods. They are as follows:

1. Implementation period refers to the approximate time period needed to acquire and implement that category of methods,
2. Ownership cost refers to the monetary cost for the purchase of methods,
3. Data-gathering manpower refers to the person-months needed for data gathering,
4. Method implementation manpower refers to the person-months of computer staff required for method implementation,
5. Computer facilities are the type of computer facility needed to implement and use the method,
6. Recurring cost refers to the cost (rental or consulting fee) for each subsequent year,
7. Recurring manpower refers to the person-months needed in each subsequent year for the development of routes,
8. Efficiency refers to the relative efficiency of the routes produced (for a given size bus fleet), and
9. Flexibility of method refers to the relative ease of using this category of methods to evaluate the effects on the route structure when changes are made in the constraints and policies.

Based on these criteria, a comparison between the different categories of methods is shown in Table 1. Information on the various resources required and method effectiveness were obtained from the literature, discussions with school bus routing consultants, and in-house assessments. As shown in the table, no single method is clearly superior. Trade-offs must be analyzed, primarily in the area of resources required versus effectiveness.

Table 1. Comparison of school bus routing methods by category.

Criterion	Manual	Computer Assisted	Owned Computer	Service Computer
Implementation period (months)	2	2-6	8-12	6-8
Ownership costs ($)	0	100-1000	2000 to 80 000	45 000 to 100 000
Data gathering (person-months)	0-1	1-3	4-6	3-4
Method implementation (person-months)	1-3	1-3	4-12	1
Computer facilities	None	Small to large computer	Large computer	None
Recurring costs ($)	0	0	0-200/month[a]	30 000-60 000
Recurring manpower (person-months)	1-3	1-3	1-2	0.5
Efficiency				
<20 buses	Good	Good	Good	Good
20-100 buses	Fair	Good	Good	Good
>100 buses	Poor	Fair	Good	Good
Flexibility	Poor	Fair	Good	Good

[a]Rental fee.

Once a general category of methods has been selected, specified methods available in that category are evaluated for application. Criteria for this phase of the evaluation process were developed for all but the category of manual methods. Criteria were not developed for manual methods because manual methods vary substantially in application and thereby defy convenient description, and the merits and the successful applications of manual methods are almost entirely dependent on the users. For the remaining methods, two separate sets of evaluation criteria were developed.

For the evaluation of computer-assisted methods and owned-computer methods a common set of criteria is used. They include the first seven criteria that were used to compare the general categories of methods plus consideration of the success in prior applications.

A different set of criteria is used for the evaluation of service-computer methods. Services are provided by consulting firms, usually on a yearly contractual basis, to develop school bus routes. Data could be gathered by either the school district or the consulting firm, however, the development of routes and the production of reports for administrators, transportation supervisors, drivers, students, and parents are done only by the consulting firm. The criteria that summarize the attributes of the service computer methods for comparison include the measures defined previously, implementation period, data-gathering manpower, implementation costs, the success of prior applications, plus the following added considerations:

1. Reputation of the firm refers to the experience of the firm in school bus routing and the assurance that the firm will continue to provide service in this area,
2. Purchase option refers to whether the firm offers the option of selling the method and training the district's personnel to use the method to develop the school bus routes locally,
3. Purchase cost refers to the capital cost involved for purchase of the method (computer software and documentation), and
4. Computer facilities refers to the type of computer the school district needs if the method is purchased for local implementation.

APPLICATION

Selection of Method

To apply the framework developed above to the selection of a routing method it was first necessary to identify the resources available. For this task, the pupil transportation system of Albemarle County, Virgina, was chosen as a case study (12). The various resources available were determined from discussions with local school officials and are numbered below according to the criteria for the evaluation of the general categories of methods.

1. A maximum of four months was available for method implementation,
2. A maximum of $1000 was available for method purchase,
3. Approximately three person-months were available for both data gathering and method implementation,
4. See item 3,
5. The computer at the University of Virginia (a CDC Cyber 172) was available,
6. No funds were set aside for recurring costs in subsequent years, and

7. About one full month of the transportation supervisor's time is available for school bus routing in each subsequent year.

When this information was compared with the attributes of the general categories of methods (see Table 1), the category of computer-assisted methods was selected, primarily on the basis of the resource limitations of time, money, and manpower.

The specific methods available to the Albemarle School District in the category of computer-assisted methods are the SPSS-assisted manual method and a specially written program-assisted manual method. These two methods are compared in the table below, by using the criteria developed for the evaluation of computer-assisted methods.

Criteria	SPSS	Specially Written Program
Implementation period (months)	3	3
Ownership costs ($)	0	0
Data-gathering manpower (person-months)	1	1
Method implementation manpower (person-months)	0.5	2
Computer facilities	Computer with SPSS installed	Any computer
Recurring costs ($)	Minimal	Minimal
Recurring manpower (person-months)	1.5	1.5
Success in prior application	None	None

As can be seen, the SPSS-assisted manual method was found superior because it required less implementation manpower. Consequently, the SPSS-assisted manual method was selected to develop Albemarle's school bus routes for the 1979-1980 school year.

Results of the Application

Several significant results were noted in the application of the method to the Albemarle County school system. As expected, the computerized features of the method provided an organized and rapid determination of the disaggregate and summary statistics necessary for the evaluation of the various routing alternatives. This made it a relatively simple task to assess the implications of changing various policy constraints (e.g., changing school starting times) and to identify the inefficiencies of the current routing configuration.

The final routes selected represent a significant net savings potential to the county. The number of buses required was reduced by nearly 20 percent and there was a 57 percent reduction in the number of vacant seats. These reductions were achieved with only a 10 percent (4.6 min) increase in the average trip length.

That the case study application was completed within the resources estimated for that method is also significant. Thus, for the current case study, substantial improvements were provided at a very low cost. These costs were recoverable many times over within the next year of operation.

CONCLUSIONS

Although only one case study has been presented, when it is considered with the framework developed for selecting among the various methods, important implications for further effort in this area are apparent.

The computer-assisted method was found to be well suited for an extremely wide variety of school districts, excluding only the very large and very small areas. As a general class of methods, they make use of the better features of the completely manual and fully computerized methods while not incorporating their inherent disadvantages. Moreover, the computer-assisted method provides an interactive facility to help plan, manage, and critique local bus systems at several levels. The method is responsive to local concerns, policy level planning, and design considerations. It is interactive in that computer feedback is provided for the manually designed routes.

Finally, it is evident that much additional work is needed in this area. The general framework developed here identifies only the basic concept of the computer-assisted methods. The case study presented demonstrates only that the general approach can produce operationally efficient routes. The work that remains, therefore, includes the development of various computer programs and extensive application testing. A sufficient number of approaches should be used to adequately explore the various person-computer interface arrangements. Although the cost of such development and testing will not be small, it should be more than offset by the savings realized by the school bus systems used as case studies.

ACKNOWLEDGMENT

This research was sponsored by Albemarle County and the University of Virginia. The opinions, findings, and conclusions expressed in this paper are ours and not necessarily those of the sponsoring agencies.

REFERENCES

1. UTPS Network Development Manual. Urban Mass Transportation Administration, Aug. 1974.
2. N.H Nie and others. Statistical Package for the Social Sciences. 2nd ed., McGraw-Hill, New York, 1975.
3. D. Soule. Bus Routes by Punch Cards. Safety, Jan. 1978, pp. 30-34.
4. R.A. Boyer. The Use of a Computer to Design School Bus Routes. Univ. of Mississippi, University, 1964.
5. R.M. Newton and W.H. Thomas. Developing a Computer Program for Bus Routing. State University of New York Research Foundation, Albany, July 1970.
6. G. Clark and J.W. Wright. Scheduling Vehicles from a Central Depot to a Number of Delivery Points. Operation Research, Vol. 12, 1964, pp. 568, 571.
7. R.D. Angel and others. Computer-Assisted School Bus Scheduling. Management Science, Vol. 18, No. 6, Feb. 1972, pp. B279-288.
8. IBM. IBM Vehicle Scheduling Program-Extended, Program Description Manual. IBM, Germany, SH19-234-0, Nov. 1970.
9. J.A. Robbins and W.C. Turner. CAWLIP: Good, Fast, and Easy Bus Routing by Computers. School Business Affairs, Vol. 44, No. 2, Feb. 1978, pp. 43-44.
10. T.C. Richards. OPTIBUS, A Computer Program for Selecting Bus Routes. Association of Educational Data Systems (AEDS) Monitor, Vol. 11, No. 3, 1973.
11. T.C. Richards. A Survey of Computerized School Bus Routing. Paper presented at the Association for Educational Data Systems Annual Con-

vention, Philadelphia, April 1973, 7 pp.
12. M. Sze Ming Chan, B.T. Hargroves, and M.J. Demetsky. An Evaluation of the Albemarle County Pupil Transportation System. Department of Civil Engineering, Univ. of Virginia, Charlottesville, Rept. UVA/530156/CE79/101, Nov. 1979.

Publication of this paper sponsored by Committee on Rural Public Transportation.

Abridgment

Post-Bus for Rural Passenger Transportation and Rural Mail Delivery: An Idea Whose Time Has Come

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Rural areas have a growing need for public transportation, but service is declining due to high costs and diminishing subsidies. The U.S. Postal Service faces similar problems with its rural service. A number of European countries faced similar problems and have solved them, to some extent, by combining public transportation with mail deliveries. Several studies have shown that this approach may be successful in this country. The possibility of reducing the cost of providing both services by combining them demands experimentation.

Rural areas have become increasingly isolated in the last several decades. Declines in rural population and the competition of urban shopping centers have caused the demise of many small-town stores and service enterprises. The resulting rural job loss has been compounded by declining agricultural employment, which has forced many rural residents to commute to urban job locations. Social services, which are important to rural as well as urban residents, locate in cities and large towns where most clients live. Many rural communities have become "bedroom towns" and rural citizens are now dependent in many ways on a distant urban center.

These trends have created a hardship for the rural poor, elderly, handicapped, and young, who cannot operate or afford an automobile. Unfortunately, public transit has been unable to alleviate this problem. Low, dispersed demand and long distances make commercial bus services unprofitable in rural areas. Government-sponsored transportation is costly and funds for it are scarce and decreasing. Certainly this instability warrants the investigation of new approaches to fulfilling the growing transportation needs of rural residents.

THE POST-BUS CONCEPT

One possible approach is to combine rural transit with the conveyance of mail between post offices. Postal service, like transportation, is a deficit operation in rural areas. Since both public transportation and postal services involve similar driver and vehicle costs, there would appear to be potential savings for both (and a reduction in the overall need for government subsidies) if one driver and one vehicle could perform the duties of both mail delivery and passenger transport.

Highway contract routes (commonly known as star routes) are contracted mail pickup and delivery routes that serve most rural post offices. In general, star route carriers make runs twice a day to outlying post offices from either a regional mail processing center or a larger post office. Often these distribution points are also regional retail and human service centers. If passenger service were added to highway contract routes, they could take rural residents into regional centers in the morning and return them to outlying towns in the afternoon.

Another advantage of bus service on star routes is the suitability of post offices as bus stops. Most have a heated lobby where passengers could wait out of the weather. Also, post office clerks would be on hand to answer questions and, perhaps, also to sell tickets. Post offices already provide other community services, such as passport registration and food stamp distribution, so the addition of bus stop services is not unthinkable. Dale Massie, director of Appalachian Ohio Regional Transit Association, a rural system that uses post offices as bus stops, remarks that rural post offices are generally the focal points of rural communication and, therefore, make ideal focal points for rural transportation.

No U.S. Postal Service regulation prohibits the combination of star route service with passenger transportation. In fact, the U.S. Postal Service may pursue contracts with passenger common carriers when their routes and schedules fit postal service needs (39 U.S. Code 5214). A star route contractor may be an individual, a partnership, or a corporation (1). Contractors must abide by the rules and regulations of the Basic Transportation Services Contract General Provisions. Concerning passenger service, the provisions require the following (2):

> The mail shall not be delayed to accommodate passengers .... The mail shall be transported in an enclosed, water-proof compartment, equipped with secure locking devices .... If the contractor is authorized to carry passengers, the mail must be carried in a compartment separate from the passengers so that they cannot have access to the mail.

The idea of combining mail and passenger delivery is not new. For instance, the stage coaches of early America performed both duties. In more recent times the postal departments of Britain, Switzerland, Finland, and Sweden have established motorized Post-bus service. The continental services are the oldest; they began between 1910 and 1930. Swedish and Finnish Post-buses operate in rural areas and use vehicles that range in size from 9 to 55 seats (3,4). The Swedish and Finnish buses are owned and operated by the respective postal services. In Switzerland, the post office contracts some routes to private carriers (5).