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CONTENTS

FOREWORD

The papers in this RECORD report on research in the area of public transportation planning and development.

Rea and Miller describe the development of supply functions for 7 urban transit technologies. A supply function is a schedule of service quality that an operator is willing and able to supply for a corresponding schedule of passenger volumes. Comparisons of supply functions among the various modes are made to provide a means of assessing relative qualities of service.

Sophisticated modeling, forecasting, and other analytical techniques normally used in urban transportation planning do not provide the kind of information most pertinent to the decisions that must be made in planning transit for small urban areas. Miller and Goodknight discuss a transit planning process for small cities that can effectively accomplish the goals of a conventional transit technical study and at the same time minimize costs. They identify a series of major issues associated with each decision, the major inputs required, and the role of organizations or participants in the planning process.

Schnell and Smith summarize goals and objectives of a research project sponsored by the Urban Mass Transportation Administration and designed to measure the scope of vandalism and crime in terms of its characteristics and costs. The paper discusses efforts being made to reduce vandalism, passenger harassment, and crime and describes a demonstration project designed to measure the effectiveness of particular procedures and techniques for reducing vandalism and crime.

Transit planning for major activity centers is discussed by Davis. The needs of center users and the attitudes of center planners are described.

Abdus-Samad and Grecco report on a study concerned with the determination of design criteria for predicting parking demand at park-and-ride facilities. Data were collected from 93 change-of-mode facilities. An analysis is presented of the important physical and operational characteristics. The authors also report on a prediction equation that they have developed and tested by using data supplied by a committee of the Institute of Traffic Engineers.

Jitney operations in the United States have almost ceased to exist because of restrictive ordinances enacted in most cities. Saltzman and Solomon analyze the history of jitney service and point out the importance of understanding the past lessons that are applicable to innovations in demand-responsive transit systems. They suggest that there is a need to create a favorable climate for experimentation with more operations of the jitney type.

Bergmann reviews several contemporary fixed-guideway public transportation systems to show the major technical and operational characteristics. The paper describes the station layout, vehicle spacing control, general operating specifications, and vehicle performance. The systems described are compared with the Morgantown personal rapid transit research and development project.

COMPARATIVE ANALYSIS OF URBAN TRANSIT MODES USING SERVICE-SPECIFICATION ENVELOPES

John C. Rea and James H. Miller, Pennsylvania State University

The use of envelopes of transit service functions is proposed as a technique for comparing the output space of transit technologies. A service-specification envelope defines the boundaries within which an operator is able to specify transit service for a given technology in predefined circumstances. An envelope is defined on one side by an economic or viability boundary and on the other by a capacity boundary. The basis for comparison is the location of the service-specification envelope in an output space defined by axes representing passenger flow and level of service. Three technologies—minibus, minirail, and regular transit buses—are examined in a collector-distributor context. The bus appears to be more flexible but has poor quality of service. Thus, new technologies, such as dial-a-bus, are needed in the collector-distributor context. Five technologies—monorail, skybus, freeway flyer, busway, and rail rapid system—are examined in a line-haul context. There appears to be much redundancy in the capabilities of the first 4 systems. Busway systems (reverting to a freeway flyer mode of operation where freeways are not congested) can cater to a much wider range of demands than rail and can cater to high flows albeit at a somewhat lower service quality than rail. A comparison of transit service-specification envelopes and highway service functions indicates that rail rapid transit can offer comparable qualities of service only when flow levels are high and when freeways are congested.

•IN RECENT years urban transit has become a focus of public and governmental attention. The resurgence of interests stems from many sources, e.g., a concern for the urban environment and aesthetics; realization of the mobility needs of the young, the aged, and the disadvantaged; and a desire to provide a less resource-consuming mode than the automobile. Although public transportation may not be the panacea for all urban woes, it can at least make a positive contribution in some areas—provided that the limitations and potentials of urban transit hardware systems are realized. Although large sums are being spent on existing transit systems and on developing new technologies, relatively little work has been done to compare the capabilities and feasible areas of application of existing and proposed urban transit hardware systems.

Bouladon (1) advanced a hierarchical concept for interrelating transport technologies in a gross manner. Although the analysis identified gaps in the spectrum of transport technologies, from walking to supersonic aircraft, the method is not appropriate for a comparative analysis of urban transit systems. Rice (2) did some interesting work on the output efficiency of different transport modes in terms of fuel consumption per passenger-mile, but that is too limited an approach to be of general utility. Morlock (3) analyzed some intercity transportation modes and defined the "feasible output space" of a number of technologies. The objective of Morlock's approach is similar to that of this paper, i.e., to "make direct comparisons between different technologies in order to identify those regions of output space for which each is inherently well suited."

In this paper the approach adopted for the comparison of transit technologies rests on the concept of service functions or, rather, on the envelope of such service functions.

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The approach has the advantage of providing direct inputs to equilibrium analysis and the service-specification model for planning transit systems (4).

TRANSIT SERVICE FUNCTIONS

A transit service function is a schedule of service quality that the operator is willing and able to provide for a corresponding schedule of passenger flows. In terms of the equilibrium approach to transport system analysis as expounded by Manheim et al. (5), a transit service function can be written as

$$L = S(V, T)$$

where

L = some measure of level of service,
V = passenger volume in passengers per unit time,
T = vector describing the characteristics of the transit system, and
S = supply or service function.

The vector T may include attributes such as transit routes, speed, acceleration, station dwell time, frequency of service, seating comfort, ride quality, privacy, and safety.

Such a formulation implies that quality of service improves as use of a transit system increases because a more frequent service must be provided to cater to increasing flows (assuming, of course, that additional units are available to do this and that one does not provide for increasing volumes by maintaining a given frequency of service and increasing the length of a train). Quality of service cannot increase indefinitely, however, because the control system and operating conditions dictate a minimum operating headway that constrains service frequency. Beyond that point, service quality will degenerate because of overcrowding. The general form of a transit supply or service function under the conditions and assumptions outlined above is shown in Figure 1a. In practice, the service function will take the form of a step function as shown in Figure 1b. Frequency of service is not a continuous variable for practical scheduling reasons, and the operator will assign a given headway for a corresponding range of flows. The level of service provided by a given headway will, in fact, decline as flow increases within its designated flow range because of decreased privacy, increased personal contact, and the like. The effect is shown in Figure 1b. For the sake of simplicity, the index used for level of service measures only technological performance in a given operating context and does not measure perceived level of service. As such, the level of service is assumed to be constant for any given headway as shown in Figure 1c. Thus,

$$L = S(V; a, s, d, f)$$

where

a = acceleration-deceleration capability of the technology,
s = cruising speed in the operating context,
d = dwell time at stops, and
f = frequency of service.

FORMULATION OF TRANSIT SERVICE-SPECIFICATION ENVELOPES

It was earlier stated that a service function is a schedule of service quality that an operator is willing and able to provide for a corresponding schedule of passenger flows. The service-specification-envelope approach is oriented toward establishing the boundaries within which an operator may provide service. Two factors play a role in constraining an operator's ability to offer transit service, i.e., to use a given technology-headway combination: the economic viability limit and the physical capacity limit. The first constraint dictates that, for a given technology-headway combination and fare level, a minimum level of passenger flow must be available if a break-even operation is to be achieved. The second constraint is based on the physical ability of a given technology-headway combination to transport passengers at a given seat-standee ratio.

These limits established for a number of headways make it possible to define an envelope for a given technology bounded on the left by the viability constraint and on the right by the capacity constraint, within which a service function for that technology must be defined. How an operator defines the service function within the envelope is determined by his "willingness" to provide a high or low level of service. This concept of economic and capacity boundaries for a service-specification envelope is now illustrated by a simple example.

Consider the range of flows for which a hypothetical 60-seat bus operating at a 10-min headway may be used. If all passengers are to have a seat, the upper limit of the applicable flow range is the physical capacity, i.e., (60 × 6) or 360 passengers/hour. To establish the lower or viability limit requires that the cost of using this technology-headway combination be determined. If the cost is, for instance, $1/mile, the cost of providing the above level of service (i.e., 10-min headway) will be $6/mile/hour. If the average fare rate is $0.05/mile, a flow of 6.00/0.05 or 120 passengers/hour is the minimum viable passenger flow. In general,

$$\text{Capacity flow limit} = (1 + \text{SPC})\ \text{VSC} \times \text{NVT} \times (60/\text{HDWY})$$
$$\text{Viability flow limit} = \text{CPM}\ (60/\text{HDWY})/\text{AFPM}$$

where

SPC = ratio of standees to vehicular seating capacity;
VSC = vehicular seating capacity;
NVT = number of vehicles in train (one for bus operation, generally);
HDWY = headway, in min;
CPM = cost per mile of the technology configuration, e.g., a bus or a 5-car train; and
AFPM = average fare per mile.

The above computations can be made for all operating headways for a given technology once the appropriate assumptions are made, as given in columns 2 and 3 of Table 1. Data given in Table 1 are based on the following assumptions: AFPM = 5 cents/mile, CPM = $1, NVT = 1, VSC = 60, and SPC = 0. Use of each headway is constrained to the corresponding passenger flow range as defined by the viability and capacity limits.

It should be noted, however, that in an operating transit system the viability constraint for a given headway (service level) would not necessarily pertain to individual links but rather to the aggregate of all links offering that service level; i.e.,

$$\frac{1}{n} \sum_{e=1}^{n} F_e^s \geq F_v^s$$

where

s = particular service level (technology-headway combination),
n = number of links offering service level s,
F_e^s = directional flow on the eth link offering service level s, and
F_v^s = viability flow for service level s.

One could, of course, also aggregate the service levels and obtain a total aggregate system "break-even" criterion; such a gross level of aggregation, however, obviates the use of the concept proposed in this paper.

The computations previously described, in fact, establish only a one-dimensional output space, i.e., the manner in which the 2 boundaries of a service-specification envelope relate to flow. To portray the service specification graphically, a second dimension must be defined that encompasses other qualities of a transit technology in addition to its operating cost characteristics and physical capacity. The most logical dimension for this purpose is a level-of-service index because it is consistent with the concept of service and demand functions. Level of service is inherently difficult to define comprehensively, for it is a perceived quality and hence subjective. For the sake of simplicity, level of service in this paper is defined as the overall speed between boarding and egress points for characteristic routes in given operating contexts. That is,

$$\text{NET SPEED} = \text{ATD}\Bigg/\left[\left(\frac{\text{ADBS}}{\text{MV}} + \frac{\text{MV}}{\text{ACC}}\right)\text{NLAT} + (\text{NLAT} - 1)\ \text{DWELL} + \text{HDWY}/2\right]$$

where

ATD = average trip distance (ADBS × NLAT),
ADBS = average distance between stops,
MV = maximum velocity,
ACC = average operational acceleration and deceleration,
NLAT = number of links in average trip,
DWELL = average dwell time at intermediate stops, and
HDWY = headway offered at the boarding point.

It is assumed that the distance between stops will permit maximum velocity to be attained. Continuous service systems such as moving belts, systems offering continuity of through movement at intermediate stations, and walk mode can be encompassed by this approach.

Suppose that the 60-seat bus described earlier is operating in a distributor-collector context with stops every ¼ mile and that it has a maximum speed of 44 ft/sec and an average operational acceleration and deceleration of 4 ft/sec^2. For an average trip length of 3 miles and an average dwell time of 10 sec, the net speed of travel on a service offering a 10-min headway is

$$3.0 \times 5{,}280\Bigg/\left(\frac{1{,}320}{44} + \frac{44}{4}\right) 12 + 11 \times 10 + 600/2 = 17.6 \text{ ft/sec}$$

The relative quality-of-service indexes computed on this basis for the hypothetical bus are given in column 4 of Table 1. The data given in columns 2, 3, and 4 of Table 1 constitute the information necessary to draw the service-specification envelope shown in Figure 2. For a real hardware system, the top of the envelope would correspond to the minimum practical operating headway as determined by the control system and operating conditions. That may differ for each technology. The bottom of the envelope would represent lowest frequency of service judged acceptable in the operating context.

In formulating the above quality-of-service index, one could argue that waiting time will not normally exceed about 10 min, for when headways are long passengers will use their knowledge of the service schedule. On the other hand, one can regard waiting time in excess of the maximum as a surrogate for the inconvenience of an infrequent service. A maximum value of waiting time can be imposed if required. Station dwell time could be computed on the basis of the number of boarding and disembarking passengers at stops en route and on the size of doors and vehicle configuration to include appropriate vehicle characteristics in the quality-of-service index.

The above quality-of-service index obviously ignores many other features of the vehicle such as ride quality, seating comfort and space, and environmental quality. A number of studies have determined the relative weight attributed by passengers to such qualities and to the various time components of a trip. A more comprehensive relative quality-of-service index could be developed on the basis of those relative weights.

ALTERNATIVE TRANSIT COST FORMULATIONS

In the above analysis, no attempt was made to define the cost of providing transit service. There are, in fact, 3 distinct approaches to determining this cost:

1. Total costs associated with providing a service, including depreciation of assets and debt service;
2. Operating costs, excluding costs associated with depreciation of assets and debt service; and

3. Marginal or direct out-of-pocket costs associated with a particular movement, including fuel, labor, and maintenance, which is a function of wage, but excluding general administrative and overhead expenses.

Economists would argue that total cost should be used so as to avoid any bias between capital-intensive and low-operating-cost systems and systems that have low capital investment but high operating costs. Unfortunately, this approach might largely obviate the use of capital-intensive systems because, in general, such systems cannot attract sufficient patronage from fare-box receipts to cover total costs.

The use of operating cost is perhaps more realistic from the local viewpoint because federal capital grant programs contribute substantially to the capital costs of a system. Such aid makes it necessary to recover only direct operating costs from fare-box revenues. Furthermore, some states (e.g., Pennsylvania) have programs to subsidize direct operating costs and, thus, the use of marginal costing becomes a possibility. This has merit especially for rail systems where marginal operating cost is a small percentage of total operating cost. Because such capital-intensive systems are installed mainly to cater to heavy peak-hour traffic, it seems reasonable to charge overhead and fixed components of operating cost against peak-hour fares. This approach would require off-peak fares to support only the marginal cost of the service. It is, of course, possible to develop many proportional costing schemes on this basis depending on local circumstances.

In this paper, viability limits are based on operating costs. The use of marginal operating cost for rail systems is, however, shown to demonstrate the effect on the service-specification envelope (Fig. 5f). Both total and marginal operating cost approaches can be encompassed by the service-specification-envelope approach.

The basic problem in defining the viability boundary of service-specification envelopes is to determine operating costs for the different technologies. A number of different approaches were examined (6), but no general operating cost model could be formulated. Technologies and operating cost data given below were used to compute viability boundaries for the technologies compared in this paper.

Technology	Data Source (ref.)
Regular bus	7
Freeway flyer and busway	8, 9
Alweg monorail, minirail, and skybus	10
Minibus	11
Rail	12

Operating costs were computed for each technology, as appropriate, in the collector-distributor and line-haul contexts described later. Because of the wide range in bus operating costs revealed by the ATA data, 3 operating cost levels were used for buses, representing the 25th, 50th, and 75th percentiles in the distribution of operating costs derived from a sample of 50 properties. The variety of source material and the uncertain reliability and generality of the cost data must be borne in mind when the results of the study are evaluated.

TRANSIT-FARE STRUCTURES

In the description of the derivation of the viability boundary, use was made of an average fare per mile. In fact, operating transit systems use either a flat-fare rate or a zonal-fare structure, neither of which is strictly distance-related as shown in Figure 3. For practical reasons, a strictly distance-based fare structure will probably not be adopted until computer-operated, debit-account systems are introduced. This is of little consequence, however, if the technique is used for comparative purposes because all envelopes are derived based on this common assumption.

To determine suitable distance-based fare rates, a number of studies were examined; those by W. C. Gilmore and Company and Alan M. Voorhees and Associates (13, 14) were particularly useful. Table 2 gives the results of this study. The intra-District of Columbia and intra-Maryland routes are assumed to be collector-distributor types as indicated by the relatively short trip lengths and high per-mile fare. The District-Maryland and Maryland-District routes are assumed to be line-haul routes and have correspondingly higher average trip lengths and lower per-mile fares. Fares vary from 7.6 cents/mile to more than 12 cents/mile, and trip lengths vary from 3 to more than 7 miles.

To accommodate the dispersion of fare rates given in Table 2, service-specification-envelope data were computed for fares of 3, 7, and 11 cents/mile.

SERVICE-SPECIFICATION-ENVELOPE DATA FOR EXISTING TRANSIT TECHNOLOGIES

Data for service-specification envelopes have been developed for 3 technologies in a collector-distributor context and for 5 technologies in a line-haul context. A collector-distributor operating context was represented by a route 3 miles long with stops every ¼ mile. A line-haul operating context was represented by a route 10 miles long with stops at 2-mile intervals. The data sources given above were used to compute 3 viability boundaries for each technology based on fares of 3, 7, and 11 cents/mile. Three capacity boundaries were similarly computed for each technology on the basis of seating capacity with 0, 50, and 100 percent standees. Headways from 30 to 2 min were used for the line-haul technologies, and headways of 60 to 4 min were used for the collector-distributor technologies. Other pertinent data are given in Table 3.

In the case of minirail, the viability limit is defined in terms of 5, 10, and 20 cents/mile fares because of the high cost of operation. As discussed previously, the quality of service is measured in terms of speed (ft/sec). Table 4 gives the numerical data for the service-specification envelopes. As an example, the data for the busway have been graphed and are shown in Figure 4. By selecting different combinations of viability and capacity conditions, one can directly construct 9 different service-specification envelopes; and, of course, interpolation is also possible. The individual service-specification envelopes define the output space of a technology in terms of the flows that can be accommodated and the quality of service that can be supplied in an assumed operating context for a given fare rate and capacity definition.

COMPARISON OF LINE-HAUL MODES

Service-specification-envelope data for busway, monorail, freeway flyer, skybus, and rail rapid systems based on a 7 cents/mile fare and seating capacity with no standees are shown in Figure 5. There is a great deal of redundancy in the capabilities of these line-haul modes as demonstrated by the overlap of the envelopes. Freeway flyer is the same technology as busway but does not have the advantage of an exclusive right-of-way. Because of this separate guideway, busway has a lower operating cost and, hence, a lower viability boundary and can offer a slightly better level of service. For all practical purposes, however, busway and freeway flyer occupy the same output space. It seems reasonable, therefore, to use the freeway flyer mode until its quality of service is adversely affected by competing freeway traffic and only then resort to the busway mode. Skybus occupies a similar region of the output space as do freeway flyer and busway. Having a higher vehicular capacity, skybus has a capacity boundary that is to the right of those for the other modes. Skybus can be formed into trains, and its capacity boundary can be moved yet farther to the right as extra units are added; the viability boundary would also move slightly to the right in the latter event.

It would appear that busway and rail complement each other in their coverage of the output space. However, the service-specification-envelope technique somewhat obscures the ability of the busway, for instance, to handle larger corridor flows. Although a 2-min headway might be as close a headway as is reasonably required at any given station in a corridor, the guideway as such can accommodate much closer headways and, thereby, provide a much greater "corridor" capacity. Skip-stop operation would give rise to this condition. Thus, in fact, a busway system can be used for higher corridor flows than those indicated by the service envelope. It can serve high flows, although the quality of service may be somewhat lower than that of rail, and it can also

Figure 1. Transit service functions.

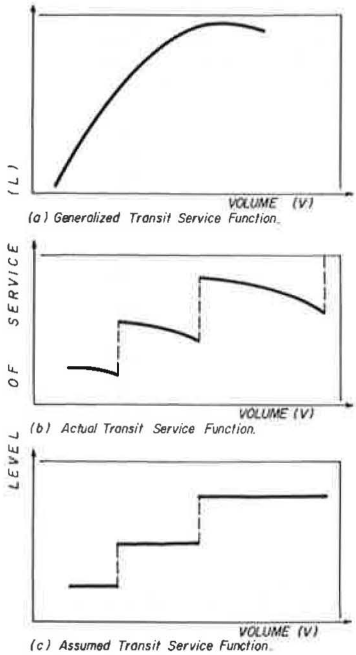


Figure 2. Service-specification envelope.

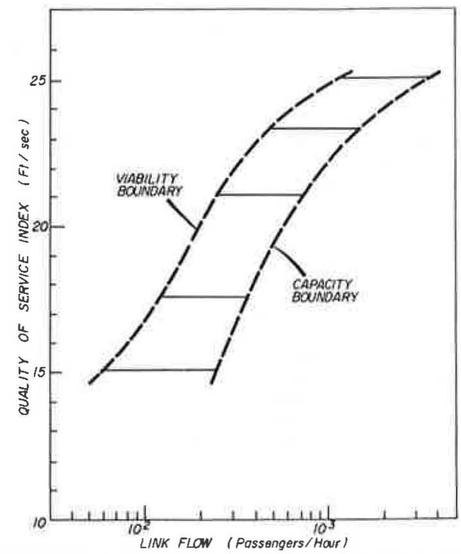


Table 1. Service-specification-envelope data for hypothetical 60-seat bus.

Operating Headway (min)	Viability Flow Limit	Capacity Flow Limit	Relative Quality of Service (ft/sec)
1	1,200	3,600	25.1
$2\frac{1}{2}$	480	1,440	23.4
5	240	720	21.1
10	120	360	17.6
15	60	240	15.1

Table 2. Average distance and fare paid in District of Columbia area.

Route	Avg Trip Length (min)	Avg Fare (cents)	Fare (cents/mile)
Intra-District	3.12	29.7	9.52
District-Maryland	7.20	54.7	7.60
Maryland-District	6.58	57.5	8.74
Intra-Maryland	3.68	44.5	12.09

Figure 3. Comparison of fare schedules.

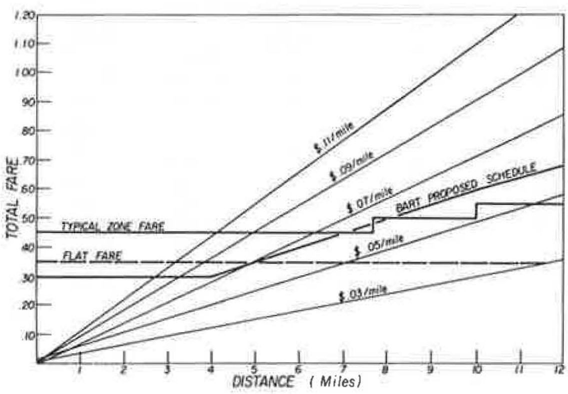


Figure 4. Service-specification envelopes of busway for 3 fares and capacities.

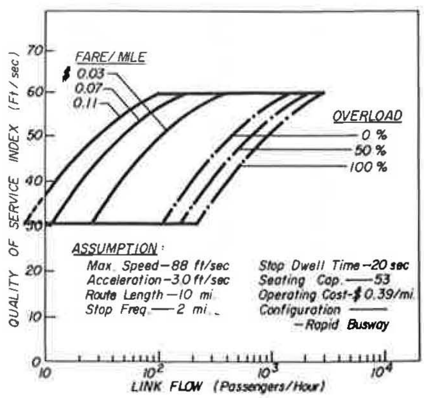


Table 3. Summary of transit technology data.

Technology	Context	Operating Cost (dollars/mile)	Passenger Capacity	Max Speed (ft/sec)	Acceleration (ft/sec)	Route Length (miles)	Station Frequency (miles)	Dwell Time (sec)
Monorail	Line haul	0.75	35	92.0	3.5	10	2	20
Rail								
Total cost	Line haul	5.60[a]	360	110.0	4.0	10	2	20
Marginal cost	Line haul	0.625[a]	360	110.0	4.0	10	2	20
Skybus	Line haul	0.35	70	73.0	3.5	10	2	20
Freeway flyer	Line haul	0.81	53	73.0	3.0	10	2	20
Busway	Line haul	0.39	53	88.0	3.0	10	2	20
Regular bus								
1	Collector-distributor	0.62	53	44.0	3.0	3	¼	20
2	Collector-distributor	0.74	53	44.0	3.0	3	¼	20
3	Collector-distributor	0.89	53	44.0	3.0	3	¼	20
Minibus	Collector-distributor	0.49	22	44.0	3.0	3	¼	20
Minirail	Collector-distributor	4.90	28[b]	13.0	2.0	3	¼	20

[a]5-car train. [b]Per train with 7 cars.

Table 4. Data and assumptions for service-specification envelopes.

Technology	Headway (min)	Quality of Service (ft/sec)	Viability Limit by Fare[a]: 3 Cents/Mile	7 Cents/Mile	11 Cents/Mile	Capacity by Percentage of Standees: 0 Percent	50 Percent	100 Percent
Monorail	30	31.33	50	21	13	70	105	140
	20	38.11	75	32	20	105	158	210
	15	42.74	100	42	27	140	210	380
	12	46.10	125	53	34	175	263	350
	10	48.65	150	64	40	210	315	420
	6	54.70	280	107	68	350	525	700
	4	58.32	375	160	102	575	788	1,050
	3	60.32	500	214	136	700	1,050	1,400
	2	62.46	750	321	204	1,050	1,575	2,100
Rail								
Total cost	30	32.5	373	159	101	720	1,080	1,440
	20	40.0	559	239	152	1,080	1,620	2,160
	15	45.0	746	319	203	1,440	2,160	2,880
	12	49.0	933	399	254	1,800	2,700	3,600
	10	52.0	1,119	479	305	2,160	3,240	4,320
	6	59.0	1,866	799	509	3,600	5,400	7,200
	4	63.0	2,799	1,199	763	5,400	8,100	10,800
	3	65.5	3,733	1,599	1,018	7,200	10,800	14,400
	2	68.0	5,599	2,399	1,527	10,800	16,200	21,600
Marginal cost	30	32.5	41	17	11	720	1,080	1,440
	20	40.0	62	26	17	1,080	1,620	2,160
	15	45.0	83	35	22	1,440	2,160	2,880
	12	49.0	104	44	28	1,800	2,700	3,600
	10	52.0	124	53	34	2,160	3,240	4,320
	6	59.0	208	89	56	3,600	5,400	7,200
	4	63.0	312	133	85	5,400	8,100	10,800
	3	65.5	416	178	113	7,200	10,800	14,400
	2	68.0	624	267	170	10,800	16,200	21,600
Skybus	30	29.0	23	9	6	140	210	280
	20	34.5	34	14	9	210	315	420
	15	38.5	46	19	12	280	420	560
	12	41.0	58	24	15	350	525	700
	10	43.0	69	29	19	420	630	840
	6	47.5	116	49	31	700	1,050	1,400
	4	50.5	174	74	47	1,050	1,575	2,100
	3	52.0	233	99	63	1,400	2,100	2,800
	2	53.5	349	149	95	2,100	3,150	4,200

Table 4. (Continued).

Technology	Headway (min)	of Service (ft/sec)	Viability Limit by Fare[a] 3 Cents/Mile	7 Cents/Mile	11 Cents/Mile	Capacity by Percentage of Standees 0 Percent	50 Percent	100 Percent
Freeway flyer	30	31.03	54	23	14	106	159	212
	20	37.67	81	35	22	159	239	318
	15	42.18	109	46	29	212	318	424
	12	45.45	136	58	37	265	398	530
	10	47.93	163	70	44	318	477	636
	6	53.79	273	117	74	530	795	1,060
	4	57.29	409	175	111	795	1,193	1,590
	3	59.29	546	234	149	1,060	1,590	2,120
	2	61.28	819	351	223	1,590	2,385	3,180
Busway	30	30.58	26	11	7	106	159	212
	20	37.01	39	17	10	159	239	318
	15	41.36	53	22	14	212	318	424
	12	44.50	66	28	18	265	398	530
	10	46.86	79	34	21	318	477	636
	6	52.45	133	57	36	530	795	1,060
	4	55.78	199	85	54	795	1,193	1,590
	3	57.60	266	114	72	1,060	1,590	2,120
	2	59.55	399	171	109	1,590	2,385	3,180
Regular bus 1	60	6.0	21	9	6	53	79	106
	30	9.5	41	17	11	106	159	212
	20	11.5	61	26	16	159	239	318
	15	13.0	82	35	22	212	318	424
	12	14.0	103	44	28	265	378	530
	10	15.0	123	53	33	318	477	636
	6	16.5	206	88	56	530	795	1,060
	4	17.5	309	132	84	795	1,193	1,590
Regular bus 2	60	6.0	25	11	7	53	79	106
	30	9.5	49	21	13	106	159	212
	20	11.5	73	31	20	159	239	318
	15	13.0	98	42	26	212	318	424
	12	14.0	123	52	33	265	378	530
	10	15.0	147	63	40	318	477	636
	6	16.5	246	105	67	530	795	1,060
	4	17.5	369	158	100	795	1,193	1,590
Regular bus 3	60	6.0	30	13	8	53	79	106
	30	9.5	59	25	16	106	159	212
	20	11.5	88	38	24	159	239	318
	15	13.0	118	50	32	212	318	424
	12	14.0	148	63	40	265	378	530
	10	15.0	177	76	48	318	477	636
	6	16.5	296	127	80	530	795	1,060
	4	17.5	444	190	121	795	1,193	1,590
Minibus	60	6.0	10	5	3	22	33	44
	30	9.5	19	9	5	44	66	88
	20	11.5	29	14	7	66	99	132
	15	13.0	39	19	9	88	132	176
	12	14.0	48	24	12	110	165	220
	10	15.0	58	29	14	132	198	264
	6	16.5	97	48	24	220	330	440
	4	17.5	146	73	36	330	495	660
Minirail	60	5.0		49	24	28	42	56
	30	7.0		97	48	56	84	112
	20	8.0		146	73	84	126	168
	15	8.75		195	97	112	168	224
	12	9.25		244	122	140	210	280
	10	9.5		293	146	168	252	336
	6	10.25		489	244	280	420	560
	4	10.75		734	367	420	630	840

[a]For minirail, the fares are 5, 10, and 20 cents/mile.

serve low flows. In the latter instance, rail systems can compete only by resorting to a marginal-cost approach, and that is hardly a feasible policy for peak-hour operation without high subsidies. The complementarity of the modes is thus superficial; in fact, they compete with each other.

Skybus has the disadvantage of requiring a fixed guideway at all levels of flow. It, thus, does not have the flexibility of the freeway flyer and busway combination, nor does it have the high service quality of rail. One could argue that skybus is not, in fact, intended to function in the line-haul mode but rather in a collector-distributor context. The use of a fixed guideway in such an operating context would, however, require special conditions. Monorail also requires a special guideway for all flow levels, and the above comments apply. In addition, at least on the basis of the assumptions made, monorail has a very thin envelope and would be suitable only in special situations. In selecting a system, the planner must trade off the flexibility and wide viable range of the busway and freeway flyer against the superior service of a fixed-route rail system.

COMPARISON OF COLLECTOR-DISTRIBUTOR MODES

The service-specification envelopes of minibus, conventional bus, and minirail systems are shown separately in Figure 6. It is immediately apparent that minirail is not a viable system. Even at a fare rate of 20 cents/mile, the viability boundary and the capacity boundary are virtually coincident. The difference between the regular bus and the minibus system is largely one of capacity because there is little difference between the viability boundaries of the 2 systems. Informal discussions with transit operators, moreover, indicate that maintenance problems exist with current minibus vehicles, that upkeep is expensive, and that they lack operational flexibility. It would thus appear from a comparison of modes in a collector-distributor context that the regular urban bus is superior to the other modes. The term superior is perhaps inappropriate, however, for the quality of service offered compares poorly with the performance of the automobile in a similar context. It is evident that there is need for a much better technology for the collector-distributor function if any but captive riders are to be attracted to transit. It is just this area, of course, to which the dial-a-bus and PRT technologies are addressed.

COMPARISON OF TRANSIT AND HIGHWAY SERVICE FUNCTIONS

The previous sections have dealt only with transit service functions, and it is illuminating to compare those with highway service functions. Service-specification envelopes for rail, busway, and regular bus and service functions for different types of highways are shown together in Figure 7. The highway service functions relating vehicular flows and operating speed were taken from the Highway Capacity Manual (15) and converted to passenger flows based on 1.3 passengers/vehicle.

As expected, a 3-lane expressway is superior to rail rapid transit up to approximately 5,000 passengers/hour. However, if automobile occupancy were increased to 4 persons/car, a 3-lane freeway would be superior to rail rapid transit for flows up to about 10,000 passengers/hour. Private automobile transportion is superior in most cases to transit even at high volumes because automobile transportation involves no waiting time and provides nonstop service from origin to destination. The line-haul envelopes do not include the time required to gain access to the facility from the trip origin nor the time required to reach the trip destination after using the line-haul mode. Only when highways become congested does rail rapid transit become a viable alternative in terms of quality of service.

SUMMARY

The analysis has demonstrated that the concept of supply or service-function envelopes is a useful device for comparing technologies and can also be used in equilibrium modeling. The approach outlined in this paper is capable of considerable refinement as indicated in the discussion, and extensions of the technique are being investigated. It would be most desirable to derive service-specification envelopes on the basis of

Figure 5. Service-specification envelopes of 6 technologies for 7 cents/mile fare and 0 percent standees.

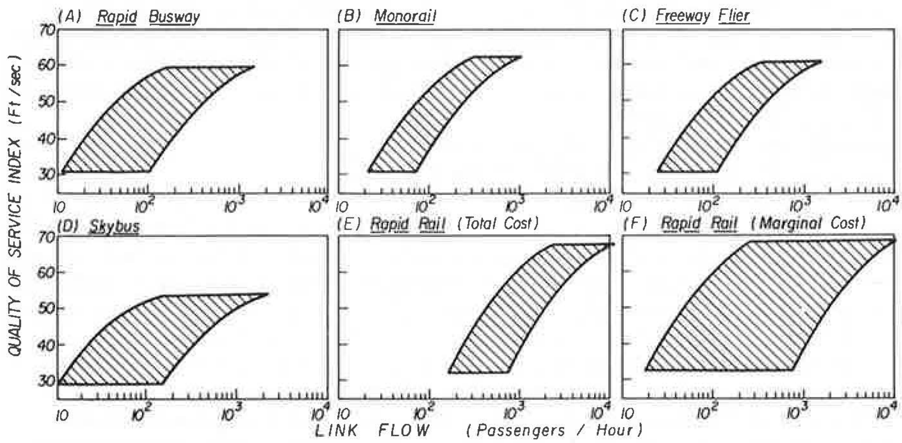


Figure 6. Service-specification envelopes of 3 technologies for fares of 7 cents/mile (bus and minibus) and 11 cents/mile (minirail).

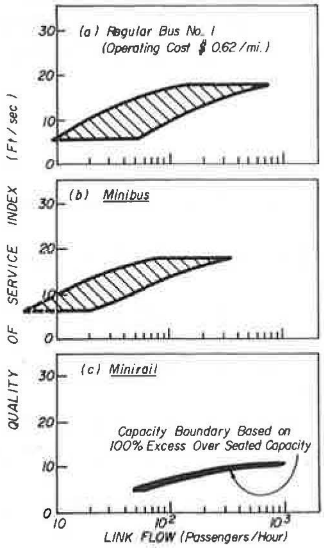
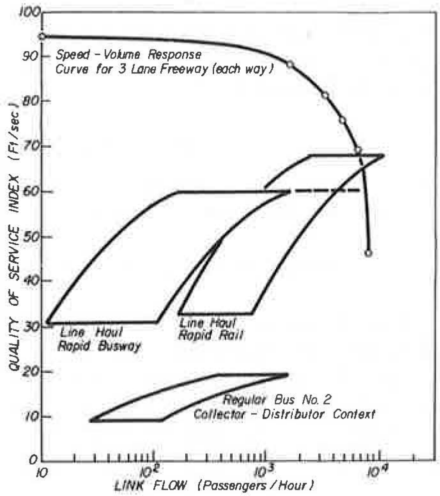


Figure 7. Service-specification envelopes for 3 technologies and service functions for highways.



total costs, for that would provide further insights into the flexibility and viability of the various modes. In addition, it would be interesting to extend the study to include other technologies in such a comparative analysis; the service-specification-envelope approach indicates the intrinsic merits of existing and possible future technologies. Indeed, the approach could be used to define normative specifications of future modes to replace or complement existing modes, and that may be one of the most interesting and fruitful applications of the technique.

The analysis indicates that, of the collector-distributor modes studied, the regular urban transit bus has the greatest flexibility in that it is able to cater to a wide range of demand levels. The quality of service offered, however, is quite poor, and there is a need to devise superior technologies for this type of service. In the line-haul context there appears to be much redundancy. Two technologies, namely, busway and rail systems, appear to complement each other in their coverage of the output space although the complementarity is more superficial than real. The application range of the busway system is greater than that of rail, and it seems to be a more flexible mode because, when freeways are uncongested, it can revert to the freeway-flyer mode and avoid the cost of a separate guideway. The quality of service is, however, slightly lower than that for rail in the line-haul context. When they are compared with the automobile, all transit technologies perform poorly. Only when flow levels are high and when freeways are congested can rail rapid systems offer a comparable quality of service.

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POLICIES AND PROCEDURES FOR PLANNING TRANSIT SYSTEMS IN SMALL URBAN AREAS

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This paper suggests an approach to transit planning for small urban areas. It represents the transit planning process as a series of key decisions and identifies the major issues associated with each decision, the major inputs required, and the role of each organization or participant in the planning process. For cities of the size discussed here (smaller than a standard metropolitan statistical area), a detailed inventory of travel information usually will not have been developed and a transit system may not exist. Several specific procedures are suggested that can effectively accomplish the goals of a conventional transit technical study and at the same time minimize costs by maximizing the use of readily available data resources and by replacing sophisticated quantitative procedures with rational qualitative techniques wherever possible.

•TRANSIT planning techniques for large metropolitan areas are not appropriate for small urban areas. They are costly, cumbersome, and to a large degree irrelevant. The sophisticated modeling, forecasting, and other analytical techniques do not provide the kind of information most pertinent to the decisions that must be made in improving or implementing a transit system in a small urban area.

This discussion suggests a transit planning approach that consists of a series of key decisions and identifies the major issues associated with each decision, the major inputs required, and the role of each organization or participant in the planning process. The comments reflect, to a great extent, the experience gained in preparing a transit plan for the city of Key West, Florida.

The financial status of most present transit operations suggests that a new or substantially improved transit system is not likely to be self-supporting. That should be recognized and some local commitment to support the system should be obtained before a detailed study of the feasibility of a transit system is begun.

Local motivation is likely to be oriented toward providing transit service for particular groups (i.e., low-income, elderly, or tourist). The goals and the extent to which the community is willing to commit local resources to attainting the goals should be established at the outset of a transit study.

The several factors discussed below suggest that for small urban areas only a limited amount of analytical detail is appropriate. The factors suggest a rather qualitative approach to the analysis of transit demands and emphasize the identification of specific requirements of the decision process and testing alternatives through actual implementation and continuing surveillance rather than through detailed analysis of demands, revenues, and the like.

1. Analytic techniques, no matter how sophisticated or detailed, do not provide completely accurate estimates of transit patronage. That is especially true for small cities that do not now have transit service.
2. The cost of the analytic determination of market potential should be less than the cost of making the determination by trial and error. For many of the smaller

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cities, the set of feasible alternatives (i.e., routes, number of buses, and level of service) to be considered is limited, and the cost of testing the most promising alternatives by actually implementing the service is not great.

3. For a small system, the cost of an error is relatively small. If the number of routes put in service is too few, additional buses can be ordered at little added cost. An extra bus is not an extremely expensive item and can be sold, leased, or put to other uses.

4. Factors entering into the decisions pertinent to implementation of major transit improvements include social, political, economic, and technical considerations. The precision with which transit patronage and related estimates are made should be balanced in accordance with the role those estimates play in the various decisions.

DECISION PROCESS FOR TRANSIT SYSTEM IMPLEMENTATION

The following comments attempt to identify the major decisions required for implementing a transit system in a small city, the specific issues that must be addressed, the significant elements of information required, and the responsibility for providing the information and for making the decisions.

For small urban areas, participation in transit planning can be expected from 3 levels: federal, state, and local. Each urban area is unique with respect to local autonomy, availability of local planning resources and expertise, and other characteristics that can markedly affect the organization for transit planning at the local level. In many cases, there will also be an overlap of functions between local and state participants. Therefore, this discussion will attempt to identify participants by function rather than by a specific organizational structure.

Local Participation

Local control over the decision process and local participation in the data collection and analysis are essential. If the local community has transit planning expertise, it may be best equipped to perform the analysis. However, even if the local participation involves only laymen, the community's judgment regarding the needs and goals of the various sectors of the local community is essential to sound analysis of the transit alternatives. Local communities, through civic organizations, schools, job training centers, and the like also command considerable low-cost manpower resources for any data collection that may be necessary.

Local participation can take many forms. At one extreme, a strong mayor in a small city may have sufficient knowledge and "feel" for his constituents to speak for the entire community with respect to policies and decisions pertinent to the development of a transit system. Where he adequately represents the local sentiments, local participation involves mainly working directly with the mayor, his staff, and other city government officials and with consultants and other appropriate agencies or organizations.

At the other extreme, local participation may focus on involvement of the individuals within the community. They may be in the form of a "bus committee" composed of interested citizens, public officials, and leaders of civic organizations. It may involve direct participation by organizations and groups such as the chamber of commerce, businessmen, Boy Scouts, special interest groups, poor people, elderly people, school board, city commission, county commission, military officials, and so on.

State Participation

The state agency with transit planning responsibility provides a vital pool of expertise and data essential to transit planning and operation for small cities. These functions are essential not only for the initial implementation of a system but also for its continued maintenance and operation.

Most smaller urban areas cannot commit the resources necessary to maintain such a permanent staff. However, an agency such as a state department of transportation, a state public transportation commission, or a state planning agency will generally have personnel available for those functions. Much of the data needed for these studies (i.e., census information, statewide travel patterns, urban and travel characteristics, and transportation system inventories) are readily available from the existing data files and can be accessed at minimal cost.

The state transportation planning agency also maintains considerable transportation and other inventory data files. From this viewpoint, the state is usually well equipped to assist with the continuing monitoring and reevaluation functions for transit planning and operations.

Once the appropriate mix of advocates is decided, specific responsibilities of those individuals may be agreed on. The role of each participant should be clearly defined in the decision-making process. Simultaneously, the role of the transportation planner and the study product should be clearly defined.

Study Financing

If properly approached, the small urban area should be able to commit sufficient human resources to the study to more than offset its share of the study costs. In states where departments of transportation or public transportation agencies exist, state participation may be obtained in conjunction with the Urban Mass Transportation Administration's study-grant program. The important issue here, however, is the maximization of the local commitment in manpower, not necessarily in dollars. Human resources can be more easily committed by local government, and that type of commitment has much more potential usefulness and value than cash when measured in terms of work output and local involvement. That kind of participation also "builds in" to the local government staff expertise and knowledge necessary to perform system-surveillance functions.

Community Values and Goals

Of primary importance before a transit study is begun is local recognition of the fact that a study is needed. Without concurrence in this, there is little doubt that use will be made of the conclusions reached by the study.

The first task to be addressed by the local participants in the study is setting goals. Transit goals can be conveniently divided into 2 interrelated categories: transit service and local financing. It is important for the tranportation planner to obtain a clear reading on the community's value system if he is to be responsive to public policy. In this case, the local participants should be asked to address questions such as, Who needs transit services the most? Who after that? What particular "choice" transit markets should be served? Where should a subsidy come from? What role should transit play in alleviating traffic congestion as opposed to providing services to the disadvantaged? What span of fares can be deemed appropriate? How much subsidy is too much? Questions such as those should provide the planner with an understanding of service-design goals and the associated financial constraints.

In this early phase, the planner should also attempt to obtain general knowledge of existing transportation problems and issues in the area. Sensitive issues should be carefully dissected by appropriate questioning to reveal any possible hidden but highly regarded transportation or social values. The callous disregard of such values in the study can very easily disintegrate the credibility of the plan and create a highly volatile and potentially uncontrollable situation.

It may be possible at this point to gain some insight into the general land use configuration, neighborhood patterns, socioeconomic conditions, and general level of traffic congestion within the urban system. A broad familiarity with these items will greatly facilitate later data analysis and validity checks.

Study Goals

An important goal for any transit study is to produce a well-defined program for transit improvements. Such a plan should delineate what should be purchased, when it should be purchased, how much it should cost, and who should pay for it. In effect, a budget should be prepared, pinpointing what the capital needs are and where the resources required for those needs should be obtained.

The study should also yield an operations program that includes the information necessary to educate, as needed, those who will operate the system. It should also suggest a route structure, bus schedules, and system maintenance programs. A management surveillance system is considered by these authors to be a critical component of the total study package output. The suggested management surveillance system should include an organizational plan and an information network and should identify specific decisions or work tasks or both as they relate to elements within the organizational plan. Responsibilities should be clearly defined.

OPERATIONS PROGRAM

Management System

An almost standard practice today in the development of transit plans is the discussion of the advantages and disadvantages of the different mixes of public and private ownership and operation of bus systems. Specific local people available to the local public body should be assessed for their potential contribution and role in each alternative management system. Only in this way can a determination be made as to the appropriate use of private operational forces. Functional personnel needs may be categorized into six general areas: system management, bus drivers, route-schedule supervision, equipment maintenance, public information, and finance.

Opportunities for overlapping these functions should be explored in smaller systems to minimize personnel costs, but it is desirable to maintain the division of labor in larger operations. For example, revenue collection and accounting can be achieved by drivers' depositing and logging their daily revenues with an employee, such as a dispatcher, of the night police force. In the morning, the accounting department could pick up the cash and deposit it in the appropriate accounts and update the record system accordingly. Likewise, the system manager could double as the route-schedule supervisor for small systems.

Existing laws and administrative arrangements should also be explored thoroughly. If a regional authority is contemplated, relations among different bodies of elected officials should be understood and carefully accounted for. The advantages and disadvantages to each political entity should be weighed and presented very objectively when partnerships among public bodies are sought.

The overall role of the new body should also be consistent with the total transportation needs of the community. Multimodal agencies would appear to enjoy slightly more success in coordinating community transportation programs particularly where an airport or seaport might be located and successfully integrated with ground-transport systems. The advantages of cooperative multijurisdictional political entities over those that are fragmented and competing should be presented, particularly where harmful interpolitical jealousies prevail and disrupt efforts to unify, coordinate, and integrate transportation programs and policies on a regional basis.

Essential in outlining a suitable management structure are the delineation of the hierarchy of decisions to be made and the assignment of functional organizational entities to an overall framework for decision-making. Particular ingredients to this task include specifying from what group or groups of people participants should be drawn to compose a particular decision-making body and what specific decisions each group should be charged with executing. Generally, key financial decisions should be made at the highest level, probably by local elected officials, while day-to-day operating policy should be formulated by a management executive or by a subordinate board or committee appointed by an elected body or elected by the recipients of transportation services. Specific lines of authority will, of course, have to be drawn in accordance with local goals and existing power relations.

In communities where little or no technical expertise is available for data analysis, the state transportation agency's human resources should be tapped for technical advice. However, to be useful, that advice must be solicited by the local decision structure. Therefore, it is important to establish what technical decisions might be required of the local operating agency and to identify what the informational requirements of such decisions are. It is then necessary to identify who will act on it. Basically, these decisions are service-design questions related to changes in land use, ridership patterns, fare structure, socioeconomic activity, and operating subsidy requirements. These questions can take the following form: Should routes be extended? Should headways be reduced, or should new routes be added? The probable consequences of the alternative for each question are best displayed by technical experts. Note, however, that this should be not a decision by the expert but merely advice to the proper decision-making group within the total organizational framework.

It is also important to involve the local governmental agencies to the extent practical in technical analysis with the hope of eventually developing the expertise necessary at the local level to provide their own technical advice without external assistance. Initially a commitment from the local building and zoning department to provide land use information about major developments should be obtained. Likewise the operational managing component of the management system should be approached to provide ridership and revenue data periodically. Each data gatherer should be provided with forms for obtaining specific data in the desired formats and with the necessary instructions for form usage and reporting. In an environment adverse to additional work loads or even technical advice, a more generalized and behavioral management approach could be performed by merely interviewing those having knowledge of the types of information relevant to the decisions needed. In either case, the informational requirements, the informational sources, and the flow pattern should be clearly identified in relation to the uses to which this continuing surveillance mechanism will be applied.

The output of this portion of the transit study should be charts and tables delineating specific work tasks, work responsibilities, decision-making responsibilities, information flow, functional personnel requirements, and bureau relations to other organizational components.

Financial Plan and Budget

Essential to the successful implementation of any transportation plan is a detailed, accurate forecast of cash needs through time accompanied by the mechanism for funding those needs. It is also important to obtain the cash commitments from the questionable sources before their funds are unrealistically budgeted without their knowledge. In the case of a small transit system, financial needs take the form of capital outlay and operating costs.

Included under capital outlay are items such as bus purchasing and replacement program, bus-shelter program, route-map and schedule-display stations, spare-parts purchasing programs, and plant purchases. The operating costs should include a detailed breakdown of all fixed and variable costs. Variable costs are composed of manpower, revenue, vehicle maintenance, fuel, oil, and tires. Fixed costs can be broken down into administrative overhead, vehicle depreciation, and plant depreciation.

Resources generally available to meet the capital needs of transit systems may be obtained from the UMTA capital grants program. If a state transportation agency exists, additional funds may be obtained from that source. Once the external sources and their corresponding funding ratios are identified, the local financial requirement can be accurately forecast. At this point, an analysis of the current local budget may reveal some padding that could be applied toward transit improvements. However, the legality of using particular types of local funds should also be investigated. Should no funds be available from existing tax sources, the task of identifying alternative equitable forms of taxation should be explored. Among the more popular taxes for transit purposes are the utility tax, local sales tax, ad valorem tax, and air- or sea-departure head tax. Often an existing tax is not being levied to its fullest extent, in which case the alternative of increasing an existing tax source should be analyzed.

The possibility of securing funds from large businesses that will directly benefit from a transit service should also be assessed. Other potential revenue sources are military bases or school boards. Both of these public agencies could possibly share a portion of their transportation budgets with the local community in return for transit service.

When alternative forms of taxation are analyzed, the following questions should be carefully addressed: How would the costs of transit service be allocated among the users and other groups in the community for each tax structure? How well does the distribution of benefits match the distribution of wealth and the ability for these sources to pay? What specific advantages and disadvantages would be forthcoming for each taxed group? The decision to select an outside revenue source should be made locally.

SYSTEM DESIGN METHODOLOGY

Elements to be addressed in the design of a transit system include route structure, schedules, fare structure, vehicle size and quantity, plant location and requirements, and ridership estimates. From that list, it can be readily discerned that several interrelations exist among individual elements. For instance, number of routes and frequency of service (schedules) will dictate vehicle-quantity requirements. Likewise, schedules, fare structure, and route structure will influence ridership patterns, which in turn dictate vehicle size.

Ridership Estimates

In urban areas where origin-destination data exist, ridership estimates should be used to the fullest extent possible. The design year should be short range in order to design services for immediate implementation and with an effective surveillance mechanism designed to make adjustments simultaneously with growth. There is limited need for long-range planning of transit systems because small urban areas seldom require exclusive rights-of-way or substantially large financial outlays that are permanent or irreversible in nature.

Major interchanges of total trips between potential transit market areas should be identified and some portion of that market "split off" according to its propensity to use transit. If origin-destination data are available, the task of quantifying a reasonable range of transit usage is simplified. If not, some generalized, aggregate estimate can be used based on trip rates for similar communities or neighborhoods in urban areas where origin-destination data are available.

Census files or a general knowledge of the socioeconomic characteristics of the area can be used to identify particular markets for transit. Another good source is the local chamber of commerce.

In areas where transit services are in existence, an on-board ridership survey is a must. A boarding-and-alighting survey will also be useful in defining an optimum bus-shelter improvement program and display locations that are the most frequently associated with transit service. This latter statistic is important in that an existing service should be maintained to the extent feasible because principal ridership patterns are fixed and major route revisions may result in a loss of patronage.

Route Structure

Before the existing route structure is revised, a careful analysis should be conducted of the route for circuity, directness of service, coverage, accessibility to target markets, schedule adherence, and running speed. Of those measures, all are easily quantified except for coverage and accessibility to markets, even though all are subject to qualitative judgment.

Assessing the viability of an existing service to a particular market or attempting to design a new route requires a base map showing all streets suitable for transit routes (i.e., adequate widths, running speeds, turning radii, and abutting land use). Several overlays depicting the location of each market sector separately then give the analyst sufficient information to lay out several alternative routes.

Basic potential markets common to all urban areas are shopping centers, low-income housing and minority groups, low-income employment, elderly housing, health-care facilities, tourist attractions, hotels and motels, middle-income housing, high-density housing, employment centers, areas not served by school buses, and junior and senior high schools. Once those areas are plotted on overlays, alternative routes can be effectively analyzed subjectively for their coverage characteristics of these markets.

Finally, the selection of the routes to be implemented must be related to the particular market sector the transit system is intended to serve—consistent with local community goals. Use of graphic overlays superimposing various route structures over the various market areas provides a highly effective means for evaluating alternative system configurations.

Schedules

Once a generalized pattern of routes achieving suitable coverage is devised, the job of adding or deleting route segments in order to obtain 20-, 30-, 40-, 45-, or 60-min turnaround times or some combination that yields 15-, 20-, or 30-min headways with layover can be attacked. The headways will always produce schedules that maximize rider comprehension and memory retention. A maximum headway of 30 min has always been a good standard to follow.

Fare Structure

For most small urban areas, zonal fares are usually inappropriate and transfers are minimal. That simplifies the fare structure. Alternative fares should be assessed for their revenue-generating capability in order to estimate the operating deficit requirements. Again, fare structure is a policy decision and not a technical decision; therefore, alternatives are stressed as the form in which technical information should be presented to the appropriate decision-making group.

Among the alternatives that should be assessed are "free" service or area-wide 5-cent fare and fare plans for students, the elderly, the disadvantaged, and shoppers. Reduction of fare for shoppers and school children should be coordinated with approaches made toward the school board's transportation budget and business subsidies when outside revenues are sought.

Fleet and Plant

Once routes, schedules, fares, and patronage estimates have been completed and load-factor policies are established, vehicle quantity and size can be estimated in a straightforward manner. Plant requirements are a direct function of those 2 variables, and plant location is a function of route structure, land use, adequacy of existing maintenance facilities, and real estate costs. In most cases, existing municipal or county vehicle maintenance facilities could be expanded to provide the required services. An estimate of these financial needs will provide the basic inputs to the operations program and capital grant application.

SUMMARY

In summary, this paper has 4 essential messages. First, "desophisticate" the planning process, cut costs, and do not spend $40,000 to study a $40,000 capital improvement! Second, be issue-oriented. Address questions that are important and relevant to the local community. Be responsive to its needs. Third, be action-oriented. Develop a prescription on Monday morning for what action needs to be taken by whom. Delineate specific work tasks that should be attacked immediately and get the ball rolling. It is time that planners begin to play a more meaningful role in forging the link between planning and implementation. Fourth, be management-oriented. Do not just draw an organizational chart or discuss generalized alternative forms of management. Address the issues in terms of function and responsibility. Design an information system that will permit the recommended organization to effectively monitor, control, and manage system performance. Pinpoint data collection needs, and obtain commitments to secure that information. Identify decision-makers and the flow of the information to them. If we can ensure that an effective surveillance and control mechanism is installed in the management system, then we can be assured that the system will continue to be responsive to changing needs and we can forego any long-range forecasting as a part of the small urban area transit study.

VANDALISM AND PASSENGER SECURITY IN THE TRANSIT INDUSTRY

John B. Schnell and Arthur J. Smith, American Transit Association

This paper summarizes the goals and objectives of an Urban Mass Transportation Administration project designed to measure the scope of transit-related vandalism and crime in terms of its characteristics and costs. The discussion includes all current efforts to reduce vandalism, passenger harassment, and crime in terms of vandal-resistant materials and equipment; community, social, and educational programs; and deterrent, protection, surveillance, and apprehension systems. The paper also discusses problems of institutional cooperation and conflict as well as current and planned demonstration projects designed to measure the effectiveness and costs of particular procedures and techniques for deterring vandalism and crime.

•IN THE FALL of 1970, the Urban Mass Transportation Administrator suggested to both the American Transit Association and the Institute for Rapid Transit that a study be undertaken concerning the cost and forms of transit vandalism and the problems associated with passenger harassment.

The American Transit Association and the Institute for Rapid Transit both had committees to consider the problems of vandalism and passenger security but formed a joint Vandalism and Passenger Security Committee and through the American Transit Association submitted to UMTA a proposal that had the following purposes:

1. To ascertain and categorize the scope, severity, dollar costs, and characteristics of the vandalism and passenger security problem;
2. To summarize and evaluate types of antivandalism and passenger security campaigns, procedures, techniques, and devices;
3. To summarize the types and nature of vandal-resistant transit vehicle equipment and materials;
4. To summarize the types and nature of design modifications for transit stationary site facilities and to improve passenger security and reduce vandalism;
5. To compare the concept of public versus private police protection for transit vehicles and stationary facilities;
6. To conduct a number of demonstration projects; and
7. To draw conclusions from the demonstration projects and to furnish detailed recommended courses of action to combat the major forms of vandalism and to improve passenger security, including a carefully worked out set of proposed experimental project activities, methods, measurements, and projected possible results.

The Urban Mass Transportation Administration agreed to fund this project in June 1971.

GOALS AND OBJECTIVES

The Vandalism and Passenger Security (VAPS) project has 2 basic goals. The first is to determine the national scope of transit crime and vandalism. This task includes the development of statistics that will measure the components of the various types of

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crime, vandalism, and passenger harassment. It also includes the development of statistical measures that relate crime and vandalism to a variety of transit operational parameters such as 100,000 passengers served, 100,000 vehicle-miles operated, and percentage of total operational costs.

The second goal is to examine what can be done to control the problems of crime, vandalism, and passenger harassment and to make specific recommendations on the basis of this research. That goal is being fulfilled by a dual research process. First, we are examining what transit systems are currently doing to control crime and vandalism, and, second, we are attempting to determine which strategies are particularly effective.

Objectives, or major tasks of this study, are as follows:

1. Ascertain the scope, severity, dollar costs, and characteristics of the vandalism and passenger security problem;
2. Summarize the types and nature of antivandalism and passenger security campaigns and indicate any measures of effectiveness;
3. Summarize the types and nature of vandal-resistant transit vehicle equipment in areas where additional materials research is likely to be most beneficial;
4. Summarize the types and nature of design modifications for transit stationary-site improvements for passenger security and vandalism control;
5. Compare the concept of public versus private police protection for transit vehicles and stationary equipment as well as other institutional areas of cooperation and conflict;
6. Examine public attitudes toward vandalism and crime;
7. Visit transit systems to conduct in-depth interviews of pertinent personnel concerning all of the project tasks;
8. Prepare demonstration projects in cooperation with participating transit systems in order to consider alternative means of controlling or preventing vandalism and passenger harassment;
9. Furnish detailed recommended courses of action to combat the major forms of vandalism and to improve passenger security, including carefully worked-out experimental project activities, methods, measurements, and projected possible results; and
10. Prepare, publish, and distribute a final report.

CONCLUSIONS

Transit system efforts to control vandalism consist of programs that include some or all of the following:

1. Concerned municipal government or citizens' groups that try to coordinate efforts of municipal leaders and representatives of the schools, police, courts, parents' associations, and news media to stop vandalism and passenger problems within their communities;
2. Juvenile and municipal court systems that stress firmness and administer punishments (rather than warnings);
3. Local news media that publicize the decision to "crack down" on vandalism and passenger harassment but at the same time avoid glamorizing or giving sensational coverage to acts of vandalism and passenger harassment;
4. Transit systems that are willing and able to assist the police and the courts and also to conduct extensive cleanup campaigns to help eliminate broken glass, cut seats, graffiti, and other evidence of past vandalism; and
5. School systems that cooperate with the police, courts, and parents' associations in helping to promote a healthy relation with school children and cooperation in preventing vandalism and apprehending violators.

The problem of transit crime is entirely distinct from that of vandalism. Community relations or rapport-building activities are unlikely to deter criminals from using transit vehicles or stationary sites as the scenes of crimes. Efficient and cost-effective means of deterrence, surveillance, and apprehension (as discussed further in another section of this report) have been found effective to some extent. In this connection, the "crime transfer" phenomenon is noteworthy. This is to say that, although increased security measures applied to a particular site, route, or time period can result in lower levels of crime, the criminal activity may well "transfer" to different sites, routes, or time periods.

A specific incident of savage, senseless crime at a transit site or in a transit vehicle presumably will reduce transit patronage on that route or in that area for a period of time. However, the typical transit user (even in areas where there is a relatively high incidence of transit crime, vandalism, and passenger harassment) is likely to consider frequency of service, convenience of routes, and fare level more important than his personal security when considering the use of transit.

SCOPE OF TRANSIT VANDALISM AND CRIME

Vandalism

Transit vandalism is currently a multi-million-dollar problem. The estimated national transit vandalism bill was approximately $9,000,000 for 1970 and was at least $500,000 more for 1971. The rise might have been even higher had not the transit systems made a diligent effort to control vandalism.

Actually these cost estimates undervalue the real costs of vandalism because they measure only the costs of labor and material for vandalism repairs. The costs of lost trips due to fear of being harassed or hit by a stone or to displeasure with the physical appearance of a vandal-plagued bus remain at this time unmeasured. So too do the costs of transit management's time and effort devoted to combat this problem. Moreover, the costs of transit police forces and of municipal police are not included in this estimate.

The problem of vandalism costs appears less severe when calculated as a percentage of system operating expenses. In 1970 no transit system showed vandalism costs of more than 1 percent of operating expenses. The national average was 0.4 percent.

Crime

Robberies of bus drivers were a major crime problem in the late 1960's, but the adoption of exact-fare plans by most large- and medium-sized transit systems has reduced that problem substantially. However, other types of transit crime directed at both transit personnel and passengers still continue.

In comparison with overall urban area crime rates, transit crime occurs relatively infrequently. Approximately 7,200 violent transit crimes occurred in the United States in 1970; the total number of national violent crimes was more than 731,000. Violent crimes include criminal homicide, forcible rape, robbery, and aggravated assault. Criminal homicide and rape together account for less than 1 percent of this total. The most common form of transit violent crime continues to be robbery; aggravated assault runs a very distant second. In terms of passengers and vehicle-miles, on a national level in 1970, 1 violent transit crime occurred for every 8,238,472 revenue passengers served and for every 2,615,417 vehicle-miles operated.

Even in the cities having the highest transit crime totals, the degree of transit security is still quite impressive. In some cases the crime per passengers and crime per vehicle-mile figures are close to the national averages just mentioned.

Other types of transit crime, which includes acts such as larceny, simple assaults, and disorderly conduct, are more frequent than violent crime and are approximately 4 to 6 times as likely to occur. (However, the number of those offenses associated with transit is small when compared with the total frequency in a typical metropolitan area.) In all cases analyzed in the VAPS study, transit crime was less than 1 percent of urban area minor crime for all categories.

Statistics

The final VAPS report will include a statistical analysis of the categories and nature of transit vandalism and crime, the costs, and the incidents.

Bibliography

The VAPS project will also include a comprehensive and partly annotated bibliography arranged in categories such as vandalism, crime, law enforcement, new equipment, and human factors. As of this writing, more than 80 articles on vandalism and 230 articles on all VAPS aspects have been annotated.

VANDAL-RESISTANT MATERIALS AND EQUIPMENT

Glazing

Glass breakage in transit vehicles accounts for 50 to 75 percent of transit vandalism costs. To cope with the glass breakage problem, manufacturers have conducted intensive efforts to develop acceptable glass substitutes. Plexiglass, the first to be developed, has great strength and clarity but is relatively soft and prone to surface scratches from washer brushes. Recently General Electric has developed Lexan MR-4000 and Rohm and Haas has made an acrylic plastic that, when coated with a Dupont product called Abcite, have proved acceptable substitutes for safety glass.

The Abcite-coated acrylic is currently under test on approximately 45 transit systems and is being used in rail cars. Although more expensive than laminated safety glass, it is said to be approximately 15 times more break resistant. Abcite-coated acrylic meets, under laboratory test, the standards established by American Standard Safety Code for Safety Glazing Materials for Motor Vehicles Operating on Land Highways, Z26.1, which in turn is specified by Federal Motor Vehicle Safety Standard 205.

Lexan MR-4000, a coated polycarbonate material, also meets all test standards of Safety Code Z26.1 under laboratory testing. It is more expensive than safety glass or coated acrylic but is approximately 200 times more break resistant than safety glass and, in fact, has come through laboratory tests in which a metal monster is hurled against ⅜-in. Lexan MR-4000 sheets without breakage.

The recognized standard for motor vehicle safety glazing is Safety Code Z26.1. That standard is also used by the National Highway Traffic Safety Administration of the U. S. Department of Transportation in establishing the safety glazing requirements for all buses sold in the United States.

Until 1972 there was a question within the transit industry as to the legality of using either Lexan or an acrylic in bus windows because Z26.1 did not specifically permit them. One question concerned the meaning of "readily removable." A firm definition of these words was published in the Federal Register (Vol. 37, No. 120, Wed., June 21, 1972, pp. 12238-12239):

> SF 1.1.4 The phrase "readily removable" windows as defined in ANSZ26, for the purposes of this standard, in buses having a GVWR and more than 10,000 pounds, shall include pushout windows and windows mounted in emergency exits that can be manually pushed out of their location in the vehicle without the use of tools regardless of whether such windows remain hinged at one side to the vehicle.

Thus, Lexan and acrylic plastic can be used everywhere in transit vehicles except in the front windshields and in windows to the immediate left and right of the driver.

Seats

Many transit systems have begun to switch to fiber-glass seats in transit coaches in order to reduce or eliminate the cost of upholstery repair. San Francisco Municipal Railway, for example, has begun using fiber-glass seating in all areas behind the rear exit doors because almost all damage to seating occurs in the rear of the bus where the driver's view is limited.

But even fiber-glass seats have not been immune to vandal attack. Because these contoured seats collect water from dripping-wet raincoats, some transit systems have drilled holes in the seats to let the water drain through. Vandals have found it challenging to chip with knives at the drain holes.

The American Seating Company is marketing a new seat of cast nylon that has a "warmer" look and is claimed to be more resistant to damage than fiber glass. The Detroit Street Railway and the Baltimore MTA are among those now testing the cast-nylon seats.

Many transit systems would prefer to keep using upholstered seats for maximum passenger comfort. The Craftex Company has produced a new type of rip-resistant fabric that can be punctured with a knife but is extremely difficult to tear. This fabric is currently being used in 1 PATCO rail car and in 3 Cleveland Transit System rapid transit cars. Both systems report satisfactory results from their use so far. AC Transit in Oakland, California, is ordering Craftex fabric for seats in some of its new buses.

Graffiti

The problem of removing graffiti has become a serious one in many urban centers. In Philadelphia, which has been called by some newspapers the Graffiti Capital of the United States, the general superintendent of rolling stock and garages for SEPTA has disclosed that in 1971 graffiti removal cost $98,880. Just 30 months ago, there were only a few graffiti writers in Philadelphia. Unfortunately, the magazine section of a prominent paper carried a sympathetic front page picture story that had the effect of making graffiti artists "folk heroes" in Philadelphia. A massive graffiti fad developed, and, according to some estimates, more than 5,000 practicing graffiti writers were defacing city and private property by late 1971.

This "artistry" occurs in the rear of buses and is costly to remove. Many types of markings on upholstery penetrate the vinyl cover all the way down to the cloth backing. Often this requires either replacement of the upholstery or repainting of the vinyl fabric.

The VAPS staff considers that several factors contribute to the impulse to deface transit vehicles with graffiti:

1. The good odds for anonymity in large cities as far as the Establishment (police, school, and parents) are concerned;
2. The opportunity to have "exposure" among one's peer group and to make one's nickname famous (in Philadelphia some prominent nicknames have been Cornbread, Cool Clam, and Cool Earl);
3. The scarcity of transit system or municipal police, or their inability to apprehend the vandals;
4. The leniently inclined court system whose tendency to issue warnings rather than punish offenders has negated police enthusiasm for apprehending vandals;
5. An apathetic public;
6. News media that give exposure and glamor to vandals; and
7. The inability to quickly remove graffiti from vehicles or stationary sites of transit systems.

The following actions have been found helpful in deterring vandalism:

1. Coordination by citizens' groups of efforts of representatives of schools, the police, the courts, parents' associations, municipal government, and the news media to deter antisocial activities within their communities;
2. Fair trial and due punishment of vandals;
3. Prompt and complete cleanup of all graffiti;
4. Encouragement of transit system and municipal police to apprehend violators;
5. Denunciation of vandalism activity by municipal officials;
6. Impartial administration of justice by the juvenile court system, including fines and assignments to violators to help in clean-up work; and
7. Cooperation by the school system with transit and municipal police in apprehending vandals.

Interior Panels of Transit Vehicles—A VAPS demonstration project is currently under way to help solve the graffiti problem. We currently have acrylic side bus panels, manufactured by Swedlow, Inc. of Garden Grove, California, installed in the rear of 5

Metro buses in the District of Columbia. These buses are in regular service on one of the most graffiti-prone routes.

Graffiti Solvent Study—To obtain information on the types of solvents and cleaners and the cleaning procedures that the transit industry uses, a questionnaire was sent to all transit systems. A summary of these data has been returned to all transit systems so that they may more effectively experiment with products and techniques used by others.

In addition, the VAPS staff is working with the manufacturers of indelible felt-tip pens via their trade association, the Writing Instruments Manufacturers' Association. Its test standardization committee is preparing a set of recommendations concerning the best methods for removing the various types of ink markings.

Wall Protection at Stationary Sites

We are also concerned with wall-coating developments that can aid in graffiti removal. One such product is Hydron 300, which is being tested on wall surfaces at subway sites at both SEPTA and NYCTA.

COMMUNITY, SOCIAL, AND EDUCATION PROGRAMS

School Programs

Transit systems are conducting public relations and rapport-building programs in a number of cities. Some of those programs rely not only on presentations but also on channels of communication that continue between the Establishment and the students.

Charles Gaston, a black transit supervisor with the Seattle Transit System, gives slide shows and talk presentations to local junior and senior high schools. Before each talk, Mr. Gaston visits the school site to chat with students as they board buses in the afternoon and to find out whether they have any particular complaints. He uses these occasions to photograph the students in their own environment and during the presentations uses the photographs to attract the students' attention. The students recognize their friends and begin to realize that the Establishment is really interested in them. After any serious transit incident, Mr. Gaston promptly visits the site, talks with the students if possible, and follows up with the school vice principal. Often he finds out the names of the offenders and contacts their parents to request that they reimburse the transit system for the damage incurred.

Al C. Brasill, chief supervisor of the Atlanta Transit System, provides liaison between the transit system and Atlanta's elementary, junior, and senior high schools. He has built up an excellent working knowledge of not just the names of the principals, vice principals, and others at those schools but their personalities and their abilities to exercise discipline and control over their students.

Mr. Brasill calls on school officials in late July or August of each year and discusses shifts in student enrollment, additional busing needs, school bus routes, and problems relating to the transportation and conduct of students for the coming school year. He welcomes opportunities to present lecture programs to students. He discusses vandalism and other problems with new bus drivers of the Atlanta Transit System during their training period, including matters such as handling of drunks, unruly students, and fare evaders.

The Port Authority Transit Corporation has recently completed a series of educational presentations given in the public schools of Camden, New Jersey, and other suburban communities along the system's right-of-way as part of an attempt to cope with a series of train stonings. Extensive vandalism has not been a serious problem to the system, but stonings of the rail cars have been. According to J. J. McBride, chief of PATCO's police department, about 40 percent of the incidents are in "nice" neighborhoods. The areas where stonings occur are those that offer easy access to the right-of-way, have a good supply of ammunition (rocks and bottles), and have convenient escape routes. The core of PATCO's educational presentation is a talk given to the students by Mr. McBride. First, the personal safety of the youngster is stressed. It is pointed out that PATCO's right-of-way is a very hazardous place. Second, Mr. McBride points out the potential for injury to PATCO passengers from stonings, passengers who could well be students themselves, their friends, or members of their families. The PATCO presentations in public schools, which began on March 10, 1971, and continued to May 5, involved a total of 35 schools and 10,681 pupils. PATCO experienced 28 stonings in March and only 13 in April. PATCO officials think that the decrease can be attributed to the combined effects of the school presentations and increased police patrols at likely stoning sites.

School Bus Monitors

Because vandalism on AB&W buses serving Alexandria, Virginia, climbed from $3,110 in 1969 to $7,963 in 1971, Alexandria school board officials and AB&W officials installed 15 school monitors to ride buses to and from school with students each day on routes suggested by AB&W officials. The monitors observe the boarding and discharging from the bus as well as the conduct of the students during the trip. The monitors are predominately male (22 out of 37) and are paid $3.75/hour. Any difficulty on a bus is reported directly to the principal of the school serviced by that bus. The bus driver, therefore, is not called on to discipline the riders.

School Bus Passes

In Baltimore during the fall of 1969, free bus transportation (on MTA buses) was given to any school child living more than a mile from his school. In addition, a free-choice policy permits each student to attend any school in the city he desires. Therefore, the school board issued passes that were valid all day, and no control was placed on student movements. Groups of students chose to play hooky and ride the bus all day, and such groups often became rowdy and harassed passengers. The passes were then discontinued at the end of the school term in June 1970 and replaced by tickets that were valid for a month and in a different color each month. The back of the ticket books had an identification card bearing a serial number that was also on all tickets in the book. Bus drivers could demand to see the ID card if they suspected that tickets were stolen.

Also in Baltimore the Almagamated Transit Union (representing the 1,300 MTA drivers) agreed to cooperate and support a "get-tough" program to reduce vandalism. Included in the proposed program was the request that the board of education revoke for the full school year the free bus transportation for students involved in any vandalism and suspend from school those involved in transit incidents. Community leaders also agreed to support a "tough" policy by judges. Thus encouraged, some judges handed out stiff sentences to vandals instead of mere warnings.

Results were swift. An editorial in the Baltimore Evening Sun on May 21, 1970, said, "The word got around quickly, particularly after a few arrests showed that the police meant business. From as many as nine incidents a day, the rate has dropped to only two or three a week." In one case, an entire busload of 52 students (mostly girls from 14 to 17) was arrested and held for juvenile court.

This hard-nosed, antivandalism program was successful. Joseph B. Garvey, resident manager for the Urban Mass Transit Administration in Baltimore, said that as of March 1970 vandalism on MTA buses was down 46 percent and arrests were up 145 percent compared to the same period a year earlier. He reported that arrests for vandalism and assaults on MTA buses rose to 34 per week in May 1970. There was only 1 per week before the antivandalism program started.

Graffiti Alternatives Workshop

The Graffiti Alternatives Workshop of Philadelphia was organized in 1971 by Sandy Rubin. The workshop received support from the University of Pennsylvania and the Philadelphia Art Museum; SEPTA donated one of its buses. The original group of youths who were the creators of the graffiti fad in 1970 numbered no more than 25. At least two theories have been advanced to explain their behavior. First, they may have been marking out "turf" (part of a city considered to be its own by a teen gang). Second, they may have been attempting to gain status and recognition within their peer groups. Both reasons have been verified in interviews with the most famous graffitiers in the city.

An article on graffiti and its "creators," which appeared in a local Philadelphia paper in May 1971, portrayed the errant youngsters as personalities akin to folk heroes. That publicity seemed to reinforce the already growing fad, and graffiti became an epidemic. Many other youths sought to copy the "heroes" with their own scrawls. In a number of cases, youths admitted they were trying to borrow glory from the "big names" by producing a copy of the famous writer's name and writing their own names next to the copy.

In an interview, Sandy Rubin suggested several reasons why the involved youths selected the transit system as a prime target. The transit system is public, and, if the goal is to have one's "mark" seen, a transit station or vehicle is a prime location. The youths admitted that they knew they were doing something wrong but felt SEPTA was a "fat cat" that could well afford the expense of cleaning. In addition, the act of scoring a "hit" (term used for producing one's mark) was viewed as a chance to strike "the man" (term used by minority youths to describe the white businessmen seen dominating the city).

In Philadelphia, graffiti are largely confined to names or symbols. Political graffiti and profanity are uncommon. Many of the names have been formed into intricate and unusual designs and painstakingly worked into symbols representing the writers' names. Various writing materials are used, ranging from felt-tip pens to spray paint, hair dye, and shoe polish. Because the signatures and symbols had an artistic flair, Ms. Rubin conceived the idea of a workshop to direct the "artists'" talents into constructive fields through means other than punishment.

Youths who were found writing on a SEPTA subway wall were offered the opportunity to take art lessons with art materials provided free. Ms. Rubin and Robert Rivera, an art instructor at the university, began the operation of the Graffiti Alternatives Workshop in rooms provided by the University of Pennsylvania. About 25 youths attended workshop sessions originally, and the number grew as word spread. Eventually 75 youths, including all the "biggies," became involved. The GAW has become a referral center in Philadelphia to which youngsters can be sent at the option of juvenile judges.

In a joint SEPTA-GAW project, SEPTA provided one of its Route 42 buses to be painted by youths attending the Workshop. The bus has returned to revenue service, complete with multicolored stripes and designs. For the most part, passengers have accepted the change well, although some have said they had trouble identifying the vehicle as a SEPTA bus. An interesting point is that the bus remained unmarked by graffiti for 6 weeks after returning to regular service.

Films for Elementary Schools

The potential of the film medium as an educational tool in elementary schools is being demonstrated by the Regional Transportation Service in Rochester, New York. Jim Reading, the resident manager, has had an antivandalism film prepared, called "Trickles the Raindrop," which will be used in a series of school presentations in Rochester.

Same Bus and Driver

To eliminate the anonymity characteristic and to encourage rapport building between bus driver and students, AC Transit in Oakland, California, has instituted a program of using the same bus and the same bus driver with the same school routes as often as possible. Because this procedure allows the bus driver to become familiar with the students on his school bus routes, there is little possibility that he would not be able to recognize and identify any students involved in rowdyism or a vandalism act. In addition, it is hoped that the students will realize that this is "their" bus; AC Transit will even consider marking the bus with the name or mascot or symbol of the school that the students attend. This type of scheduling is not normally possible, however, because of the problems of maintenance scheduling and of scheduling drivers so that they work as continuous a day as possible.

DETERRENT, PROTECTION, SURVEILLANCE, AND APPREHENSION SYSTEMS

Automatic Vehicle Monitoring and Emergency Alarm

The use of automatic vehicle location techniques and clandestine alarms to ensure fast reaction to criminal acts (particularly in incidents of bus hijackings) is currently under demonstration in Chicago. Currently being tested in Philadelphia are 4 different types of vehicle-locating systems. Large congested cities present many problems for vehicle-locator systems, and the tall buildings, radio interference, and closely spaced streets constitute a difficult testing ground for these sophisticated systems.

Communications Systems

Although many transit systems have had 2-way radios in all or most of their buses, additional experiments are being conducted to make these communication systems more helpful when serious incidents occur.

Sometimes there may be jealousy and misunderstanding from the local police department when a transit system installs 2-way radios and begins to report unusual non-transit incidents observed by its bus drivers. There is no question that police departments have much serious police work to attend to other than responding to "rowdy students" calls relayed by a radio dispatcher from a harassed bus driver. Nevertheless, police departments can be persuaded to cooperate. For example, AC Transit in Oakland, California, reports that 352 calls were relayed during 1971 from bus drivers reporting on nontransit incidents such as accidents, fights, riots, fires, robberies, and other miscellaneous incidents. The police departments surrounding Oakland have seen fit to commend a number of the AC Transit drivers with certificates acknowledging the timely help and assistance they have provided.

Surveillance Systems

UMTA is said to be considering research on improved methods of using surveillance techniques (characteristically closed-circuit television on platforms and possibly in vehicles as well) in both rail and personal rapid transit systems. This approach will encompass new concepts in micro-miniature-integrated electronic circuits and optic sensors with moving-target software.

An existing surveillance system using television cameras at each of the PATCO station gates has proved to be remarkably successful, especially when the lack of any manpower at each of the station gates is considered.

The Port Authority Trans-Hudson (PATH) uses television surveillance in the World Trade Center to observe the fare-collecting and money-changing areas and also the station platform.

Alarm Systems

UMTA is also considering research into the technological means of providing tamperproof points of communication for victims of, or witnesses to, criminal acts on sites such as platforms and bus-loading zones. Such systems would include direct communications with law enforcement, area alerts (phones and flashing lights), and personally actuated alarm signals. Some transit systems have 2-way radios with hidden buttons that the operator may depress to signal trouble. Others use operator-actuated 4-way flashing lights on the roofs of vehicles as pre-arranged signals to request police assistance.

Observation Post System

The VAPS staff has made a proposal to UMTA regarding a crime deterrent system at a rail rapid station. The system is composed of an observation location where there is the capability to use a television monitor and videotape system, a public address system, an alarm system, an entrance-exit closing device, and a direct communication link to the police. The purpose of the system is to minimize and perhaps eliminate violent crimes in rail stations by deterring such events, thwarting violent criminal acts, apprehending criminals engaging in violent acts, and helping to prosecute apprehended criminals. A prime objective is to minimize man-hours used to operate the observation structure. It is expected that initially the structure will have to be occupied for a high percentage of time, especially during those hours of the day when violent crimes are most likely to occur, but that the use of manpower during the initial phase of the project will establish its deterrent image. Because the observation structure will be built in such a manner that people using the station cannot tell whether it is manned, a cutback of the occupation hours can be begun once the initial deterrent image has been established.

Television cameras located in appropriate locations in the stations will be monitored by screens located in an observation booth. In addition, a videotape unit will be available to record all incidents of violent crime. One camera will be located in such a manner that it can record any persons entering the station. Signs will clearly point out to all patrons that the station is under a security control system comprising several elements. The station selected would only have 1 or 2 points serving as an entrance and an exit. This would enable the person inside the observation booth to activate the closing device in appropriate situations.

A direct communication link would be established between the observation booth and the police-controlled facilities. That link could consist of a 2-way radio or a phone line and would aid in summoning police assistance in minimum time. The final 2 components of the security system would consist of a public address system and an audible alarm system. Both systems would be used for issuing alerts or for communicating information to station occupants in the event of an act of violent crime or for doing both.

Police Actions

Frank K. King, superintendent of the Municipal Transit System of San Bernardino, California, has explained that sometimes psychology helps to combat vandalism. He indicates that, when they have a problem bus route, they have a police car meet the bus half-way on its route. The police board the bus and install a camera and a tape recorder. The camera, which is the type used in banks to photograph bank robbers, is mounted on the bulkhead behind the driver. The tape recorder is placed under a seat. The passengers already on board see the devices installed and pass the word to other passengers boarding later. Mr. King comments that often there is no film in the camera and no tape in the recorder, but their presence on the bus usually proves enough of a deterrent to prevent a repeat of any vandalism for some time.

One unique bit of police work in Tacoma, Washington, involved the theft by high school students of the gasoline tank tops of the buses on a particular school bus route. One day the gas tank top was coated with clear gelatinous material and school officials were notified to watch for a student with purple hands. This gelatinous material remained colorless until the culprit tried to wash his hands. This action then stained his hands purple. The ruse was successful, and the purple-handed student eventually led transit system executives to a vacant lot where 26 gas tank tops were recovered.

School Detectives

Atlanta has 20 school detectives who are paid by the police department with funds provided from the Atlanta Board of Education. The detectives are assigned to particular areas of the city including a number of schools, and they become very familiar with all of the students, especially the trouble-making students. During an investigation with students, they know how to be stern or to "jolly" the students into being more frank and honest about themselves and fellow students.

Transit Personnel as Special Police

Operators and other company personnel of the City Transit Company of Dayton, Ohio, can become special police officers on completing the state-certified basic training program. As special policemen, operators are permitted to carry firearms while operating their vehicles in revenue service. A brief overview of this strategy since its inception in 1967 shows a sharp reduction in the number of bus driver robberies and no deaths or serious injuries resulting from the use of firearms by CTC Special Police. The City Transit Company has not implemented an exact-fare plan as a result of successes obtained via this alternative program. As of October 1, 1971, 91 CTC employees out of a total of approximately 180 drivers had completed the 130-hour training program. All candidates for the program are volunteers and take the 130 hours of training on their own time without extra pay, but the company does pay for the cost of the training, approximately $80.

Firearms used by the special police are provided by the employees at their own personal expense. Some CTC drivers have expressed the opinion that they would resist driving in high crime areas should the program be terminated. It appears that operators who are not special police and who do not carry weapons are also experiencing the same increased safety because the criminals do not know which drivers are carrying firearms.

Screens for Drivers

Although the exact-fare plan has largely eliminated driver assaults and robberies, some assaults are still occurring because of spur-of-the-moment antagonism or some other anti-Establishment disturbance. In January 1972, the American Transit Association sent its members a questionnaire to obtain information on assaults against bus drivers and especially on the use of protective shields for bus drivers. Eight of the 111 respondents had tried or were using a type of shield or screen for the protection of the bus driver.

Training of Police

The Chicago Transit Authority has received a grant from the U. S. Department of Justice for training security officials responsible for passenger security on the rapid transit system.

Both Chicago and New York use plainclothes "decoys" to try to trap criminals during night hours at remote station sites. These decoys pretend to be drunks or sleeping passengers so that they seem to be easy marks for a pickpocket or mugger. A police confederate is always within sight so that he may assist in preventing the crime and arresting the suspect.

On the PATCO system, dogs are trained to make transit patrols with their masters. PATCO has used an extensive public relations campaign in the communities it serves to convince municipal officials and citizens that the dogs are not dangerous except when a criminal act occurs and the dog is commanded to assist his master. The PATCO communities have enthusiastically accepted the man and dog patrols, and local newspapers give good coverage to any incidents of vandal or criminal arrests.

Police on Buses

In Buffalo and Boston, serious crime and passenger harassment have required that uniformed police ride the bus and rail systems at particular hours in particular neighborhoods. In both cities discontinuance of police protection is disquieting to the transit drivers because the basic crime problem persists.

INSTITUTIONAL COOPERATION AND CONFLICT

Atlanta Judicial System

Al Brasill of the Atlanta Transit System is on a first-name basis with the judges and clerks of the municipal court system and with the judges, referees, probation officers, clerks, and personnel of the juvenile court system. Mr. Brasill, who is always willing to provide any information needed by the municipal or juvenile court authorities, is often called to testify in cases involving the transit system.

Seattle Transit System

One of the most disruptive factors in the afternoon school-to-home trip is the presence of nonstudents who (either playing hooky from another school or having quit or been suspended from school) visit schools in small gangs and try to create havoc either in the corridors or in the school buses.

At Ranier Beach Junior-Senior High School in Seattle, Washington, 4 persons classified as field-security personnel carry walkie-talkie radios and patrol the corridors and grounds of the school throughout the day in order to prevent outsiders from wandering through the school and disrupting the normal school activities. These field security personnel check all passes but are not authorized to make arrests. The problem of intruders was quite severe at one time because expelled students soon learned that school officials had no power to either enforce their expulsion from school or arrest them. The situation was alleviated when the board of education's attorney prevailed on the court system to begin issuing restraining orders. If the school makes available to the court a documented record of a sufficient number of incidents regarding the violation of expulsion, the court may issue a restraining order. School officials can request the police to arrest students who violate such restraining orders.

PATCO Transit System Police

PATCO (from Philadelphia to Lindenwold, New Jersey) has a transit system police force of 18 men and 6 dogs. They patrol on board the PATCO trains as well as in the stations, parking lots, and the railroad right-of-way. The PATCO police officers have walkie-talkies and are in constant communication with the Central Control Center in Camden. When problems occur, a police officer who is already on a train can usually arrive at the scene within minutes.

Prior to the initiation of service on the Lindenwold Line, PATCO officials held intensive talks with representatives of the two states and the many municipal jurisdictions that PATCO serves. The necessary legislation was passed so that PATCO police are empowered to make arrests anywhere on the transit system regardless of where the criminal or vandalism act occurs. Although there is always some jealousy between police jurisdictions operating within the same area, the PATCO police have tactfully endeavored to assist local communities whenever possible and to slowly build the confidence and cooperation of local police jurisdictions.

Arrests made on the PATCO system are tried in the jurisdiction where the incident occurs. Although there is a tendency for local court officials to hear first all cases brought by the local police, court hearings are still rather prompt. The system seems greatly preferable to the alternative of having local police make investigations and arrests within their own jurisdictions.

Washington, D. C., Study

The Washington Metropolitan Area Transit Authority has awarded a $58,500 contract for a study of Metro's security. Concurrently, the Washington Metropolitan Council of Governments (COG) has decided to make its own study of the question of transit police versus local police. The two studies are to be made cooperatively, and the COG study is aimed broadly at all emergency services including police, fire, and ambulance.

The transit system suffers in some cities where this question has been left undecided. The Cleveland Transit System does not have sufficient money to provide its own transit security force, and the city of Cleveland does not want to expand its police force to provide occasional police patrols for vehicles and stations. Some cases of transit crime have occurred and have received much publicity, and ridership has suffered as a result.

SUMMARY

This paper has given highlights of the American Transit Association-UMTA study of vandalism and passenger security. Every major avenue of research provides several subideas that should be investigated, time and resources permitting, to provide a complete report. The scheduled completion date for this project is June 1973; copies of the final report will be available through the American Transit Association, the Urban Mass Transportation Administration, and the National Technical Information Service.

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BUS TRANSIT SYSTEM FOR A MAJOR ACTIVITY CENTER

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This paper examines a bus transit system for a major activity center. First, the needs of the transit system users are examined to determine what they want and expect from the bus service. Second, the attitudes of the activity center planners are examined to determine why the bus service was implemented and what benefits to the activity center are expected from the service. Third, the interaction of those perspectives is examined to predict the success of the transit system. The activity center used for this study was Michigan State University.

THE PROLIFERATION of major activity centers such as universities, central business districts, hospital complexes, amusement parks, airports, and military bases has precipitated the need for a transit service that differs substantially from the more familiar neighborhood and extended area transit services. [Neighborhood travel consists primarily of the collection and distribution of people within a subdivision or residential area. Extended area travel refers to the line-haul movement between neighborhoods and major activity centers. More detailed discussions are given elsewhere (1, 2).]

Major activity center (MAC) transit is planned and implemented not by an entrepreneur catering to a travel market nor by a government unit concerned about making transportation available to its non-automobile-owning constituents but by an administrative planner who theoretically views transit as a means of providing design flexibility and of improving synergistically the effectiveness of the center. Thus, in MAC transit the user is not the object of the service but only one of the elements to be considered in planning the service.

This paper has 3 objectives: to examine the needs of the transit system users to determine what they want and expect from the bus service, to examine attitudes of the MAC planners to determine why the bus service was implemented and what benefits are expected from the service, and to examine the interaction of these perspectives to predict the success of the MAC transit system. The MAC used for this study was Michigan State University.

The enrollment at Michigan State University, the nation's oldest land-grant college, nearly doubled in the 9 years from 1960 to 1969, surging from 21,157 students in the fall of 1960 to 40,820 in the fall of 1969. The increase in enrollment was paralleled by a massive building program to provide classrooms, research space, and on-campus housing facilities for a majority (53 percent) of the students.

The on-campus traffic and parking problem likewise grew, forcing the administration to restrict on-campus student parking during daylight hours. The nature of the parking problem is indicated by the fact that the police were issuing approximately 1,500 traffic and parking tickets per month in order to enforce the parking restrictions, but they complained vigorously that issuing that many tickets was futile because it only alienated the campus community they were trying to serve. The students were developing a negative attitude toward the officers for giving the tickets, and the faculty felt that the officers were not effective in controlling the traffic situation.

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As a result, the administration created the ad hoc Faculty-Student Motor Vehicle Committee to find workable solutions for the traffic and parking crisis. This committee made 2 recommendations. First, parking for students was to be limited to peripheral parking lots, and no driving was to be allowed anywhere on campus except by the most direct route from the peripheral parking lot to an off-campus street. Second, the commitee recommended that the university develop an "efficient and sufficient bus system servicing all parts of the campus and with service under the control of the university." It should be stressed that the major emphasis of the committee's report concerned the control of traffic and parking. Thus, it appears that the proposed bus system was primarily a means to make more palatable the new parking and traffic controls. This was indicated by a statement of the chairman of the Faculty-Student Motor Vehicle Committee: "Until we devise an improved transportation system, we cannot legitimately prohibit students from driving."

Carrying out these recommendations, Michigan State University began its own bus service in the fall quarter of 1964. It ordered 8 new buses, purchased 4 used ones, and hired the manager of the Grand Rapids Transit System to administer the operation.

At first the bus system was well received; during the 1967 winter quarter, 58 percent of the on-campus residents purchased bus passes. Service was excellent with headways of 15 min on the least traveled routes and 4 min on the main routes. However, ridership decreased in the 1968 fall quarter primarily because of a substantial fare increase and the termination of growth in on-campus housing. (Ridership is primarily limited to on-campus residents because the bus service does not go off campus.)

Currently, the Michigan State University bus system owns and operates 33 buses of the 51-passenger size. During the 1968-69 school year, 24,728 passes were sold at $14 per quarter, and 5,600,000 rides were provided.

USER EXPECTATIONS OF BUS SERVICE

Major Determinants of Bus Ridership

To determine what users desire of the MSU bus system, an analysis of bus ridership was made from 2 data sources. First, student numbers collected from the 6,831 riders during the 1969 fall term who also purchased passes during the 1970 winter quarter were used to obtain demographic data from the university registrar's master file. That data source represented 89.5 percent of all purchasers of bus passes during the 1969 fall term. Second, 568 survey questionnaires (1 in 33 sample) were mailed to on-campus students during the 1970 spring quarter. More than 80 percent (453) were returned and usable. Of those returned, 128 indicated that the respondent had purchased a spring quarter pass. The following analysis uses data from both sources to audit user expectation and to verify the findings.

To determine the factors that had the greatest effect on the students' propensity to purchase quarterly bus passes, a least squares multiple regression analysis was made on 16 independent variables obtained from the 453 completed survey forms. [A detailed description of the model development and the methodology used to compensate for the heteroscedasticity inherent in the use of a binary dependent variable is given in another report (3).] Seven of the variables were significant at the 95 percent levels or greater and explained 24 percent of the variance in the purchase of spring quarter bus passes. Those variables, ranked in order of importance, are total weekly travel distance, frequency of bus service to the student's living area, distance between living area and center of campus, sex of rider, class level, number of trips made each week, and percentage of night travel.

Total Weekly Travel Distance—This variable is a measure of the total distance students travel each week to attend class, to meet work schedules, and to participate in regular social engagements. It explains 6.34 percent of the total variance in bus ridership and was statistically significant at the 99.95 percent level. According to this analysis, an additional 7.4 percent of the students purchase quarterly passes when the average travel distance increases 10,000 ft/week.

Frequency of Bus Service to Student's Living Area—This variable, measured in minutes between regularly scheduled buses during the day, explained 5.6 percent of the total ridership variance. Figures 1 and 2, plotted from the 90 percent sample of 1969 fall term riders, show that an additional 25 to 30 percent of the on-campus students living in an area will purchase bus passes if the frequency of service is increased from 8- to 4-min intervals. That relation held true for both sexes and at all campus locations.

Distance Between Living Area and Center of Campus—This variable, a measure of the shortest walking distance between the student's residence area and the center of campus, explains 3.72 percent of the total variance in quarterly pass purchases. Figures 1 and 2 show the importance of the bus service to the remote living area; 50 percent of the males and 75 percent of the females in those areas purchase quarterly passes.

Sex of Rider—A comparison of Figures 1 and 2 indicates that females have a greater propensity to purchase bus passes at each level of service and distance. Figure 3 shows that ridership differences between sexes are greatest during the first year at the institution but rapidly decrease as students become more familiar with the campus. A possible reason for this difference in ridership between sexes, as suggested in the open-ended section of the survey, is that girls often buy a pass as a security measure because they dislike traveling alone, especially at night. The second reason might be that miniskirts are very cold in the late fall and winter in Michigan.

Class Level—Figure 3 shows that the probability that a student will purchase a bus pass decreases each year that the student is in residence at the institution. During the 1969 fall quarter, for example, 42 percent of the freshman class (17- and 18-year-olds) and only 10 percent of the senior class (21-year-olds) used the bus system.

Number of Trips Each Week—This variable was very interesting because it indicated that a student who made many long trips each week had a strong propensity to purchase passes. If, on the other hand, the student made many short trips within the academic area, the probability of bus-pass purchase was low. Two factors would explain this relation. First, the bus system was apparently viewed by riders as a commuter service from the remote living areas to the center of campus and not as a shuttle service within the academic community. Consequently, a person who made many trips within the academic area often did not purchase a bus pass for commuter use. Second, those who made a large number of trips tended to seek to live in dorms in less remote areas so that they would not be dependent on the bus. This point was, in fact, also brought out in the open-ended part of the survey.

Percentage of Night Travel—Students who traveled primarily at night had a lower propensity to purchase passes. This was probably explained by the facts that headways between buses were greater and students were allowed to drive their automobiles on campus during the evening. Consequently, students who took classes primarily at night would probably not use the bus extensively.

Ranking of Service Variables

Because user expectations also include the type of service that is offered, the survey sought details about the ranking of service variables, the scheduling of buses, and campus movement patterns.

Table 1 gives the results of the user ranking of transit service variables. These data reveal that service variables such as headway and interval dependability were considered much more important than the comfort variables of crowding and cleanliness. It is not known, however, whether cleanliness is really considered as unimportant or whether the buses are so well kept that cleanliness is not now considered to be a problem. The low ranking of crowding, on the other hand, was surprising since the buses were very crowded during fall and winter quarters.

Ridership and Scheduling

To determine the extent of travel within the campus, questions were asked to learn where students try to schedule their classes and where they go between classes. Students strongly prefer to schedule classes in many different buildings and do not support the "living-learning complex" concept around which MSU has designed many of its dormitories (Table 2). (The preference for single-building classroom scheduling

Figure 1. Bus ridership by male students versus distance of dormitory from campus center.

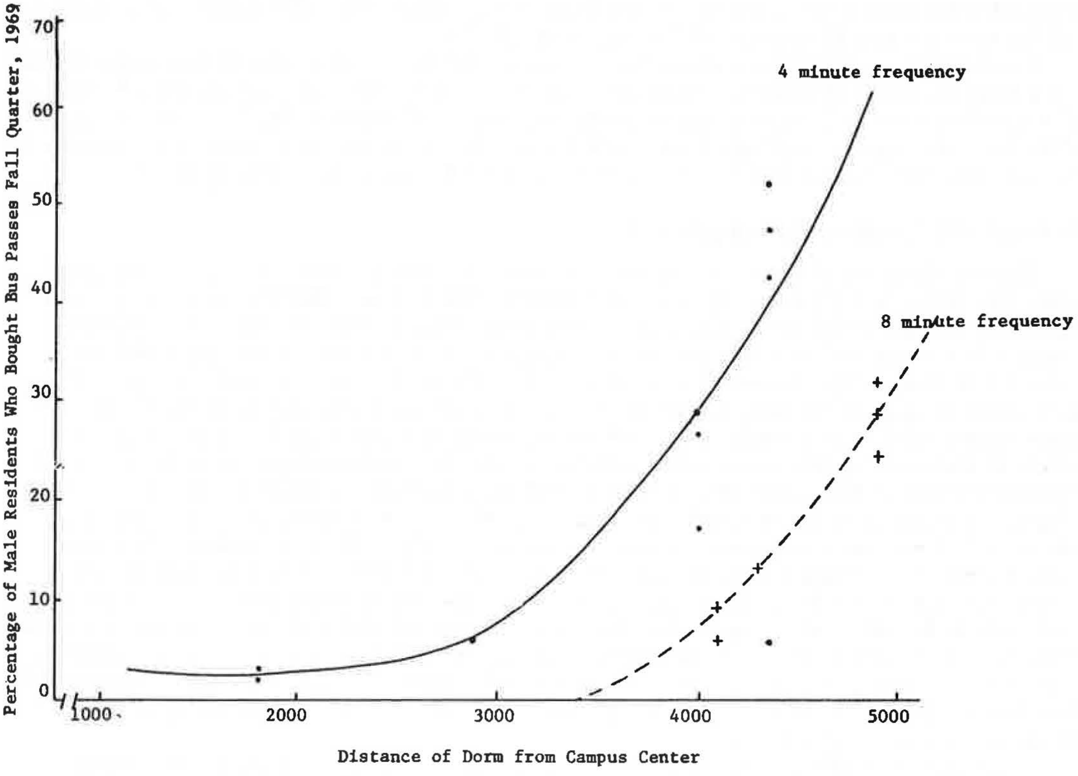
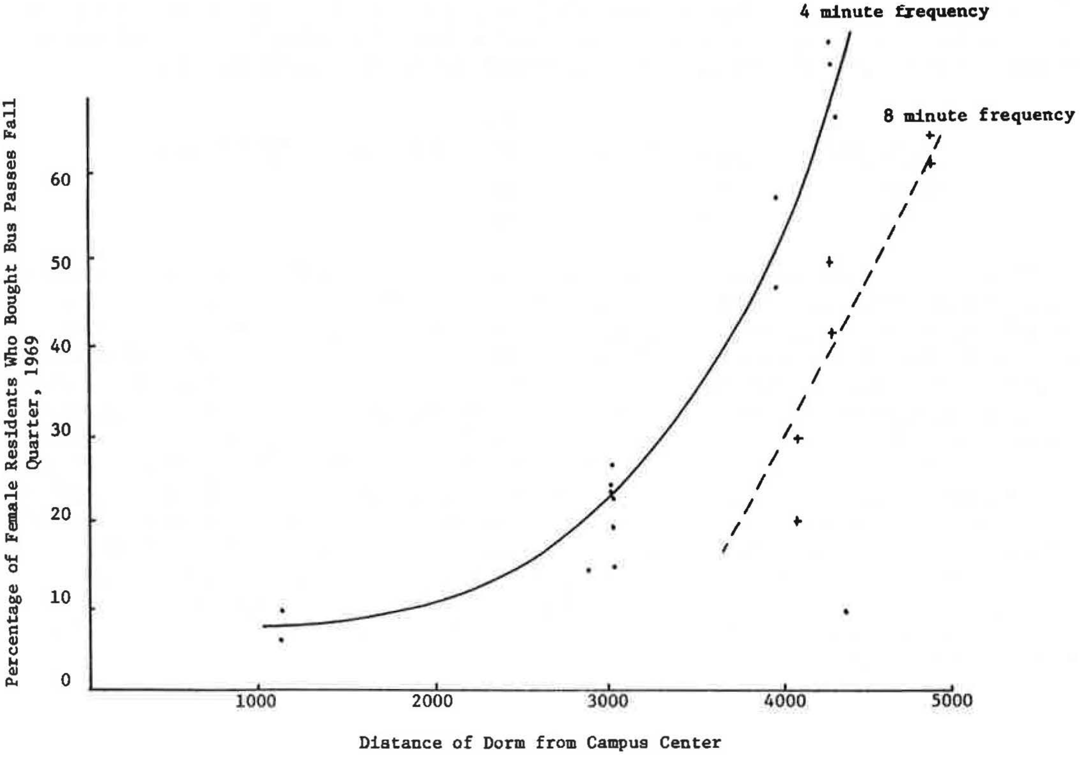


Figure 2. Bus ridership by female students versus distance of dormitory from campus center.



ranged from only 2 to 3 percent of the freshmen, sophmores, and juniors to 17 percent of the seniors and 47 percent of the graduate students.)

Furthermore, most students return to the dormitory area if they have a class break of 1 hour or more (Table 3). This break destination preference ranges from 80 percent for freshmen to 18.4 percent for graduate students. Consequently, it becomes apparent that bus users make multiple trips during each day, preferring to move from building to building for classes and to return to their dormitories during longer breaks.

Individual's Relation With Bus Service

During the pretest phase of the survey, students would frequently single out particular bus drivers they knew by name and would often indicate that these were the only drivers who provided the service the users desired of the bus system. Further investigation indicated that the operating manager felt that it was these same drivers who were frequently to blame for delays in meeting schedules and who were packing too many people on the buses. However, the respondents felt that less than strict punctuality and overcrowding were not so annoying as having the bus pull out as the student was leaving the building to catch it (Table 4). The user-preferred drivers exhibited behavior that coincided perfectly with user ranking of service variables. Those drivers regularly made it a habit to look in the doorways of each dormitory to make sure that there were no more students on the way. Also, if there were more riders who wanted to be loaded onto the bus, those drivers were vocal in joking about the crowding and trying to pack the bus so that everyone could be loaded. This behavior not only was observed by the writer but also was verbalized by both the drivers and the riders. Although punctuality was deemed to be more important when the headway between buses was greater (Table 4), in general the most important service criterion of the users appears to be to serve everyone even if the bus is slightly delayed or if overcrowding should occur.

A second area of real concern to bus riders was the apprehensive feeling about missing the bus and arriving late at their destinations. This feeling was first mentioned when bus-pass holders living in the housing area for married students were asked their reasons for driving their cars some days and riding the bus on others. The typical response was that, if they left their apartments less than 5 min before the bus was due, they would rather drive than run the risk of missing the bus. As shown below, 68 percent of the students were apprehensive about missing the bus.

Respondent	Apprehensive	Not Apprehensive	Sample Size
Riders	68.0	32.0	124
Nonriders	71.0	29.0	293

Neither sex, marital status, nor bus ridership made any significant difference in this apprehensive feeling. There are probably 2 major factors contributing to the apprehensiveness. First, people have difficulty memorizing a bus schedule because they tend to think in time blocks of 5, 10, or 15 min. In fact, the meeting of transportation schedules may well be the only scheduled activity people have that does not begin on the hour or quarter hour as most meetings and appointments do. Consequently, the memorizing of a timetable is probably foreign to a person's thought patterns. Second, because most people do not have their watches synchronized by a common source, there is probably substantial variance among watches, and people may simply lack confidence in the complete coordination of their timepieces with those of the bus drivers. In light of this fact, it was not surprising that 62 percent of all respondents felt that they should allow at least a 5-min wait at the bus stop if they were going to try to meet a bus schedule. As shown below, 82 percent of the bus riders abandon the effort required to try to meet a bus schedule, simply leaving when they are ready and taking the first bus that comes along.

Figure 3. Bus ridership versus age of student group.

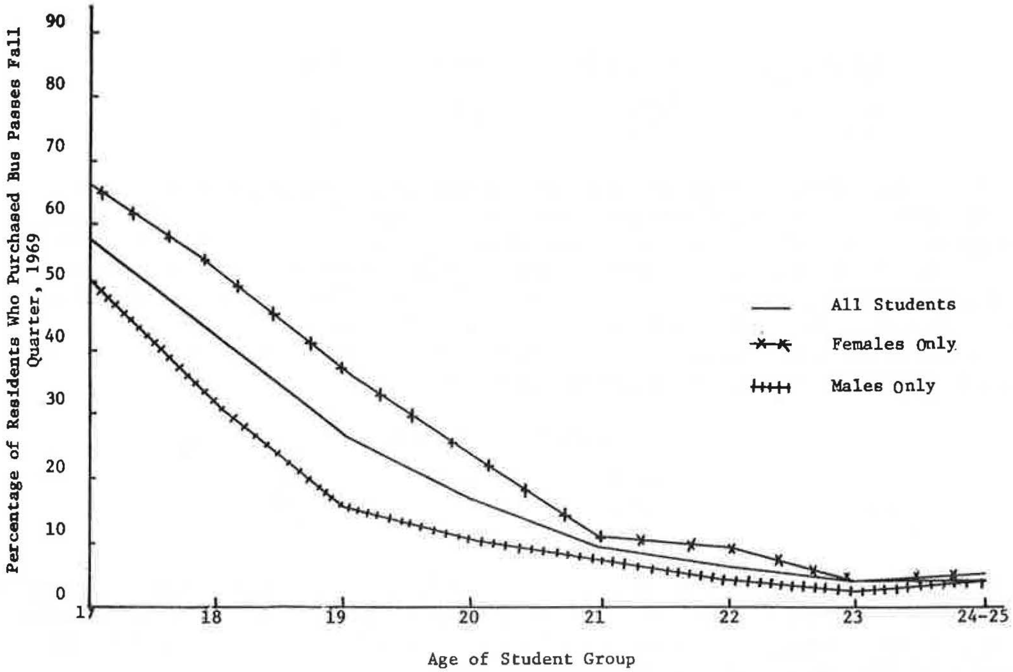


Table 1. Ranking of service variables by MSU bus riders.

Variable	Median	Median Rank	Mode	Mode Rank
Headway	1.926	1	1	1
Dependability	2.822	2	2	2
Coordination	3.423	3	2	3
Cost	3.984	4	3	4
Directness	4.361	5	5	5
Driver's attitude	5.236	6	6	6
Crowding	6.008	7	7	7
Cleanliness	7.187	8	8	8

Note: 1 = most important variable, and 8 = least important variable. Number of respondents was 128.

Table 2. Location preference for classes (percentages).

Respondent	Sample Size	All Classes in Living Complex	All Classes in Same Building	One or Two Classes in Different Buildings	Each Class in Different Building
Freshman	151	20.5	2.0	47.0	30.5
Sophomore	108	17.6	3.7	42.6	36.1
Junior	85	11.8	1.1	56.5	30.6
Senior	41	17.1	17.1	46.3	19.5
Graduate	49	8.2	46.9	38.8	6.1
All	434	16.4	8.7	46.7	28.2

Table 3. Destination preference for between-class breaks of 1 hour (percentages).

Respondent	Sample Size	Return to Living Area	Remain in Class Area	Go to Department Library	Go to Main Library	Other[a]
Freshman	152	80.0	7.2	3.3	3.7	5.8
Sophomore	110	72.5	10.9	4.5	3.1	9.0
Junior	85	72.0	4.7	5.9	4.6	12.8
Senior	41	53.0	9.7	14.6	0.8	21.9
Graduate	49	18.4	6.1	24.4	18.5	32.6

[a]Including the Union Building and International Center.

Respondent	Scheduled	Random	Sample Size
Riders	18.0	82.0	126
Nonriders	31.8	68.2	226

Those data indicate the preference for random scheduling as opposed to the more orthodox behavior model of scheduling by departure time. However, the following data indicate that scheduling behavior is strongly dependent on the headway between bus runs: The percentage of individuals going to meet a particular schedule substantially changes if the headway increases from 8 to 15 min. This is reasonable because a rational model would predict that a person would shift his behavior to meeting a given timetable when the expected waiting time for random scheduling exceeds the time buffer normally allowed in meeting a particular bus schedule.

Frequency (min)	Scheduled	Random	Sample Size
15	76.1	23.9	21
7.5 to 8	31.5	68.5	130
4	24.5	75.5	200

In this case, the largest percentage of respondents felt that it was necessary to allow 5 min to meet a specific bus schedule. If the expected waiting time on a random basis were half of the headway, then 10-min headways would be the point where most individuals feel it prudent to begin to meet a schedule.

In summary, the users expect the MAC transit system to provide them with the flexibility they need to schedule classes throughout the campus and to travel from academic to living areas with a minimum of delay. The users are more concerned about headways and being able to board the first bus that arrives than about softness of seats, cleanliness of buses, crowding, and strictly punctual service. Although economy is important, the users are willing to pay for the service if it is convenient and frequent and if it meets their needs. The students would also like to have buses available so that they could charter them for special events such as ball games, ski trips, and tours during quarter break.

ADMINISTRATIVE EXPECTATIONS OF THE MSU BUS SERVICE

At MSU the bus service is planned by the university administration that is also directly responsible for its operation and for the formulation of transit system objectives. Because there are only a small number of persons involved in the planning and management of the transit system, administrative views and attitudes were obtained by extensive discussion and in-depth interviews rather than by quantitative methods.

To understand the administrator's perspective, it must be remembered that the original mandate given to the bus system was the product of the special ad hoc Faculty-Student Motor Vehicle Committee appointed to find some method of solving traffic and parking problems. The committee recommended the bus system primarily as a means of implementing its numerous recommendations for restricting the use of automobiles on campus and of determining who should be allowed driving privileges. In view of these facts, the bus system recommendation was implemented, and its purpose was understood to be the reduction of parking and traffic problems on the campus. The university definitely does not view itself as being in the bus business and certainly not in competition with any of the private for-hire carriers.

In fact, there is some disagreement among the administrators as to whether the bus service is actually needed at all. One point of view questions whether the system ever should have been established because the living-learning centers were designed to minimize travel on campus, and special parking and driving permits are available for the physically handicapped. Most administrators feel that there should be some form of transit service on campus to allow students greater flexibility, but they point out that this is merely another support service like the food, laundry, and lawn-mowing services and that the university should make stringent efforts to control its expenditure in this and all support services. Although the bus service is a small item when compared to dormitories, classrooms, and research equipment, the administrators are anxious not to let the bus system use any funds that should more appropriately be spent on research and teaching—the true raison d'être of the university. Consequently, the administrative planners are anxious to control any unnecessary growth or empire building in the bus service just as they would in any other overhead service.

Because the bus service is in operation and at the present time self-supporting, most university administrators feel responsible for controlling costs and running the system in a professional manner. They encourage the operations personnel to keep the buses clean, to adhere strictly to published schedules, to serve all points on campus, to check bus passes, to obey safety rules, to control crowding, and to wear clean uniforms. They urge operations managers to have drivers reprimanded if buses are too crowded (unsafe), if they wait for straggling students (unnecessary delay of schedule), or if drivers talk to the students while the bus is in motion (unsafe). The drivers are constantly reminded that they are providing a "professional transit" service for the university and that they should not cater to the needs of individual riders.

Costs are controlled through a carefully administered preventive maintenance and safety program and by the effective scheduling and routing of equipment. Daily ridership counts are examined regularly so that load factors can be carefully controlled. If there are too many standees, additional buses are added; if ridership declines, then fewer buses can be used to supply the required number of seat-miles. Although there is some concern about the users of the transit service, most attention is given to the connection of all major campus locations, load factors, location of bus stops, and other MAC and cost-oriented considerations.

EFFECT OF CONFLICTING PERSPECTIVES

The MSU bus system apparently provides a valuable service to the on-campus students who live in the remote dormitory complexes: Fifty percent of the males and 75 percent of the females in those areas purchase quarterly bus passes at $14 to $20 per quarter. The off-campus residents also recognize the advantages of the bus transit system, having made many (fruitless) requests to the administration for service to off-campus fraternities, sororities, and apartments. As a consequence, 47 percent of the student body who would appear a priori to have the greatest need for bus service because they live farther from campus (Figs. 1 and 2) are denied bus service because they do not live in the university-supplied dormitories. That denial of service is difficult to understand from the students' point of view because the bus service could be provided without additional expenditures if some of the buses were scheduled to make the off-campus runs instead of merely circling the campus during class when there is little demand for service (Fig. 4). The potential users could also argue that there are many buses available that are not even scheduled for operation at the present time (Table 5).

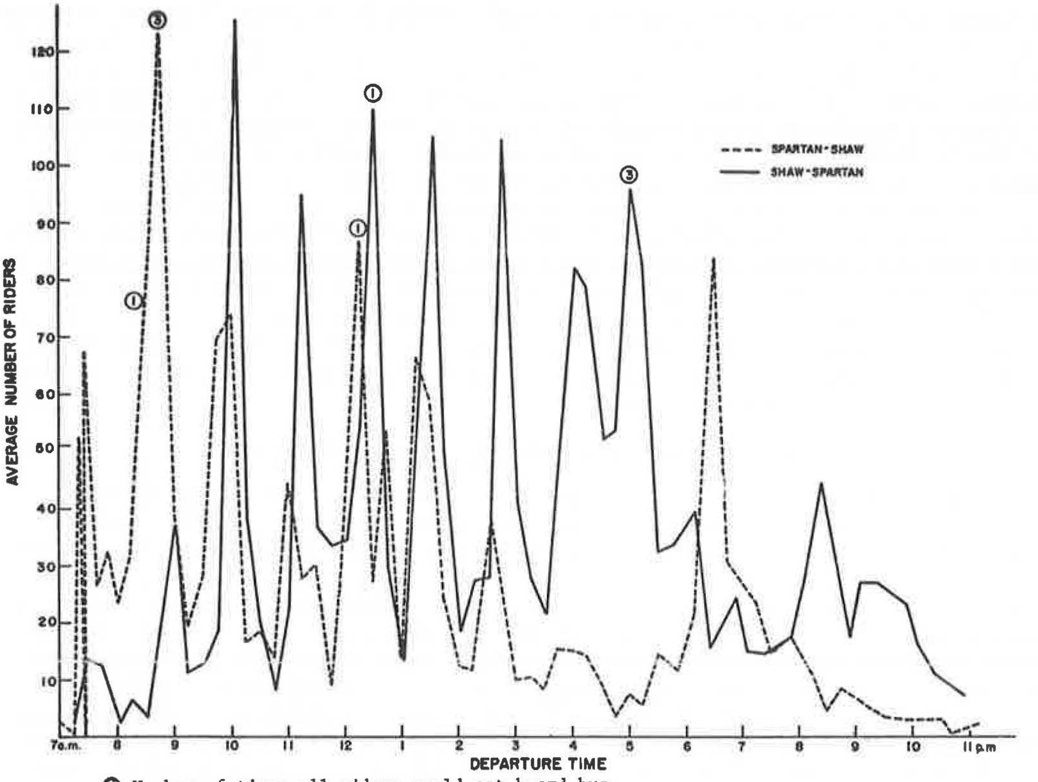
However, the denial of service to students living off-campus is logical if examined from the administrative planner's point of view. First, the university is not anxious to expand this overhead service because the off-campus students are not currently posing parking and traffic problems. (Those students usually walk or park their cars in a peripheral lot.) Second, the university does not want to compete with city transit, taxi cabs, or other private for-hire carriers. Third, the service would not further the research or educational functions of the university. Fourth, and perhaps most important, off-campus service might encourage the migration of students away from university-owned housing and further decrease living-learning center usage to the point that dormitory rents would no longer cover the construction bond expense.

The offering of charter service also points out the conflict in perspectives. There are groups of students who would like to charter buses to out-of-town activities and sporting events but are unable to do so because of the university's policy of offering charter services only to billable departments within the university. From the administration's point of view, this is a logical denial because additional charter service seems to them an unnecessary proliferation of university services and one that would

Table 4. Service preference (percentages).

Item	Sample Size	Strict Punctuality	Serve Everyone	Limit Crowding
Respondent				
Riders	124	16.9	68.5	14.6
Nonriders	308	33.1	55.5	11.4
All	432	28.5	59.3	12.2
Frequency, min				
15	28	35.6	53.6	10.8
7.5 to 8	160	30.6	57.5	11.9
4	243	25.9	61.3	12.8

Figure 4. Bus ridership on inbound and outbound routes.



Number of times all riders could not board bus.

Table 5. Utilization of MSU bus system, 1969-1970.

Season	Number of Buses Owned	Number of Buses Leased	Service Period	Service Hours	Weekly Bus-Hours Available	Weekly Bus-Hours Scheduled	Utilization (percent)
Fall	23	2	a. m.	5	625	460	73.5
			p. m.	6	750	515	68.6
			Night	5	625	125	17.3
			Weekends	16	800	128	16.0
			Total		2,800	1,228	42.3
Winter	23	5	a. m	5	700	585	83.7
			p. m.	6	840	615	73.1
			Night	5	700	130	18.6
			Weekends	16	896	128	14.3
			Total		3,136	1,458	46.5
Spring	23		a. m.	5	575	335	58.3
			p. m.	6	690	380	55.0
			Night	5	575	117.5	20.4
			Weekends	16	736	128	17.4
			Total		2,576	960.5	37.2
Summer	23		a. m.	5	575	75	13.0
			p. m.	6	690	90	13.0
			Night	5	575	0	0
			Weekends	16	736	0	0
			Total		2,576	165	6.4

almost certainly cause conflicts with the private for-hire carriers who feel that the tax-exempt university is unfairly competing with them.

The potential user might point out, however, the system profits would have been reduced by 68 percent if, during the 5 years the buses had been in operation, the current level of charter service had not been provided. During the 1967-69 period, the service would have operated at a loss without the revenue from the current level of charter operation. Thus, the potential user would argue that both the students and the university would benefit financially if charters were aggressively solicited so that the greater use of drivers and equipment would lower the costs of quarterly bus passes or the university contribution or both.

There are also differences between the users and the planners concerning operational emphasis. The users desire a frequent service between remote living areas and the center of campus, high interval reliability, and friendly drivers. They are not concerned with a service connecting all parts of the university nor a shuttle service within the academic area with timetable punctuality, clean buses, soft seats, controlled crowding, and other factors that the administration feels to be part of a professional operation.

Until now the MSU transit system has been operating under virtually ideal conditions. There has been a very strong demand for its services, congestion has been eliminated through regulation, automobile competition is nonexistent because students cannot have cars on campus, the transit system pays no taxes or user charges, equipment is new and in excellent condition, and the demand is stable with 8 to 12 class-break peaks instead of the typical diurnal rush-hour peaks. But in spite of these favorable factors, the university transit system seems prone to the same downward spiral of increasing cost and fares and decreasing ridership and service that have plagued the rest of the transit industry. [An earlier report (3) gives a detailed analysis of demand elasticity, operating costs, and revenue.] Through administrative policy the market has been limited to include only on-campus students. As student life-styles change to favor off-campus living, this market has stagnated and may even be decreasing. The demand curve is elastic and highly sensitive to headway changes. Consequently, increasing wages and other operating costs can only lead to higher operating ratios, reductions in service, and decreased revenues. (At the present time, the bus system is operating near unitary elasticity. The very profitable operations of 1964-1969 generated sufficient retained earnings to retire the bus purchase loan. The system is now more than covering out-of-pocket cost. Consequently, the system has not yet been forced to make a decision on management strategy. However, with increasing costs, a fixed market, a unitary demand curve, and highly sensitive service-related demand, it is just a matter of time until a strategy must be developed.)

The university may respond to this dilemma in various ways: (a) It may view the service as unnecessary to the educational and research functions of the university and attempt to reduce service so that the system can remain self-supporting. This would almost certainly increase the ever-familiar downward spiral of increasing costs and fares and decreasing service and ridership until it is eventually "proved" that the service is no longer needed. (b) It may view the service as necessary "to facilitate the educational and research functions of the university" and decide to maintain a given level of service even if it must be subsidized from the university's operating budget. The subsidy can be justified by the saving in parking facilities required as a cost of stemming the tide of off-campus migration from university-owned housing. (c) It may become user-oriented with changing routes, schedules, and service to reflect the changing preferences and life-styles of the students. To follow this strategy, the university would have to begin to feel that it is in the bus business and would attempt to serve student needs even if that conflicts with other MAC goals such as the complete occupancy of university dormitories.

CONCLUSIONS

1. The success of MAC transit depends not so much on public acceptance of transit as on public acceptance of the MAC infrastructure that the transit system supports.

For example, the success of the MSU transit system is largely determined by the student acceptance of the on-campus living complexes that the transit system currently serves.

The success of MAC transit depends on its raison d'être as perceived, consciously or unconsciously, by its planners and managers. Consequently, the success of MAC transit cannot be judged simply by ridership or profitability but must be evaluated by how well it accomplishes its purpose. In the MSU case, the cost-benefit analysis could consider the transit system successful if the required subsidies were less than the dormitory rental income obtained from students who would otherwise have migrated to off-campus living areas.

3. The purpose of the MAC transit system may be different from the purpose of the MAC itself. The purpose of the university is to provide students and researchers with ready accessibility to a variety of classrooms, laboratories, libraries, and people. The university transit system, however, is used primarily as a commuting service from residence areas to the MAC and not to improve interaction within the MAC. [This conclusion was supported by a study (4) conducted at the University of Tennessee. Although the University of Tennessee is divided into 3 distinctively different academic sectors—the old campus, the new campus, and the agricultural campus—only 30 percent of the bus riders used the bus primarily for a shuttle between classes. The remainder used the bus service primarily to travel from the dormitories or peripheral parking lots to the appropriate academic campus.]

4. MAC travelers, at least in the MSU case, are more interested in a convenient, friendly service than in a formalized, professional service that emphasizes appearance, comfort, and rigid timetables.

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PREDICTING PARK-AND-RIDE PARKING DEMAND

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This study is concerned with the determination of design criteria for prediction of parking demand at park-and-ride facilities in medium-to-large cities in the United States. Ninety-three change-of-mode parking facilities in 10 cities were used in the study. Data were collected through a mail survey. The report includes an analysis of important physical, operational, and locational characteristics of change-of-mode parking facilities experienced by 26 agencies operating 73 rail and 20 bus facilities. The change-of-mode demand is estimated through a prediction equation developed by linear regression analysis. The prediction model was tested for its applicability by using separately supplied data from a committee of the Institute of Traffic Engineers. Input to the model consists mainly of characteristics of the city, the transit system, and the location of the parking facility.

TRANSPORTATION engineers, who have insight into the urban dilemma, have long advocated the design of a coordinated and integrated system. A system that utilizes each different transportation mode where it is most efficient and that provides for a smooth connection among the modes qualifies as a coordinated transportation system. Change-of-mode parking facilities, also known as park-and-ride lots, perform the role of a connecting link between passenger car and transit. The passenger car is used in the collection of the trips in areas of low-density trip ends. At the same time, by increasing the service area of transit stations, change-of-mode parking increases the demand for transit along established travel corridors. Finally, by diverting such demand to locations of lower land use density and lower land value, change-of-mode parking reduces the demand for parking in downtown areas.

PURPOSE AND SCOPE

There were 2 objectives of the study. One objective was to statistically analyze the effect of the physical, operational, and location characteristics of change-of-mode parking facilities on their usage (percentage of lot occupancy). Factors such as the adequacy of the transit system and the metropolitan area characteristics were also included in the analysis.

The second objective was to predict the demand for change of mode. That was achieved by developing a multiple linear regression equation whose independent terms are a measure of the physical, operational, and location characteristics of the parking facilities. An acceptable prediction equation must possess a logical sensitivity, satisfy all statistical constraints, and be easily applied.

DATA COLLECTION

The data collection method was constrained by a limited budget. Therefore, it was necessary to rely on data already collected or easily provided by change-of-mode operators. For that reason, it was decided that a questionnaire should be sent to change-of-mode operators.

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Questionnaire

The change-of-mode demand and a variation therefrom are the dependent variables used in the regression and variance analyses respectively. Therefore, the first part of the questionnaire was concerned with measuring the demand placed on change-of-mode facilities (Fig. 1). The measurement of change-of-mode demand included the determination of the number of park-and-ride vehicles, kiss-and-ride vehicles, and change-of-mode passengers that used the parking facility each day. An average weekday demand was sought. Yearly, daily, and hourly, both peak and nonpeak, variations occur in the demand. Overflow of parking lots takes place, and a knowledge of the extent of the overflow is needed to determine the actual demand for change of mode.

The demand for change-of-mode parking depends on the characteristics of the transit serving the facility. The second part of the questionnaire (Fig. 2) obtained information on the type of transit, headways, fares, travel times, and adequacy of the distribution network at the downtown end of the trip.

The third part of the questionnaire concerned measurements of the physical characteristics of the parking lot (Fig. 3). The adequacy of lighting, egress and ingress, delineation, and pavement condition are considered to be measures of the physical characteristics. The quality of the transit terminal and the walking distance from parked car to transit platform are also necessary measures.

The fourth part of the questionnaire (Fig. 4) measured the operational characteristics of the facility, and the fifth part (Fig. 5) measured the location of the change-of-mode facilities within the metropolitan area. General questions were asked in the sixth part (Fig. 6).

A total of 357 questionnaires were mailed to 60 agencies in 12 metropolitan areas. Information was requested for 134 facilities at which the transfer is to rail and for 36 facilities at which the transfer is to bus transit. Twenty-six agencies replied and gave information concerning 73 rail and 20 bus change-of-mode facilities. As a result of the survey, 190 usable observations are made.

Table 1 gives the number of observations desired and obtained by metropolitan area and type of transit. The percentage of questionnaires that were usable, unusable, and unreturned is as follows:

Condition	Bus	Rail
Usable	50.8	53.9
Unusable	32.8	16.2
Unreturned	16.4	29.9
Total	100.0	100.0

The number of mailed and usable questionnaires per change-of-mode facility is as follows:

Mode	Mailed	Usable
Bus	2.03	1.81
Rail	2.12	2.09
Avg	2.10	2.03

The data were used to analyze change-of-mode demand. That required a minimum of variables so that the significance and reliability of the statistical analysis could be maximized. Therefore, the need for combining the many data items into more representative and comprehensive variables was evident.

Basic Concepts

Two classes of aggregate variables were developed. The first type comprised all data items that were independent of the characteristics of parking lots. The variables thus constituted were considered to behave as parameters when parking lot demand is

Figure 1. Questions relating to demand.

1. What is the average number of park&ride vehicles that use the facility, by year, since the beginning of parking service? (veh/day) SELECT ONE YEAR (DATE ______________) FOR WHICH YOU ARE SUPPLYING ANSWERS TO THE QUESTIONS THAT FOLLOW.	______ 1st year ______ Date ______ 2nd year ______ 3rd year ______ 4th year ______ 5th year ______ 6th year ______ 7th year ______ 8th year ______ 9th year ______ 10th year ______ present
2. What is the average number of park&ride vehicles that use the facility?	______ (veh/day)
3. What is the average number of kiss&ride vehicles that use the facility?	______ (veh/day)
4. What is the average number of transit passengers that transfer from atuo?	______ (persons/day)
5. What is the average number of transit passengers that board at facility?	______ (persons/day)
6. What is the average number of transit passengers that board at facility, by day of the week? (persons/day)	______ Monday ______ Tuesday ______ Wednesday ______ Thursday ______ Friday ______ Saturday ______ Sunday
7. What is the proportion of morning peak park&ride vehicle arrivals to total vehicle arrivals within an average day?	______ %
8. Is there any indication that a substantial number of transit passengers park outside the parking facility? If answer is yes, please give proportion of outside to inside parked vehicles.	O ..... Yes O ..... No ______ %

Figure 2. Questions relating to transit service.

1. What is the type of the transit system being served by parking facility?	O ..... bus O ..... rail
2. What is the average headway between transit vehicles serving facility during peak periods?	______ min.
3. What is the transit fare from facility to downtown of metropolitan area?	______ cents
4. What is the overall travel time by transit, from facility to downtown of metropolitan area?	______ min.
5. What is the proportion of jobs in the downtown area (as compared to other cities) that is reached, within acceptable walking distance, by the transit system being transferred to?	O ....high O ..... average O ....low

Figure 3. Questions relating to physical characteristics.

1. What is the lighting condition at the parking facility?	O..... good O..... adequate O..... poor O.......... none
2. Is the facility well enclosed with adequate entrances and exits?	O..... yes O..... fair O..... no ____ exits ____ entrances
3. Under what category does the transit terminal fall?	O...... Luxurious building O....... adequate building O...... sheltered platform O........... platform only
4. Under what category does the facility pavement fall?	O ..... well paved with markings O .... treated surface O .... gravel
5. What is the average walking distance from facility parked cars to transit platform?	____ feet

Figure 4. Questions relating to operational characteristics.

1. Does the facility include any kiss & ride stalls? If answer is yes, please give number.	O..... yes O...... no ____ stalls
2. Does the facility have any bus berths? If answer is yes, please give number of regular buses that stop at these berths.	O..... yes O...... no ____ buses/peak hour ____ berths
3. How many hours within the day is the facility operational?	____ hours
4. How many days within the week is the facility operational?	____ days
5. How would you classify the maintenance level provided at the facility?	O..... Good O..... Adequate O..... Poor O.......... None
6. What is the parking charge at facility?	____ cents/hour ____ dollars/day
7. How many park&ride stalls are there at the facility?	____ stalls
8. Does the facility have any attendants? If answer is yes, please give number of attendants.	O ..... yes O ..... no ____ attendants
9. Is the parking facility operated for the sole use of the transfer passengers? If answer is no, please indicate the nature of the other usages.	O..... yes O..... no ____

Figure 5. Questions relating to location of facility.

1. What is the major land use type in which the parking facility is located?	○ ..... Resd'l ○ ..... Res+Ind ○ ..... Comm'l ○ .... Ind'l ○ .... Rs+Com ○ ..... Rs+Ind+Com
2. What is the aerial distance from facility to downtown center of metropolitan area?	______ miles
3. What is the aerial distance from facility to nearest competitive facility?	______ miles
4. What is the aerial distance from facility to next lower transit fare zone?	______ miles
5. What is the distance from main facility entrance to major highway arterial access?	______ blocks
6. What is the name of this major highway arterial access?	______
7. What is the ADT of this major highway arterial access?	______ Vpd
8. How many lanes does this major highway arterial access have?	______ lanes
9. How visible is the facility from its major highway arterial access?	○ .... quite visible ○ .... slightly visible ○ ....Info. signs are posted ○ .... not visible

Figure 6. General questions.

1. Who owns the parking facility?	______
2. Who operates the facility?	______
3. Are transfers between transit systems and/or lines allowed in metropolitan area served? If answer is yes, please give the charge for such transfers.	○ ..... yes ○ ..... no ______ cents
4. Does the transit system being transferred to at the facility have more than one fare zone? If answer is yes, please give number.	○ .....yes ○ ..... no ______ Fare zones
5. What is the average overall travel speed within metropolitan area, by type of transit?	____ Mph ____ Transit type ____ Mph ____ Transit type ____ Mph ____ Transit type
6. How would you classify the parking condition in the downtown of metropolitan area served by facility?	○ .... Intolerable ○ .... Problematic ○ .... Worrisome ○ .... little to worry
7. At what distance from downtown, along arterial corridors, would you estimate the traffic to become heavily congested during the morning peak period?	______ miles

predicted. Three aggregate variables were in this category: transit service rating, metropolitan area rating, and parking facility location rating.

The variables that measure the parking lot characteristics made up the second class. Successful change-of-mode design criteria were developed by finding those values of this class that optimized the savings that accrue to the community. The 5 variables that were developed are facility safety rating, rating for physical quality of facility, facility reliability rating, facility flexibility rating, and facility parking fee rating.

Each aggregate variable was made up of a combination of data items (factors). Once an item was included in the formulation of a variable, it did not enter in the formulation of any other. Data items were combined in an additive manner or a multiplicative manner or a combination of both. The decision to add or to multiply the effect of different factors was intuitively based on the manner in which a commuter would combine the factors in the process of choosing change of mode over passenger car.

To each of the factors that made up a given aggregate variable was attached an average rate that measured its relative influence in the decision-making process of a commuter trying to choose between change of mode and passenger car. It is worth noting that, at this stage, there was no need to worry about the relative importance of variables because an additive regression model was to be developed eventually.

A set of discrete levels was formulated in order to measure the variation within factors. For each factor, a different rate was attached to each of its levels. For any given factor, the rates of its levels varied around its previously assigned average relative rate.

In this manner many qualitative (discrete) and quantitative (continuous) factors were combined to create a smaller number of mainly integer-valued variables. It should be noted that the whole process of rating the different factors and their levels and of combining factors was based on subjective engineering judgment. That judgment is based on an exhaustive evaluation of the previous literature in the field of modal split and on a study of commuter decision-making considerations.

A variable that measures some of the characteristics of a parking facility requires that a unique solution be obtained for those parking lot characteristics once a value is assigned to that aggregate variable. If an economically optimal set of values for all such variables were found, then it would be possible to determine all the associated parking lot characteristics. The lot characteristics thus determined were the design criteria we sought.

Sample Development—Transit Service

The reason for this choice is that the transit service rating was found to be significant in both the analysis of variance and the regression analysis. Also, this aggregate variable involved the combination of factors by both addition and multiplication and comprised discrete and continuous factors.

The transit service rating is made up of the following factors: (a) quality of station terminal building, (b) transit fare to the downtown, (c) overall corridor travel speed of transit, (d) proportion of downtown jobs easily reached by the transit being transferred to, (e) availability and cost of transfer within transit system, (f) number of transit fare zones, and (g) ticket marketing and collection methods.

Factors e through g are measures of the flexibility of the transit system available at the change-of-mode parking facility. A commuter will define flexibility as the addition of these 3 factors.

The transit service rating is given by Eq. 1.

$$\text{Transit service rating} = (\text{station terminal building} + \text{transit fare}) + (\text{transit speed} \times \text{transit flexibility}) \quad (1)$$

Equation 1 implies that

1. The effects of transit speed and flexibility are multiplicative as far as the commuter is concerned; and

2. The commuter's sense of aesthetics (quality of terminal), his cost considerations (out-of-pocket transit fare), and his comfort and convenience (transit speed and flexibility) are additive.

The 7 factors that combine to describe the transit service were each subdivided into discrete levels. A rate was assigned to portray the influence of every level in the commuter's decision-making process. The levels and their associated rates, which are given in Table 2, require some explanatory remarks.

First, the average rates for quality of terminal, for transit fare, and for transit flexibility (sum of the last 3 factors) are all equal to four. This fact implied that the 3 factors have an equal influence on choice of mode.

Second, the average rate for transit speed is equal to 12 and to the sum of the average rates of all other factors. Modal-split models have all recognized the importance of speed, and the rate assignment stated above takes that importance into account. The implication of such rate assignments is that transit speed is as important to the commuter as the sum of all other factors. In other words, a decrease in the transit speed level if accompanied by a comparable increase in the level of all other factors will not change the decision of a commuter choosing between change of mode and passenger car because the transit service rating will be unchanged.

Third, the transit service improves with an increase in the quality of the station terminal, a decrease in the transit fare, an increase in overall transit travel speed, an increase in the proportion of CBD jobs easily reached by transit, the availability of low-cost transfers, the existence of more than one fare zone, and an increase in the quality of ticket marketing and collection methods.

As an example, a transit service rating is computed for a change-of-mode parking facility that has the following factors:

1. Adequate station terminal at the change-of-mode lot;
2. Transit fare of 40 cents or 6.67 cents/mile (the station is 6 miles from the central business district);
3. Transit travel time from station to downtown of 16 min, a peak headway of 5 min, and an overall travel speed of 19.5 mph;
4. Transit distribution network in the downtown area easily in reach of a low proportion of jobs;
5. No transfers within the transit system;
6. Two fare zones in the transit system; and
7. Good ticket marketing and collection methods.

Rates for these factors (Table 2) are 4, 3, 9, 1, 0, 1, and 1. Combining these rates according to Eq. 1 gives

$$\text{Transit service rating} = (4 + 3) + (9 \times 1 + 0 + 1 + 1) = 34$$

Seven factors were combined to obtain an integer-valued variable that will be used to predict change-of-mode parking demand. Methods used in developing the remaining aggregate variables (i.e., the factors involved in each variable and the levels and associated rates for each factor) are also given in Table 2 and shown in Figure 7. The equations used to combine the factors into aggregate variables are given below. Table 3 gives the results of the modeling technique.

$$\begin{aligned}\text{Transit service rating} = {} & (\text{station terminal building} + \text{transit fare}) \\ & + (\text{transit speed} \times \text{transit flexibility})\end{aligned} \quad (1)$$

$$\begin{aligned}\text{Metropolitan area rating} = {} & \text{transit speed} + \text{CBD parking congestion} \\ & + \text{radial highway congestion} \\ & + \text{metropolitan area population}\end{aligned} \quad (2)$$

Table 1. Questionnaires mailed, returned, and usable.

Metropolitan Area	Mailed		Unreturned		Returned		Unusable		Usable	
	Bus	Rail	Bus	Rail	Bus	Rail	Bus	Rail	Bus	Rail
Milwaukee	13	—	—	—	13	—	—	—	13	—
Baltimore	3	—	—	—	3	—	—	—	3	—
Washington	35	—	—	—	35	—	21	—	14	—
New York	2	59	—	23	2	36	—	32	2	4
Chicago	2	99	2	54	—	45	—	12	—	33
Pittsburgh	—	5	—	—	—	5	—	—	—	5
Cleveland	4	44	2	—	2	44	2	—	—	44
Miami	6	—	6	—	—	—	—	—	—	—
Boston	6	57	—	—	6	57	1	2	5	55
Philadelphia	—	14	—	8	—	6	—	—	—	6
Toronto	—	6	—	—	—	6	—	—	—	6
Newark	2	—	2	—	—	—	—	—	—	—
Total	73	284	12	85	61	199	24	46	37	153

Table 2. Factor ratings.

Variable	Factor	Level	Rate
Transit service	Quality of transit station terminal	Transportation center with extra services	10
		Luxurious	7
		Adequate	4
		Shelter	2
		None	1
	Transit fare to CBD, cent/mile	< 4	5
		< 4 ≤ 6	4
		< 6 ≤ 10	3
		< 10 ≤ 20	2
		> 20	1
	Transit overall speed, mph	≥ 30	24
		≤ 20 < 30	15
		≤ 15 < 20	9
		≤ 10 < 15	6
		< 10	3
	Proportion of CBD jobs reached by transit	High	4
		Average	2
		Low	1
	Transfer availability, cost within transit	Available, 10 cents and less	1
		Not available, or available and more than 10 cents	0
	Transit fare zones, more than one	Yes	1
		No	0
	Ticket marketing and collection methods	Innovative	2
		Good	1
		Adequate	0
Metropolitan area	Representative transit speed in metropolitan area, mph	< 20	10
		< 15 ≤ 20	6
		< 10 ≤ 15	4
		≤ 10	2
	Condition of parking in CBD	Intolerable	5
		Problematic	3
		Worrisome	2
		No worry	1
	Distance from CBD where heavy congestion starts, miles	< 8	8
		< 5 ≤ 8	6
		< 3 ≤ 5	4
		≤ 3	2
	Metropolitan area population, $\times 10^6$	< 2.5	9
		< 1.0 ≤ 2.5	6
		< 0.5 ≤ 1.0	3
		≤ 0.5	1
Facility location	Distance to lower fare zone, miles	< 5	5
		< 2 ≤ 5	3
		< 1 ≤ 2	1
		≤ 1	0
	Distance to nearest competitive facility, miles	< 5	3
		< 2 ≤ 5	2
		< 1 ≤ 2	1
		≤ 1	0
	Distance to highway access, blocks	< 2	3
		≤ 2 < 5	2
		≤ 5	1
	Width of highway access, lanes	> 4	6
		4	3
		< 4	1

Table 2. (continued).

Variable	Factor	Level	Rate
Facility location (continued)	Visibility of facility from access	Quite visible	3
		Slightly visible	2
		Information signs are posted	1
		Not visible	0
	Distance from facility to CBD, miles	< 16	10
		< 12 ≤ 16	8
		< 8 ≤ 12	6
		< 4 ≤ 8	4
		< 2 ≤ 4	2
		≤ 2	0
	Surrounding land use type	Res.	6
		Res.-Comm.	4
		Comm.	3
		Res.-Ind.	2
		Res.-Ind.-Comm.	1
		Ind.	0
	Surrounding residential density, 10^3/sq mi	< 22	7
		< 16 ≤ 22	5
		< 10 ≤ 16	3
		< 4 ≤ 10	1
		≤ 4	0
Facility safety	Condition of lighting in facility	Good	3
		Poor	2
		Fair	1
		None	0
	Availability of enclosures, number of gates/200 stalls	Yes, > 1	3
		Yes, ≤ 1	2
		Fairly enclosed	1
		None	0
Physical quality	Type of pavement at facility	Paved, marking, and landscaping	8
		Paved and marking	6
		Treated surface	4
		Gravel	2
	Avg walking distance from facility to station, ft	< 300	4
		≤ 300 < 500	3
		≤ 500 < 700	2
		≤ 700	1
Facility flexibility	Agency type of facility owner	Transportation or planning or both, public or private	2
		Other	1
	Agency type of facility operator	Same as transit operator	2
		Different from transit operator	0
	Proportion of kiss-and-ride stalls to total stalls, percent	< 6	8
		< 3 ≤ 6	4.5
		< 1 ≤ 3	2.0
		< 0 ≤ 1	0.5
		0	0.0
	Availability of connecting bus lines	Yes	10
		No	0
Facility reliability	Days/week operated	7	2.0
		6	1.0
		≤ 5	0.4
	Hours/day operated	< 20	2.0
		≤ 12 ≤ 20	1.0
		< 12	0.4
	Attendant availability, number/200 stalls	Yes, < 1.5	10
		Yes, < 0.5 ≤ 1.5	5
		Yes, ≤ 0.5	2
		No	0
	Maintenance quality	Good	5.0
		Adequate	2.5
		Poor	1.0
		None	0
Facility parking fee	Dollar/day	0.00	6
		< 0.00 ≤ 0.20	4
		< 0.20 ≤ 0.50	3
		< 0.50 ≤ 1.00	2
		< 1.00	1
Years from start	Years from polling to start of operation	≤ 1	0
		≤ 2 ≤ 6	1
		≤ 7	2

Facility location rating = (distance to fare zone x distance to competition)
+ (distance to access x width of access)
+ visibility from access + distance to CBD
+ (surrounding land use type + residential density) (3)

Facility safety rating = facility lighting + availability of enclosures (4)

Physical quality rating = pavement type + walking distance (5)

Facility flexibility rating = (agency type of owner x agency type of operator)
+ availability of bus berths
+ proportion of kiss-and-ride stalls (6)

Facility reliability rating = days of operation + hours of operation
+ availability of attendants + maintenance quality (7)

PARKING LOT USAGE

This section reports on the procedure employed and the findings of the analysis of variance for the effect of the aggregate variables on change-of-mode parking lot usage. The analysis of variance is based on 190 observations made for more than 93 facilities in 10 metropolitan areas.

ANALYSIS OF VARIANCE

The object of the statistical analysis was to study the trends and significance of the effects of the parametric and design variables on the use of change-of-mode parking lots. It should be understood that the use of a lot measures its success in attracting change-of-mode parkers.

The 28 two-way classifications analysis of variance was performed at the Purdue University Computer Science Center. UNEQUAL is the name of the statistical computerized library program that was used to build the analysis of variance tables.

Tables 4 and 5 give the results of all 28 ANOVA tables. Table 4 gives the main effects of the ratings; the variables are the same as those given in Table 3. The values given in both tables are the ratios of the computed F's and their associated 0.1 critical F's. Values of 1.00 and more, for this ratio between F's, imply that the computed F is equal to or larger than the critical F. Under such circumstances the hypothesis of nonsignificance is rejected. When the ratio between F's is smaller than one, then the hypothesis of nonsignificance cannot be rejected.

The result of the analysis of variance led to the following conclusions. (Tables 4 and 5 should be referred to as the conclusions are read.)

1. The main effects of the metropolitan area rating are significant in all of the 7 cases in which they appear. The same applies in the case of the facility safety and the facility reliability ratings. These 3 factors do affect the usage of change-of-mode parking lots.

2. The main effects of the facility location rating are always found to be not significant. Four possible reasons could explain this finding. First, the modeling of the location rating could be inadequate; second, the location rating interacts to a high degree with other factors; third, the location rating truly does not affect the usage of parking facilities; or, fourth, and most likely, a high percentage of the transit facilities reporting had very good locational characteristics, which provide low variation in the location rating. Variables with low variation are generally found to be not significant.

3. The main effects of the remaining ratings (transit service, physical quality, flexibility, and parking fee) are found to be significant in more than half of the cases in which they are involved. The data seem to suggest that these factors significantly affect the use of change-of-mode parking facilities.

Figure 7. Residential density as function of location within city and metropolitan size.

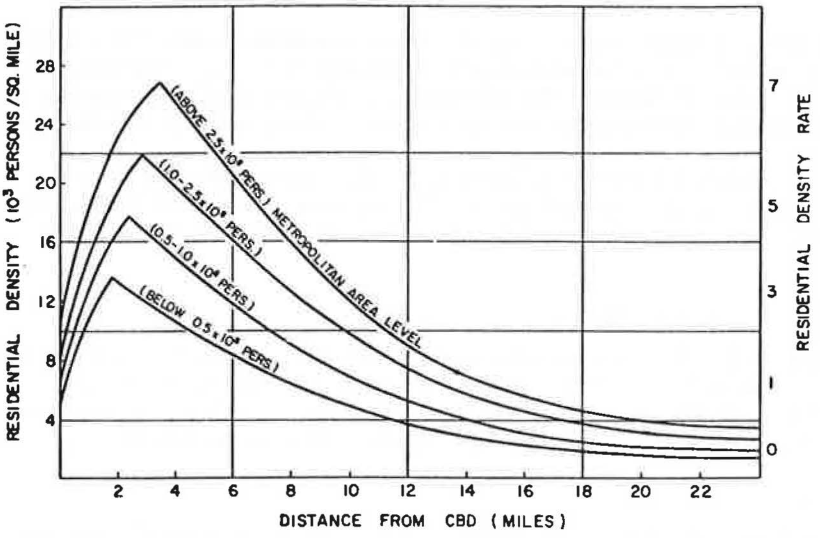

Table 3. Summary of aggregate variables.

	Theoretical Range		Sample Range		Sample Average	
Variable	Min	Max	Min	Max	ANOVA	Regression
Transit service	5	212	14	99	48.30	48.32
Metropolitan area	6	32	14	30	22.78	21.61
Facility location	0	88	6	64	33.83	34.21
Facility safety	0	6	1	6	4.03	3.74
Physical quality of facility	3	12	6	10	8.92	9.22
Facility flexibility	0.0	22.0	0.0	18.0	5.23	6.48
Facility reliability	0.8	19.0	3.0	17.0	6.61	5.85
Facility parking fee	1	6	2	6	4.28	4.40

Table 4. Ratio of computed and critical F for main effects of ratings.

Associated Variable	Variable: T	M	L	S	Q	F	R	P
T		4.78	0.90	1.58	1.11	5.30	2.06	1.69
M	0.33		0.56	3.26	0.74	2.13	3.78	0.22
L	1.73	8.21		2.78	1.47	1.32	5.15	2.38
S	0.35	2.69	0.30		2.32	2.43	4.49	1.39
Q	0.69	3.50	0.33	5.09		2.63	6.43	1.12
F	1.38	7.95	0.60	3.48	1.26		7.35	2.41
R	1.06	3.99	0.18	1.12	0.63	0.78		0.14
P	1.43	2.28	0.41	3.16	0.79	2.32	4.27	

Table 5. Ratio of computed and critical F for interactions among ratings.

Second Variable	First Variable: T	M	L	S	Q	F	R	P
T		1.47	1.58	0.87	1.85	0.66	1.46	1.95
M	1.47		0.79	1.41	0.65	0.01	0.93	1.80
L	1.58	0.79		1.07	1.10	1.35	0.98	0.11
S	0.87	1.41	1.07		2.79	0.49	0.99	2.36
Q	1.85	0.65	1.10	2.79		0.03	0.71	0.59
F	0.66	0.01	1.35	0.49	0.03		1.68	1.88
R	1.46	0.93	0.98	0.99	0.71	1.68		0.99
P	1.95	1.80	0.11	2.36	0.59	1.88	0.99	

4. Most of the interaction terms that contain the transit service rating, the location rating, or the parking fee rating are found to significantly affect the use of parking facilities. These findings seem to indicate that the extent to which a facility is used is based on combining these 3 factors with the design factors (safety, quality, flexibility, and reliability).

5. The large number of effects that were found to be significant indicates that the change-of-mode phenomenon is quite complicated. The fact that most main effects are significant tends to give credence to the modeling technique that was used to develop ratings.

PARK-AND-RIDE DEMAND

This section reports on the development of a multiple linear regression equation to predict the change-of-mode demand. This equation would apply in all metropolitan areas of the continental United States and for the forseeable future as long as no major changes occur in present travel and traffic trends, based on the sample taken.

Procedure of Analysis

In the absence of an established theory regarding change-of-mode demand, one can only assume a model form. One of the possibilities is an additive model. Therefore, one should view the linear equation as only an estimate or an approximation until further evidence is available.

A regression equation was developed to predict the number of park-and-ride vehicles. The equation was later tested to see whether it satisfied the statistical constraints placed on the error term in the regression model. The Bartlett test for homogeneity of variance was used to test for both normality and independence. The Bartlett test produced a high chi-square, indicative of the fact that the equation violated its inherent constraints. For this reason, the dependent variable was mathematically transformed into its square root, and the whole process was repeated.

Prediction Equation

The discussion that follows reports on the chosen park-and-ride demand prediction equation. The statistical qualities of the equation are given, and comments are made on the makeup of the equation. Also, both sensitivity and applicability analyses were performed, although only the application is reported.

Results

Equation 8 is the chosen prediction equation.

$$\sqrt{D} = -0.70479 + 0.00940\ Z + 1.96438\ B + 1.21122\ R + 0.00088\ T^2 + 0.00867\ M^2 + 0.04868\ F \cdot P - 0.01929\ T \cdot R \qquad (8)$$

where

D = number of park-and-ride vehicles that use a facility during a 24-hour period;
Z = number of stalls within a change-of-mode parking facility;
B = type of transit being transferred to at the facility (bus on highway right-of-way = 0, and rail and bus on exclusive right-of-way = 1);
R = reliability rating of the change-of-mode parking facility;
T = transit service rating at the change-of-mode parking facility;
M = metropolitan area rating for the change-of-mode parking facility;
F = flexibility rating of the change-of-mode facility; and
P = parking fee rating of the change-of-mode facility.

Table 6 gives the statistical qualities of the chosen prediction equation. Equation 8 explains 78 percent of the variation in the park-and-ride demand and has a multiple correlation coefficient of 0.88. All the independent variables are significant at the 95 percent level, and all but one are significant at the 99 percent level. The equation on the whole, with an F-ratio of 44.2, is significant at a much higher rate than 9,995 in 10,000. The standard error of the estimate is equal to 2.93, which implies that the 95 percent confidence interval of an estimate is from 56 to 369 parked vehicles/day.

The chosen equation was tested for homogeneity of variance by using the Bartlett test. A chi-square equal to 5.81 was obtained with 4 degrees of freedom. Because the critical chi-square at the 10 percent level (7.78) is larger than the computed one, the hypothesis of homogeneity of variance and normality of the error term is accepted.

Two of the design ratings did not enter into the prediction equation. The safety rating had a high correlation with the reliability rating, and the physical quality rating was substantially correlated to the parking fee rating. Both the reliability and the parking fee ratings affected the park-and-ride demand more significantly, and once in the equation they barred the entry of the latter two.

Application Test

At this point, a check on the ability of the regression equation to predict the park-and-ride demand seemed appropriate. For this purpose, the data from the Institute of Traffic Engineers survey were used to test how well the equation predicted the number of parked vehicles at a change-of-mode lot. Of the 179 facilities that the ITE surveyed, only 9 were used. The remaining 170 facilities either coincided with data collected and previously used in developing the equation, did not contain the necessary information to compute the independent variables, or had a demand that exceeded the supply.

The applicability of the prediction equation was tested by 2 different methods. The first test was on the hypothesis that the mean difference between estimated and measured park-and-ride demand is equal to zero. The student-t test was used to either accept or reject the hypothesis. Table 7 gives the observed and estimated park-and-ride demand and the difference between them for the 9 checked facilities. A student-t of 0.91 was computed by using the paired-comparison difference between observed and estimated demand. The hypothesis that there is no difference between observed and estimated demand is accepted well beyond the 20 percent level. The critical student-t for an α of 0.2 and 8 degrees of freedom is equal to 1.40, which is much larger than the computed one. Because the hypothesis is accepted even at an α of 0.2, this indicates that the probability of accepting when one should reject is very low.

Next, the individual estimates were tested. For this purpose, a least square regression equation was developed for the observed demand; the estimated demand was the sole independent variable. If the individual estimates are equal to the corresponding observed demand, then the equation would have a 0 intercept ($b_0 = 0$) and a slope of 45 deg ($b_1 = 1$). An F-ratio was used to test the hypothesis that the regression equation for the estimated versus observed demand possesses b_0 and b_1 coefficients that are equal to 0 and 1 respectively. Simultaneously, an F-ratio of 1.22 was computed, and the hypothesis is accepted up to the 34 percent level.

In conclusion, an equation that satisfied the statistical constraints that are inherent in a linear regression model has been developed. This equation is also able to reliably predict the park-and-ride demand at different facilities and in different metropolitan areas.

CONCLUSIONS

Statistical evidence indicates that most ratings of the developed characteristics are significant in affecting change-of-mode parking facility usage. An increase in the metropolitan area, facility reliability, and facility safety ratings causes a significant increase in the occupancy of change-of-mode parking facilities.

Because no control over the collected data could be exercised, no clear-cut decision on the effect of the facility safety, facility flexibility, and transit service ratings could be taken. The facility location rating was found to be insignificant in affecting the use of parking facilities.

A study of the park-and-ride demand prediction equation would indicate that all of its independent terms contribute almost equally in estimating the demand. All of the independent terms are positively proportional to the park-and-ride demand. In other words, an increase in the value of any independent variable would result in an increase in the estimate of the demand.

The independent variables that predict the park-and-ride demand are the size of the facility, its flexibility, reliability, and parking fee ratings, and the metropolitan area and transit service ratings associated with the change-of-mode parking facility. Four of the 6 ratings that measure the design characteristics of the parking facility are included in the prediction equation. This fact substantiates the method used in developing the ratings from the survey data. The facility safety and physical quality ratings did not enter the prediction equation because of their correlation with other ratings already included. The fact that two-thirds of the demand estimate is due to parking facility design characteristics points up the importance of these characteristics. Many of the existing methods fail to include these characteristics.

ACKNOWLEDGMENT

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DISCUSSION

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Regional Transit Service has been engaged in the development of a park-and-ride network for about 1½ years. When one attempts to estimate demand for such new service from a new suburban terminal, the lack of an applicable methodology that is comprehensible and useful to an operator in a medium-sized metropolitan area becomes evident. For this reason, the research effort by the authors is needed and appreciated.

Several elements of the paper are clearly commendable from this viewpoint: (a) the attempt to enumerate determining variables for park-and-ride usage; (b) the attempt to develop a methodology for estimating parking usage; and (c) the emphasis of the importance of developing procedures for estimating intermodal transfer. These elements would appear to justify the paper.

However, certain questions must be addressed with regard to the use of the research by an implementing agency. A discussion of the data and data gathering procedure is primary. The basic concepts and the authors' discussion of the variables and factors must be evaluated. Finally, the conceptual development of their hypothesis and their resultant conclusions should be examined in terms of validity.

I am neither a mathematician nor a statistician and am thus not qualified to evaluate the mathematical procedures used. (It should be noted that few implementing agencies, particularly transit operators, have the trained personnel available who could comprehend, or apply, the equations used.) Regional Transit Service, however, now uses 22 shared-use parking lots for 5 park-and-ride routes that have a total of 11 branches and 5 people-generator destinations (2 of which are located in the CBD) and carries approximately 2,500 passengers/day. My comment is, therefore, based on fairly extensive operational experience, though limited to only 1 metropolitan area.

Of primary concern to an operator (beyond the basic comprehensibility) is the reliability of the data collection methodology and the subsequent validity of the data of the work. The questionnaire used to develop data seems to ask highly subjective questions. The questions themselves appear to be based on prior determination by the authors of the important variables. In certain semantic differential questions, a highly subjective evaluation was required of change-of-mode operators. Based on my experience, biased answers that are likely to be barely relevant and reliable may result, but not "hard" data.

Further, response was requested from a very small number of cities of limited geographic and size distribution. Barely more than 50 percent of the responses (particularly for bus transit) were usable. The distribution of the responses, again particularly for bus transit, is even more limited than the original distribution of questionnaires. The extremely heavy emphasis on modal transfer to rail is curious, when one considers that comparatively few metropolitan areas have rail transit. Such emphasis is even more curious when conventional commuter railroad, light-volume rail transit, and heavy-volume subway appear to be considered as the same mode in the questionnaire and subsequent data. These 3 rail modes have greatly different rider characteristics; it is suggested that they cannot be so easily compared and combined in data analysis as the authors imply.

The authors' basic concepts and the subsequent factors and variables, as stated in the paper, must be challenged. Fundamentally, the concept of predicting park-and-ride parking demand as independent of park-and-ride ridership is a questionnable exercise. Although the authors mention access to the parking facility by those who do not travel by automobile, the appropriate emphasis is not given to kiss-and-ride, pedestrian access, car pools, feeder bus service, and even bicycle. Such an omission can greatly reduce the validity of an estimation model and related procedures, for line-haul riders arriving by means other than 1 person-1 car can account for significantly more riders than facility users. In an on-board ridership survey conduced by Regional Transit Service, the question, How do you usually get to the park-and-ride bus stop in the morning? was asked. Figure 8 shows the responses.

The stress on metropolitan and city characteristics (as compared to corridor characteristics) should be disputed. Various corridors of a metropolitan area are likely to possess highly dissimilar characteristics that will lead to erroneous conclusions. For example, the population of a sample metropolitan area, the distance from the CBD where heavy congestion commences, the condition of parking in the CBD, and a representative transit speed—factors used by the authors—can, in certain instances, lead to a very low rating. Yet, microanalysis of a particular corridor within the same metropolitan area can result in a very high rating for that particular corridor. In Rochester, certain radial corridors are highly congested several miles out, yet a parallel route a mile or two away is basically uncongested until a traveler reaches the core of the CBD.

The characteristics of the transit service factors are incomplete and contain several irrelevancies. Basic to the commuter's decision to transfer between modes is the comparability of transit service—bus or rail—to alternative travel modes. The transit service is of primary importance, but only as related to the perceived cost of alternative travel modes. The authors fail to evaluate the importance of the perceived cost of alternative modes, especially such an important out-of-pocket cost as parking fees. The number of fare zones (as differentiated from the authors' transit fare) is relevant only if there is a "nuisance payment"; if the zones are purely administrative boundaries for the development of the appropriate fare levels by the operator, then fare zones lack meaning for the rider and the operator.

Other characteristics that should have been discussed in the paper include the relative comfort of the transit mode; when transit vehicles operate in mixed traffic, that can be crucial, but "merely" important when they operate on exclusive rights-of-way. The headway of the transit service may be important, but it must be related to the desired travel times of the commuters. That is frequently defined as the perceived convenience factor in the commuter's decision to change modes. A person who has to arrive at the CBD terminal (or station) at 8:20 a.m. to be able to get to work at 8:30 a.m. does not want to arrive at 8:25 or 8:30; nor may the rider be willing to arrive excessively early, as he (and only he) perceives that to be. A transit schedule oriented to specific travel needs is not likely to have a commonly defined headway within such a connotation. Most important to the rider is the day-to-day reliability of the system somewhat related to the headway. If the operating timetable is almost always dependable (again, as perceived by the user), he is more likely to ride.

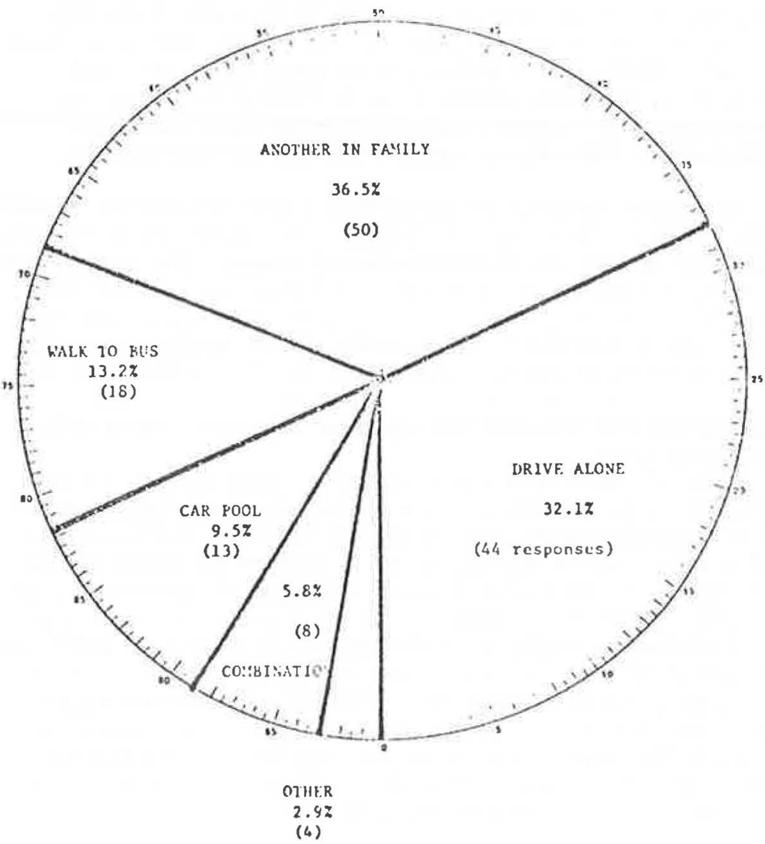
Table 6. Statistical qualities of prediction equation.

Step	Variable	Regression Coefficient	Standard Error	F-Ratio	R^2	Increase in R^2
		-0.70479				
1	Z	0.00940	0.00095	98.4812	0.6244	0.6244
2	B	1.96438	0.90511	4.7103	0.6957	0.0713
3	F·P	0.04868	0.01255	15.0351	0.7105	0.0149
4	R	1.21122	0.26075	21.5779	0.7289	0.0183
5	M^2	0.00867	0.00291	8.8602	0.7413	0.0124
6	T·R	-0.01929	0.00509	14.3574	0.7564	0.0151
7	T^2	0.00088	0.00030	8.8465	0.7786	0.0222

Table 7. Observed and estimated park-and-ride demand.

Observed		Estimated		
$Cars/Day^{1/2}$	Cars/Day	$Cars/Day^{1/2}$	Cars/Day	Difference
5.00	25	6.64	44	-1.64
22.36	500	17.62	311	4.74
20.00	400	15.37	235	4.63
10.72	115	11.88	141	-1.15
8.06	65	5.70	33	2.37
11.00	121	8.42	71	2.58
27.39	745	18.33	336	9.06
7.42	55	13.51	183	-6.09
10.30	106	12.38	153	-2.08

Figure 8. Mode used to arrive at park-and-ride bus stop.



A final consideration is the conceptual development of the paper. Decisions in intermodal transfer by commuters cannot be done "intuitively." Such decisions must be based on reliable measures, factors, and data, developed through research based on determining and evaluating the perceptions of alternative travel modes by corridor residents: riders, potential riders, former riders, and nonriders. Subjective engineering judgment must be based on an analysis of the characteristics of comparable corridors, not merely on literature searches. Subjective rating of factors and variables not based on aggregated perceived rider values, correlated to observed ridership behavior patterns, is of little use to an operator, particularly one attempting to maximize ridership and revenue.

To conclude, it is felt that the exercise by the authors fulfilled the objective of leading to the increase of knowledge concerning park-and-ride, an increasingly important transportation tool. However, the hypothesis and conclusions are highly suspect because of the concepts, methodology, and evaluations of the authors. Operational efforts in the development of new and improved service need far greater precision and analysis in the model than those presented in this paper.

AUTHORS' CLOSURE

As always, authors sit in hope that someone will take the time to critically discuss their paper. It opens the door to overriding the page limit to get a few more items clear. The first draft of this research said it all, but it was 250 pages long; the final manuscript was reduced to about 150 pages. The quantum jump to an 18-page paper can be critical.

The points raised by Alter will be acknowledged one by one. From an extensive review of the literature one would find very little data to suggest what specific variables might contribute to estimating parking demand at park-and-ride facilities. An unpublished ITE report and Highway Research Board Circular 26 by the Committee on Parking are the only 2 pertinent references. We do not agree that the data were highly subjective.

Two factors influenced the selection of the data collection method. First, we were financially constrained by a limited budget. Second, the extensive geographic distribution would have placed a strain on all but a most lucrative budget. Therefore, it was necessary to rely on data already collected or easily provided by change-of-mode operators. On that basis, it was decided that a questionnaire should be sent to change-of-mode operators. The literature was used as a starting point to solve the problem of where to send the questionnaires. A preliminary study was performed to find additional names and addresses of change-of-mode operating agencies and of the responsible personnel. Correspondence was started with the change-of-mode operators to elicit as much of the pertinent information as feasible. Through the fine cooperation of the operators, it was possible to devise an extensive and feasible questionnaire.

The third and last part of the experimental design was to select the facilities to be investigated from among those that fall within the scope of the project. Successful and unsuccessful facilities were polled so that the statistical analyses would not be biased. To ensure that there was an adequate variation within all proposed independent variables, we decided to include all facilities known (to us and operators contacted). Many of the change-of-mode parking facilities have been in use for a long period of time. During this time, many of the characteristics and the demands have radically changed. For this reason, it was decided, wherever feasible and warranted, to make observations at different points in time.

In those few instances where the questionnaire asked for a qualitative response of high, average, or low, it would have been a difficult data collection process to be more specific. Most data items were quantified to the degree feasible. For example, lighting conditions at the facility were noted as good, adequate, or poor. The level of analysis did not require measurements of footcandles; had it done so, where would one make such measurements? The authors further contend that most of the facilities are located in the 12 metropolitan areas surveyed. We further acknowledge that the results are constrained by the cities used. The discussant shows his research naiveté with his concern of having barely more than a 50 percent response. It should be noted that survey findings were critically reviewed for bias through plots of frequency distributions on various data items.

There was a valid basis for estimating parking demand and omitting nonparkers from the model. The comment—"Such an omission can greatly reduce the validity of an estimation model and related procedures, for line-haul riders arriving by means other than 1 person-1 car can account for significantly more riders than facility users"—is irrelevant on the condition that the research was attempting to predict only parkers, not riders of the transit in total.

The authors would acknowledge that corridors in metropolitan areas are different and that, if a model were to be developed for the city of Rochester, it might be appropriate to deal with those differences. It was not the research objective to be that specific.

The last two items of the discussion further emphasize a lack of research understanding. To include in the model for general application factors such as perceived cost or perceived convenience fails to recognize the great variability in such factors among users but also within users at various periods of the day. Our model is certainly not intended to predict the number of park-and-ride stalls required for those persons who perceive an out-of-pocket cost of 12½ cents and an arrival time of 3 min early.

We thank the discussant for the effort expended and the opportunity of further clarifying the research objectives.

JITNEY OPERATIONS IN THE UNITED STATES

Arthur Saltzman, Transportation Institute, North Carolina Agricultural and Technical State University; and
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An analysis of the history of jitneys in the United States is important to the understanding of the current situations faced by demand-responsive transit systems such as dial-a-ride. This paper focuses on the lessons that are applicable to innovations in demand-responsive transit systems. Within a few years of their introduction in 1910 as ad hoc motorized stagecoaches, jitney operations had spread across the country and were diverting as much as 50 percent of the peak-hour streetcar passengers. The transit industry reacted by getting legislation passed that regulated most jitneys out of existence. Many of these regulations still exist and could prove to be a major stumbling block to the implementation of systems such as dial-a-ride. Transit operators seemed to take the attitude that they were in the electric street railway industry as opposed to being in the business of urban transportation. Early conventional motor buses were slow in being introduced by those transit operators. In fact, most of the impetus for change came from outside of the established industry. There are illegal jitney operations that are now serving unfulfilled travel demands of inner-city residents. It is suggested that there is a need to create a favorable climate for more experimentation with jitney operations.

•MODIFIED 5- or 6-passenger touring cars were used for common-carrier service between some western American cities by 1910 (1, p. 2). These were ad hoc operations, and because they used the public roads they were initially ignored by both the regulatory bodies and the railroads. In essence, they were considered motorized stagecoaches.

One of the operators, who provided service between San Diego and Los Angeles, established a similar motorized "stage" operation between central Los Angeles and several suburban towns by 1911. A 5-passenger Ford Model T would cruise along the route of a downtown trolley line and pick up passengers who were destined toward some vaguely defined suburban location, such as Long Beach. A practice was made to deliver those passengers as close to their destination as was deemed feasible (by the driver) without a major diversion for the other passengers. These vehicles were called "jitneys," referring to the jitney (5 cents) charged per ride.

Within 2 or 3 years, these ideas caught on and spread across the country, principally among owners of automobiles who wished to add additional income to help pay for their vehicles. Some jitney operations—such as those in Paterson, New Jersey; Bridgeport, Connecticut; and Detroit, Michigan—diverted as many as 50 percent of the streetcar passengers in the peak hour and more in the off-peak hour along the corridors traversed (2, p. 425; 3, 4, p. 217). In some smaller cities, such as Bridgeport and Atlantic City, where the street railway company was on precarious financial grounds, the jitneys helped put the street railway out of business in the post-World War I era. As admitted by the spokesmen for the street railway industry, the jitney's prime attractions were its frequency of service, its flexibility of route to meet changing, sometimes daily, demands, and its inability to accommodate standees (5, p. 295).

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Shortly before the entry of the United States into World War I, a recession attracted many men into the jitney business, particularly those who had recently bought automobiles but found themselves without jobs. By counting its subscribers and assuming as many nonsubscribers, The Motor Bus magazine estimated that some 24,000 jitneys were in operation in the United States by 1916. By 1917, franchised street railway operators were going to great lengths to prove that the jitney was a serious menace to conventional transit. Their case rested on allegations that jitney operators were so unreliable and unbusinesslike that they actually lost money in providing the service. This was undoubtedly true for many naive operators, for depreciation was often omitted from their costs; the Fords would be run into the ground, and the would-be transit entrepreneurs would then find themselves without funds for replacement. [This discussion of the early days of jitneys is based on several documents (4, 5) published during that period. Doolittle particularly chastises lack of depreciation accounting. Also a contemporary short-lived periodical, The Motor Bus (not to be confused with a later periodical having a similar name), captured much of the flavor of the pioneering days. Farmer (6) reviews some of the early material but does not follow jitney progress after World War I.]

The large increase in the number of inexperienced operators, scarcity of parts and fuel, and particularly harassment from the streetcar interests were to decimate the jitney industry. According to Farmer (6), "By 1919, streetcar companies had effectively defeated the jitney mode through special legislation and statutes." However, the resurgence of jitneys took place many more times, though few cities reported jitney operations after that year.

Instead of trying to compete by introducing better and more variegated public transportation services, the transit industry's response to recognized competition was to attempt to regulate the innovations out of existence. This early legislation temporarily reestablished the public transportation monopoly position of the electric railways in almost all areas except noncommon carrier and single-use taxicab operations. Almost every city had some form of restrictive anti-jitney-bus ordinance. They required either high bonding levels for vehicle operations or franchise rules for fixed routes to be established according to the determination "of public convenience and necessity" (7).

It is relevant to the introduction of all innovative systems in public transportation that those regulations still exist and could prove to be a major stumbling block to the implementation of systems such as dial-a-ride by other than the public authorities or the established transit operator. This regulatory atmosphere has probably contributed to stifling the private funding of research and development in urban transportation much more than has been recognized.

DEVELOPMENT OF JITNEYS INTO MOTOR-BUS OPERATIONS

Many of the jitney operators who were able to survive the first repressive regulations assumed streetcar operating characteristics. The Motor Bus magazine often implored its readers in the early days to establish fixed routes and schedules and build "streetcarlike" bus bodies so that they would appear more "legitimate" to both the public and the authorities. Some jitney operators became feeders to streetcar and electric interurban truck routes; other jitney operators sold out to the electric railway interests and accepted employment as the managers of a railway's motor-bus division.

In a few rare cases, the existence of weak laws or lack of enforcement of antijitney ordinances permitted jitneys to survive and continue to offer more flexible, if not more reliable or comprehensive, services than those offered by the established, conventional transit operator. (Flexible scheduling permitted demand-responsive headways with an ease that more rigid operations could not assume.) For example, Mayor Frank Hague of Jersey City was powerful enough to prevent the Public Service Railway Company (a giant in its own right) from enforcing or having enacted such ordinances. As a result, Hudson County had a proliferation of jitneys that eventually settled into the pattern of the several dozen, small 1- and 2-vehicle bus operators found in Hudson County today. There is little indication that service is worse there under this method than in neighboring New York City where most of the transit operations come under one publicly operated monolith. (Public Service Railway Company seemed to learn its lesson early;

it was one of the first operators to accept the motor bus and, apparently stimulated by its earlier losses, was eager to experiment with new technology.)

In Atlantic City, New Jersey, the jitney operation (which can trace its origin back to the jitney craze of 1916) is an example of a more catholic type of operation, which yet managed to persist up to today (8). Vehicles are individually owned and, through a cooperative association, are somewhat dynamically dispatched. Until 15 years ago, Atlantic City jitney operators would take passengers to their destinations for twice the prevailing fare (regular fares were usually lower or the same as the local conventional transit operation fares) under the following conditions: (a) the operator was near the end of his route and (b) the destination was not more than a few blocks off the route. Similar legalized jitney operations can be found in a ghetto area in San Francisco and several resort type of beach communities around the country.

INTRODUCTION OF THE CONVENTIONAL MOTOR BUS

The first applications of the internal combustion engine to roadable public transport vehicles occurred soon after the introduction of the gasoline-powered automobile in both Europe and America near the turn of the century. [Glaeser (9, p. 84) noted that Chicago Street Railways experimented with the internal combustion engine on streetcars during the 1893 World's Columbian Exposition, and the American Electric Railway Association made a great point of citing the Ford Motor Company experiments (1910-1920) with gasoline-driven streetcars (4, p. 2).] By 1905, motor buses, which had designs not too dissimilar from those of contemporary streetcars, albeit somewhat smaller, were running on regular routes in London and in New York. A 34-passenger double-deck bus had been imported to the United States in 1905 for a trial, and in 1907 Fifth Avenue Coach in Manhattan had 14 more in service (10, 11, 12).

It is true that early buses were noisy, uncomfortable, and quite a bit more expensive than later versions (to both the operator and the passenger who often paid a double fare on a bus), but their use in New York, London, and many other European cities indicates that satisfactory equipment for innovation was available. In fact, by 1914, the London horse-drawn omnibuses had been entirely supplanted by more than 3,000 motor buses designed, built, and operated by the London General Omnibus Company (the company that trained Yellow Truck and Coach's chief designer).

In contrast, horse-drawn streetcars remained in service on some crosstown routes in Manhattan until 1923 because the operator could not afford to electrify and was not amenable to the motor bus. The horse cars were replaced with battery-powered streetcars. The motor-bus situation in Europe was not entirely unnoticed in the United States. In a paper read at the Sixth National Conference on City Planning in May 1914, McCollum (13, p. 5) stated:

> The operating efficiency of the motor bus in London ... probably exceeds the efficiency of many street railway systems. In Paris there are more than 1,000 vehicles of a type unlike those in London, operating under different conditions, but performing nevertheless an efficient passenger service. New motor-bus routes are being established daily in European cities. Some are being added to street railway systems and are designed to supplement the railway services by extension into districts where the traffic does not warrant the permanent investments of the large sums necessary for the operation of a railway.

Probably, the main reason that motor buses did not take hold was that the so-called "transit trusts" had vast sums invested in their streetcar lines and were not willing to make their investment obsolete or to take a chance on new technology. Those operators, with some exceptions, seemed to take the attitude that they were in the electric railway industry as opposed to being in the business of urban transportation. [Glaeser (9, p. 86) noted, "Philadelphia is unique in that under the former 'Mitten Management' a completely coordinated urban transportation system has been achieved. It consists of elevated, subway, streetcar, trolley-bus, gas-bus, and taxicab service." This coordination seems to have ended by the late 1940s. In Newark and Camden during the 1920s and 1930s, Public Service Railway of New Jersey also operated significant portions of the taxicab fleets coordinated with transit; and in Hamburg, Germany, a transfer and reduced fare pass was recently introduced for coordinated use with the local, independent taxicab and transit systems.]

A member of the motor-bus industry attended an American Electric Railway Association convention in 1922 as the representative of a bus manufacturer in Chicago. He reports (14, p. 2) that there was enough ill feeling toward the motor-bus industry at the convention that he was "testing the hardness of some red apples, being comforted in their possibilities as weapons of defense, if necessary, in covering our retreat from the convention." A few years later in 1925, the same representative was to praise the progress made by the street railway industry in changing its attitude toward the motor bus (14, pp. 3-5).

Although consistent and accurate statistics are not readily available on independent lines, the use of motor buses by electric railway companies accelerated from 370 buses on 700 route-miles in 1922 to 8,277 buses on 14,300 route-miles in 1927 (15). In 1923, buses carried 661 million revenue passengers, which was only about 5 percent of the total of 10 billion urban passengers for the entire industry. The urban transit industry hit its peak ridership between the World Wars in 1927 with about 12 to 13 billion revenue passengers; buses accounted for 2.4 billion, and streetcars and rapid transit carried the remainder. [The data collected in that period were very poorly stratified between urban and interurban operations and failed to distinguish intermodal transfer passengers. Figures are often quoted, i. e., from Moody's Public Utilities Manual or Transportation Manual, showing revenue passengers as high as 17 billion for 1927. Much more reliable are data given by Barger (16) or by the American Transit Association (17). The latter attempts to compensate for these figures.]

Streetcar companies were eventually forced to make the change to the motor bus. By the 1930s, streetcar equipment was badly in need of replacement, but investment money had been difficult to attract since the industry's growth had been stemmed after World War I and was even more so during the Depression. Buses were generally cheaper to purchase than streetcars, and the restricted capital available made the wisdom of changing over to the motor bus clearer.

However, most of the impetus for change came from outside of the established industry. This was primarily caused by the lack of financial and management resources within the transit companies and was exacerbated, perhaps, by the vacuum created during the forced divestures of operating properties from the power trusts (18).

In some colorful reporting in 1936 (10, p. 63), the virtues of the bus are contrasted with those of the streetcar.

> Over the past fifteen years or so, the city bus has clawed, butted, and fought its way through traffic-glutted streets, through spongier and more perilous politic-glutted operating fanchises, until it is, today, a phenomenon of mass transportation. You see city buses everywhere—mastodonic metal hulks gliding in and out of traffic with a soft hissing of air brakes, a rich sound of balloon tires on asphalt, a resonant hum of engines concealed within their structures. And the main reason this almost brand-new vehicle became a phenomenon is because the faithful electric trolley had sunk into such a state of obsolescence as to be scarcely tolerable. During the fifteen years the bus was growing, the trolley, as an invention, virtually stood still. It just grew older and the street it was still suffered to haunt grew noisier with its clanking decrepitude. Half the trolleys now in use are twenty years old or older: the average age is around sixteen.

The streetcar industry did band together beginning in 1929 to build an ideal trolley. The group, called the Electric Railway President's Conference Committee (PCC), did an extremely good job in producing the PCC car. By the late 1930s, PCC cars were in wide use and proved to be capable performers. Drivers, operators, and the public all liked the PCC's, but their introduction has not averted the steady abandonment of streetcar lines.

The replacement of trolleys by buses ("bustitution" as it is acrimoniously described by trolley fans) has almost been complete in the United States although there are still operations in a few cities such as Boston, Newark, Pittsburgh, Philadelphia, San Francisco, and New Orleans.

RESURGENCE OF JITNEYS

Jitneys had a resurgence during the 1930s as unregulated or semiregulated operations, although a degree of regulation was often imposed by high insurance bonds. [In 1932, The Motor Bus magazine, in an article on the St. Louis operation, indicated that the service car-jitney concept was still prevalent in a number of cities well after the enactment of repressive antijitney ordinances of the early 1920s. Similar articles appeared elsewhere (7, 19, 20, 21). In 1929 Hunter (22) noted that "the taxicab business . . . with lowering of rates and introduction of lightweight cabs, gives promise of increasing competition with street railways. This is particularly true of short-haul travel where the taxicab rate for three or four persons may compare with or actually be less than the streetcar fare." He was referring to the generally illegal practice of taxis operating as transit common carriers, known as cut-rate cabs in some places, and essentially the same as jitney operations.]

There were probably 2 major reasons why jitneys reappeared in large numbers. First and most important was the same pressures from unemployment that had caused the original jitney boom in 1915-16. Many automobile owners who were out of work decided to operate their vehicles as jitneys. The second reason was that urban travel was reorienting itself spatially, temporally, and quantitatively, and the transit industry was not changing its routes and services rapidly enough to meet new demands.

During the 1930s public referenda were held in several cities to approve jitneys as a supplement or replacement for conventional transit; undoubtedly, the intention of creating new jobs underlay many of those proposals, but the fact that the transit operators fought very bitterly indicated that they anticipated a severe economic threat from the flexible jitney service. In Los Angeles, which was served by 2 major, nationally powerful trolley companies, the referendum was won by the traction interests by a hair (23)—the proposal was to turn all transit over to individually owned jitney buses.

ST. LOUIS SERVICE CARS

Few numerical data have been found on the impact of unregulated jitneys, but we do have some data on the service cars in St. Louis.

The St. Louis jitney operators had banded together in the 1920s to provide an insurance base and a means of internal self-regulation for various purposes. The jitneys, known as service cars, ran on fixed routes set by the Consolidated Service Cars Association itself. Service could be adjusted to demand and routes could be changed more easily by the association than by the conventional operator. Fares initially were the same as those on the streetcars but apparently could vary much more easily, according to economic factors, than the transit company's fares (24). In 1957, a number of years before the St. Louis service-car operators were bought out by Bi-State Transit System, which was the public transit operator, a survey conducted by Gilman (25) indicated that on the routes with which they competed the service cars carried some 70 percent of the total public transport load during midday and about 50 percent during the rush hours. [Although the numbers and following quote are from Gilman's study (25), the observations are from Lewis Schneider, an acute observer of the scene who spent many years riding the service cars. Only 3 service-car routes remained in 1957.] The 20-cent fare was the same as the streetcar fare (for a weekly pass on the streetcars, the fare was 20 cents per ride), but service cars guaranteed seats to all who could ride (during the peak the streetcars showed a passenger per seat ratio ranging from 1.2 to 1.6), ran more frequently, and, because of fewer intermediate stops and ability to dodge traffic, usually made better time than the streetcars despite the latter's private right-of-way over portions of the routes. However, Gilman recommended against continuation of the service cars, stating:

> With the exception of three half-hour periods during the p.m. rush . . . the combined passengers of both St. Louis Public Service and the Consolidated Service Cars could be carried on existing St. Louis Public Service transit service at acceptable service standards.
>
> Although the service cars offer a more frequent service than could be given a similar passenger volume by either street cars or buses, this is not sufficient justification for their parasitical ac-

> tivity. Operation of this type of transit service is extremely wasteful of street space as each service has a capacity of only eight persons as compared to the 50 or more seats in a transit vehicle. Since individually operated vehicles cannot be expected to exchange transfers, general coverage of the city by service cars, instead of transit, would require about half of the riders to pay two fares.
>
> Competitive services of this character should not be permitted. They can survive only in areas where there is heavy transit riding, and these are the areas in which an area-wide transit system needs all of the business to average out the thin areas in which noncompensatory service is being operated.

This consultant report is typical of the established transit industry's position. In the face of competition, the industry tries to eliminate the competition and regain its monopoly position. The lesson that better service draws more customers seems to be difficult to translate into operating practice by the transit operator. He often sees the new system only as a threat to his operation, and one that must be eliminated by prohibition rather than by innovation.

The service cars basically served white, middle-class neighborhoods during the 1930s. By the late 1950s, the service cars were primarily serving black patrons. The reasons for this change were not established in any of the published reports, but demographic changes in St. Louis and increased automobile ownership among whites were probably the major factors. It is worth noting that the private transit operators had repeatedly attempted to take over the service cars while the patronage was predominantly white and had failed. When the dominant power structure was using the service, the service was allowed to exist even against the protests of the transit company. When minority groups were the main patrons, the service was eliminated. In all fairness, it should be noted that there was another factor that caused the service takeover in 1965. The incoming mayor owned Consolidated Service Cars in conjunction with several other prominent St. Louis businessmen. The threat of conflict of interest was certainly another factor that influenced the owners of Consolidated to sell out to Bi-State Transit System.

THE FUTURE OF JITNEYS IN THE UNITED STATES

A major resurgence of jitney operations cannot take place in the United States unless the restrictive regulations that originally decimated the industry are removed from the law books. Undoubtedly, the established transit operators and regulatory agencies will block any changes in the antijitney ordinances to preserve their transit monopoly. However, various pressures may eventually force changes in those regulations. One example of that pressure is the constant complaints about lack of adequate transit facilities in ghetto areas and in low-density central city sections that are not on center-city arterials. [Farmer (6, pp. 272-273) gives other examples of pressures that could force changes in antijitney regulations.]

Current shifts in transportation demand trends would tend to indicate a need for the more diffused routes that jitneys could service. The suburban explosion has put a larger and larger portion of the population in less dense areas. The jitney seems to be better able than conventional transit to provide economical service in less dense areas. Jitneys may be an alternative to many bus routes that are unprofitable. In most low-density areas, present transportation systems either operate unprofitable routes or provide no service at all. Many bus routes have been discontinued when there was still sufficient demand along these routes to support jitney operations. No detailed analysis shall be made to justify the ability of jitneys to operate where buses have failed, but it should be evident that, because of their smaller size, lower overhead, and non-unionized workers, jitneys are less expensive to operate per mile than buses: Jitneys need lower revenues per mile than buses to cover costs and make a profit and can therefore be viable along less densely traveled routes. An additional point in favor of jitneys is that because of their superior service characteristics they could attract more passengers than buses would along any given route. It is true that jitneys in the past have tended to serve densely traveled corridors. Perhaps regulations would be necessary to restrict jitneys to the low-density areas so that they do not skim the cream off bus transit operations. Jitney operators being locally attuned may also discover innumerable new routes that are viable for them but have never been exploited by the established area-wide transit operator.

The presence of "gypsy" taxis and illegal jitney operations in low-income ghetto areas all over the United States from the Hill District in Pittsburgh to Watts in Los Angeles is further evidence of the demand for this type of service. Those gypsy taxis often appear where the established transit operation has failed to provide a needed service. Few hard data are available on the extent of such operations, but an example is the route established a few years ago in Queens, New York City, by a black surgeon to aid ghetto dwellers in reaching his hospital (26; 27, p. 58). The city eventually forced him to stop running his tailored service, but there is no evidence that the public transit operator has yet responded to this community need. It should be noted that almost every poverty transportation project has made reference to legalizing such operations. For example, the latest progress report (28) from one of those projects refers twice to jitneys, and suggests "an entirely new approach with consideration being given to less organized and more ad hoc arrangements such as the encouragement of car pools... or through the establishment of low-fare, owner-operator, jitney or taxi-type services for the carless population." Many who could not previously afford a private automobile could then own one based on its potential for producing income. Allowing jitneys to operate in any area could bring significant new employment possibilities to the poor or jobless and supplemental income opportunities for anyone who had a vehicle in good condition.

Farmer (6, pp. 273-279) has presented a thorough discussion of how jitney operations could be experimentally established at very little cost to any governmental agency that is willing to support such an experiment. Since 1965, when his article was published, there has been no known jitney experiment, yet the current proliferation of nonlegal jitneys in many urban poverty areas could precede some relaxation of restrictive legislation.

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REVIEW OF TECHNICAL AND OPERATIONAL ASPECTS OF SEVERAL FIXED-GUIDEWAY PUBLIC TRANSPORTATION SYSTEMS

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The purpose of this paper is to review the major technical and operational characteristics of several contemporary fixed-guideway public transportation systems and to determine the functional distinctions among them. Six systems are compared with respect to the following characteristics: nature of the vehicle-guideway interface, station layout, vehicle spacing control, general operating specifications, and specifications for nominal levels of vehicle performance. The 6 systems considered range from urban rail transit systems to monorail systems. Although they are unlike one another in many respects, they nonetheless function in much the same manner when contrasted to personal rapid transit systems currently being developed.

•THIS PAPER summarizes a review (1) of several contemporary fixed-guideway public transportation systems. The 6 systems are identified and their physical distinctions are delineated in the following section. Subsequent sections describe distinctions in station layout, vehicle spacing control, general operating specifications, and vehicle performance. The concluding section compares these systems with the general technical and operational characteristics of the Morgantown personal rapid transit system currently being developed by the Urban Mass Transportation Administration.

THE SYSTEMS AND THEIR PHYSICAL DISTINCTIONS

The systems considered here include the urban rail transit system of advanced design developed by the San Francisco Bay Area Rapid Transit District and opened to the public in 1972; the Japanese National Railways New Tokaido Line, an example of advanced design for conventional railroads; several subway lines in Paris where vehicles are equipped with both rubber tires and flanged wheels used in other urban rail transit systems; a monorail system with vehicles supported from below (Alweg); a monorail system with vehicles supported from above (Safege); and the transit expressway system. A summary of system characteristics is given in Table 1.

The San Francisco and Japanese designs involve the same steel wheel-steel rail concept that has traditionally characterized railway systems. The Paris subway lines are of interest because the subway vehicles are equipped with rubber tires, which provide the normal mode of vehicle support and roll on flat concrete slabs. Although the Paris subway vehicles are also equipped with flanged steel railroad wheels, those wheels are used primarily to provide guidance through switches by interacting with conventional steel railroad rails that extend the length of each subway line. The Alweg monorail system involves rubber-tired vehicles that straddle a concrete box beam.

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Page 72, in Table 1, under the ''System'' column, the 3rd entry should read: Paris Transportation Authority lines with rubber-tired trains; under the ''Safety Acceleration'' and ''Jerk'' columns, each of the 2nd entries should read -[b].

Table 1. Summary of system characteristics.

System	Station Layout	Vehicle Spacing Control	General Operating Specifications: Minimum Headway (sec)	Station Dwell Time (sec)	Train Length (ft)	Specifications for Nominal Vehicle Performance: Maximum Velocity (mph)	Deceleration (mph/sec): Operational	Deceleration (mph/sec): Emergency	Starting Acceleration (mph/sec)	Jerk (mph/sec²)	Jerk Derivative (mph/sec²)
San Francisco Bay Area Rail Transit	On-line	Automatic block system	90	20	700	80	3.0	3.0	3.0	3.0	—[a]
Japanese National Railways New Tokaido Line	Off-line and on-line	Automatic block system	300	120 to 300	1,312	130	0.9 to 1.6	1.3 to 2.4	—[a]	—[a]	—[a]
Paris Transportation Authority rubber-tired trains	On-line	Automatic block system	180	—[b]	200	37	3.2	5.6	3.1	1.8	2.2
Alweg monorail	On-line	Automatic block system	90	—[b]	201	53	3.3	5.7	2.5	—[b]	—[a]
Safege monorail	On-line	Automatic block system	90	—[b]	118	75	3.3	6.5	3.3	—[b]	—[a]
Transit expressway	On-line	Automatic block system	120	20	305	70	2.5	5.0	2.5	—[b]	—[a]

[a]No specification issued. [b]Specification not available.

Safege monorail system vehicles are suspended from rubber-tired trucks that operate within an overhead beamway that is enclosed except for a slot on the underside for the linkage that connects the trucks and the body of the vehicle. The transit expressway system involves vehicles that are supported from below by rubber-tired trucks. Another distinction of those vehicles is that their lateral guidance is through horizontally mounted rubber tires that are suspended below each vehicle's body so that they roll on opposite sides of a steel I-beam mounted over the guideway's centerline.

STATION LAYOUT

Station layout may be categorized as being either on-line or off-line. On-line stations are those that involve locations for vehicle stops that are directly on the main guideway facilities. A vehicle consequently cannot pass through an on-line station if another vehicle is standing in the station. The nature of the activity in the station therefore determines the line or guideway capacity. Off-line stations on the other hand involve locations for vehicle stops that are on sidings, thereby enabling vehicles that need not stop at the station to pass it without delay. All of the 6 systems reviewed here involve on-line stations, and only one of them—the New Tokaido Line—involves some off-line stations (Table 1).

VEHICLE SPACING CONTROL

The control of minimum spacing for each of the 6 systems enforces a requirement that the gap between 2 vehicles be not less than the following vehicle's stopping distance. An automatic block system, similar in operation to contemporary railroad signaling systems, is used on each of the systems. Basically such a system divides the length of the guideway into segments, referred to as blocks, and records information on the presence or absence of a vehicle in each block. The information is then transmitted to upstream blocks where it is processed and transferred to vehicles in those blocks.

GENERAL OPERATING SPECIFICATIONS

Table 1 gives the specifications for minimum headway, station dwell time, and train length for each of the 6 systems. Values for each of those parameters vary considerably. However, the minimum headway specification is dependent on station dwell time in the case of on-line stations and more generally on vehicle length and the various specifications for vehicle performance. A review of this interrelation is given in another report (2).

VEHICLE PERFORMANCE

Specifications for nominal vehicle performance levels are also given in Table 1. The 2 systems without rubber-tired vehicles generally have lower decelerative capabilities because of the reduced levels of adhesion existing between the vehicle wheels and the running surface. The Paris subway system involves a specification on the maximum rate of change of jerk. Such a specification, extremely unusual in other fixed-guideway transportation system designs, should contribute to passenger comfort at the outset and at the termination of periods of vehicle acceleration and deceleration.

CONCLUSION

This paper concludes with a comparison of the characteristics of the 6 systems described with those of an experimental personal rapid transit system located in Morgantown, West Virginia, and described in a recent report (3) and in a letter to me from the project director. This system was dedicated in October 1972 and is scheduled to be in operation in 1974. All Morgantown stations are off-line. Control of minimum vehicle spacing for the Morgantown system has some similarity to that for the 6 systems described in that the stopping distance spacing criterion is followed and enforced by an automatic block system. Despite the similarity in control concepts, placing all stations off-line has allowed the designers of the Morgantown system to reduce the minimum headway between successive vehicles on main-line guideway to 15.0 sec for operational purposes and 7.5 sec for test purposes. Station dwell times are variable, and vehicle length is approximately 15 ft. Vehicle performance specifications include the following: maximum velocity, 30 mph; operational deceleration, 1.4 mph/sec; emergency deceleration, 6.6 mph/sec; and maximum acceleration, 2.7 mph/sec.

Perhaps the Morgantown system's most dramatic design departure is the employment of off-line stations throughout the system and exploitation of the resultant capability to substantially decrease headways. This departure is principally operational or functional in nature. In many respects, technology for the Morgantown system is not fundamentally different from that for the newest of the 6 systems described above.

The 6 systems considered here all function in much the same manner, given their general utilization of on-line stations. Of course the inclusion of on-line stations is not required by other aspects of the designs. Thus, system-wide use of off-line stations for these 6 systems appears to be a distinct possibility. The resulting effect on operational capabilities is a matter meriting detailed review.

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