EVALUATION OF PASSENGER SERVICE TIMES FOR STREET TRANSIT SYSTEMS

Walter H. Kraft and Terrence F. Bergen, Edwards and Kelcey, Inc., Newark, New Jersey

The time required for passengers to board and alight from transit vehicles can play a significant role in the determination of realistic transit schedules and berth requirements for intermodal transfer facilities. This paper investigates the effects on passenger service time of various vehicles, different methods of fare collection, combinations of boarding and alighting through the front and rear doors, and time. The method of least squares is used to analyze and develop equations to predict passenger service time when the number of passengers boarding and alighting is known. Peak-period service time requirements were similar for a.m. and p.m. The exact-fare method of fare collection provided for faster passenger service times than did the conventional cash-and-change method. Trolleybuses with double doors had faster service times than did those with single doors. In addition, intercity passenger service times were found to be greater than those for local transit service.

•DESIGN of bus terminals and other intermodal transfer facilities is influenced by passenger loading and unloading times. For example, the amount of platform space, the number of bus berths, and transit vehicle schedules are contingent on the time required to service patrons. These design considerations often govern the acceptability of a particular site, the layout of a proposed terminal, and the cost of such facilities. In the downtown areas of many cities (prime locations for terminals), space for transit facilities is severely limited. Miscalculating the number of loading berths or required platform space can result in using too much valuable land and cause inefficiencies in facility operations. Too often, a transit vehicle arriving after its scheduled time promotes critical and dangerous density levels of patrons on the platform. Overestimating demand causes underuse of platform space. Therefore, to aid in determining requirements for berths, platform space, and scheduling, investigations have been undertaken to determine the effects of type of vehicle, fare collection, boarding and alighting patterns, and time of day on passenger loading and unloading times.

BACKGROUND

During 1968 and 1969, the authors participated in the preparation of NCHRP Report 113 (3). A phase of the project involving the evaluation of transit system operations indicated that the time required to serve bus passengers at a stop could be predicted if adequate knowledge of the number of passengers boarding and alighting was available. The method of least squares was used to predict passenger service time for 3 distinct situations, as follows:

1. When passengers were boarding,
2. When passengers were alighting, and
3. When passengers were simultaneously boarding and alighting.

Equations were developed from data collected in Louisville, Kentucky, for 2 methods of fare collection—the cash-and-change system in which the driver collects the fare and gives change when necessary and the exact-fare system in which the driver does not handle the fare. In the exact-fare system, the passengers deposited the exact fare in a sealed box as they entered the vehicle. The driver gave redeemable script for any overpayment.

Although the Louisville data indicated the predictability of the passenger service time, there still remained questions about the effects of other factors. Therefore, it was decided to obtain additional information to consider the following effects:

1. Type of vehicle (bus, trolleybus, trolley car),
2. Time of day (a.m. peak, midday, p.m. peak),
3. Type of service (local transit, intercity transit),
4. Method of fare collection (no fare, cash and change, exact fare), and
5. Various combinations of boarding and alighting through front and rear doors.

STUDY AREA AND PROCEDURES

Data on bus passenger service time used in the study were collected in San Francisco and Los Angeles, California; Newark, Morristown, New Brunswick, and Clifton, New Jersey; New York City; Chicago, Illinois; Louisville, Kentucky; and Wilmington, North Carolina.

All data were collected in 1973 except in Newark and Louisville, where data were collected between 1968 and 1970. Data on trolley cars and trolleybuses were collected in San Francisco; information on the double-deck bus was obtained in Chicago.

Passenger service times were recorded from the moment the doors opened until the last passenger alighted from or boarded the vehicle. The number of passengers boarding and alighting by each door was recorded during the same time interval. Stragglers boarding the vehicle after the initial queue were not counted in the passenger service time and passenger volume measurements. Likewise, stalling time was not included in the recorded service times.

ANALYSIS

Categories of boarding and alighting times are shown in Figure 1. Three categories of boarding are possible, but only category B1 was analyzed in this study. Sufficient information was not gathered for analysis of rear door boarding on the trolleys. Sufficient data were obtained, however, for 2 methods of local transit fare collection to analyze all 3 alighting categories. Intercity bus service was analyzed for category A1 only, because buses used for this type of service had only 1 passenger door. Only categories S1, S4, and S5 were analyzed for the category of simultaneously boarding and alighting because of the lack of information on rear door boarding.

Two types of analyses were performed by the method of least squares. The first developed a series of analysis equations that were used to investigate effects of fare collection methods, time of day, and use of front and rear doors. Although nearly 1,500 observations were analyzed in this study, sufficient data were obtained to investigate only those effects for local bus service with exact-fare and cash-and-change methods of fare collection. The results of these analyses are given in Table 1. In some cases the number of observations or the coefficient of determination or both are not adequate for reliable results, but they have been listed for purposes of interest. Conclusions that can be drawn from Table 1 are as follows:

1. Passenger service time requirements for a.m. and p.m. are similar;
2. Midday time requirements are usually greater than those for a.m. and p.m.;
3. Boarding time requirements exceed those for alighting; and
4. Rear door and front door alighting time requirements are the same.

Predictive equations were developed to estimate passenger service time requirements when the number of boarding and alighting passengers is known. These equations are given in Table 2. Conclusions drawn from this table are as follows:

1. Peak-period service time requirements for a.m. and p.m. are similar;
2. Midday service time requirements exceed peak-period requirements;
3. Boarding time requirements are greater than those for alighting;
4. Local service time requirements are less than intercity requirements, irrespective of the method of fare collection;

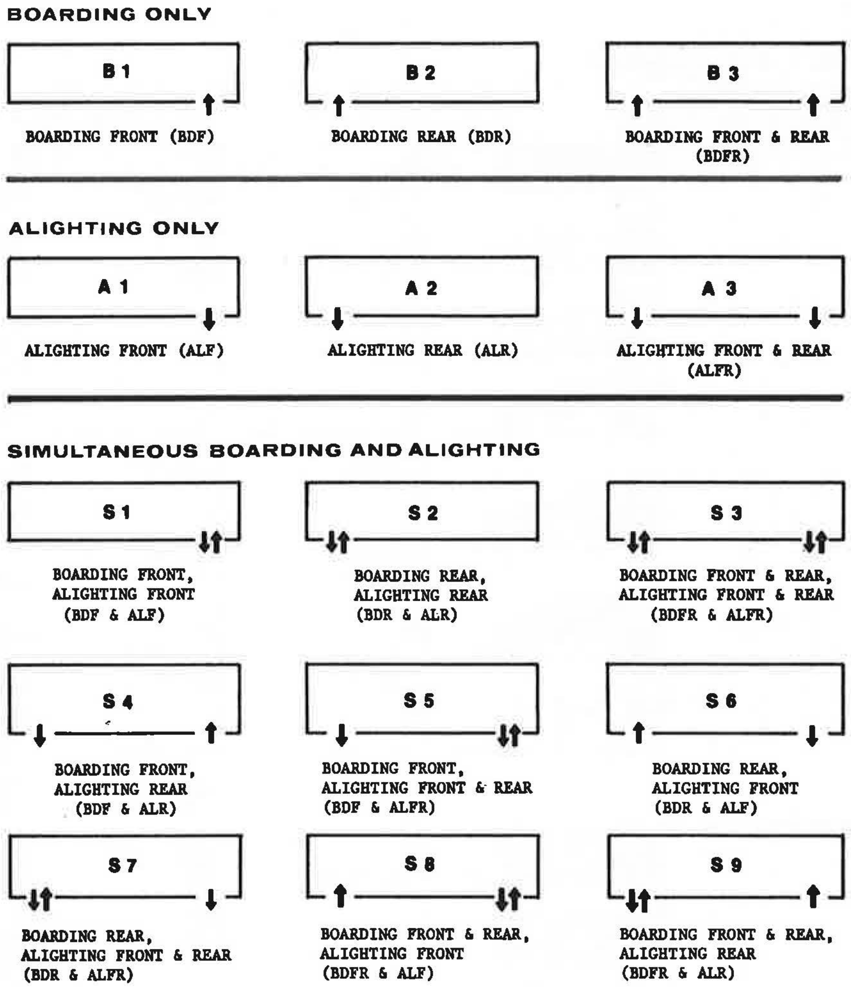


Figure 1. Passenger service time categories.

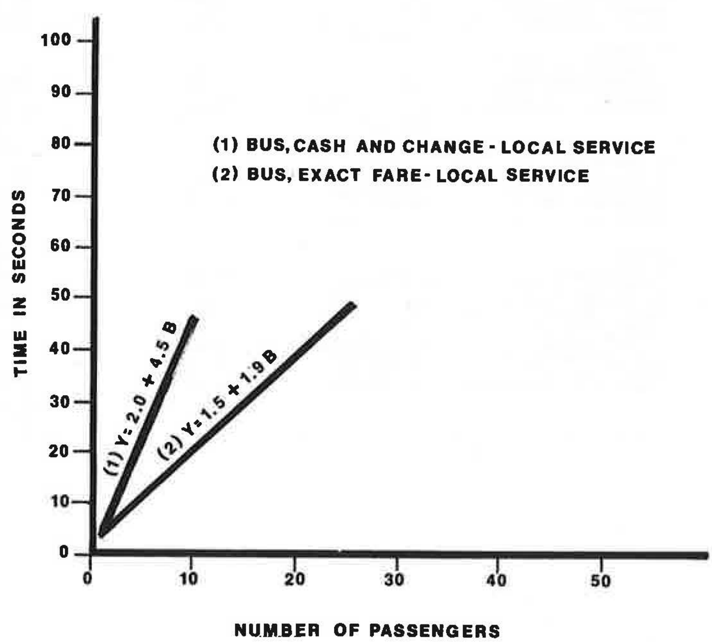


Figure 2. Time differences for boarding only, a.m. peak.

Table 1. Analysis equations.

System	Category	A.M. Peak	Midday	P.M. Peak
Exact fare, local bus	B1: BDF			
	Number of observations	50	94	257
	Coefficient of determination	0.94	0.89	0.90
	Standard error of estimate	0.34	0.41	0.40
	Equation, passenger service time	Y = 1.5 + 1.9 BDF 1 ≤ BDF ≤ 25	Y = 0.7 + 2.7 BDF 1 ≤ BDF ≤ 20	Y = 2.4 + 2.2 BDF 1 ≤ BDF ≤ 56
	A1: ALF			
	Number of observations	38	47	22
	Coefficient of determination	0.80	0.83	0.31
	Standard error of estimate	0.27	0.27	0.42
	Equation, passenger service time	Y = 0.6 + 1.7 ALF 1 ≤ ALF ≤ 9	Y = 0.9 + 2.1 ALF 1 ≤ ALF ≤ 8	Y = 2.1 + 1.3 ALF 1 ≤ ALF ≤ 4
	A2: ALR			
	Number of observations	7	13	9
	Coefficient of determination	0.67	0.47	0.29
	Standard error of estimate	0.42	0.77	0.56
	Equation, passenger service time	Y = 0.5 + 1.5 ALR 1 ≤ ALR ≤ 3	Y = 2.1 + 1.9 ALR 1 ≤ ALR ≤ 5	Y = 2.8 + 1.0 ALR 1 ≤ ALR ≤ 4
	A3: ALF and ALR			
	Number of observations	125	58	35
	Coefficient of determination	0.64	0.61	0.89
	Standard error of estimate	0.21	0.51	0.51
	Equation, passenger service time	Y = 2.4 + 0.7 ALF + 1.1 ALF 1 ≤ ALR ≤ 11 1 ≤ ALF ≤ 10 2 ≤ ALFR ≤ 19	Y = 2.3 + 0.8 ALR + 1.7 ALF 1 ≤ ALR ≤ 9 1 ≤ ALF ≤ 11 1 ≤ ALFR ≤ 20	Y = 1.9 + 2.2 ALF 1 ≤ ALR ≤ 21 1 ≤ ALF ≤ 19 2 ≤ ALFR ≤ 37
	S1: BDF and ALF			
	Number of observations	21	42	40
	Coefficient of determination	0.86	0.91	0.96
	Standard error of estimate	0.73	0.76	0.44
	Equation, passenger service time	Y = 3.1 + 2.0 BDF 1 ≤ ALF ≤ 4 1 ≤ BDF ≤ 15	Y = 1.0 + 1.0 ALF + 2.8 BDF 1 ≤ ALF ≤ 9 1 ≤ BDF ≤ 25	Y = 4.0 + 0.7 ALF + 1.3 BDF + 0.5 (ALF · BDF) 1 ≤ ALF ≤ 8 1 ≤ BDF ≤ 53
	S4: BDF and ALR			
	Number of observations	12	17	38
	Coefficient of determination	0.88	0.80	0.75
	Standard error of estimate	0.88	1.05	0.72
	Equation, passenger service time	Y = 0.4 + 2.0 BDF 1 ≤ ALR ≤ 5 1 ≤ BDF ≤ 13	Y = 3.2 + 2.2 BDF 1 ≤ ALR ≤ 4 1 ≤ BDF ≤ 16	Y = 3.0 + 1.9 BDF 1 ≤ ALR ≤ 8 1 ≤ BDF ≤ 15
	S5: BDF, ALF, and ALR			
	Number of observations	36	32	80
	Coefficient of determination	0.84	0.72	0.93
	Standard error of estimate	0.37	0.81	0.75
	Equation, passenger service time	Y = 0.1 + 1.0 ALR + 1.4 ALF + 2.4 BDF 1 ≤ ALR ≤ 8 1 ≤ ALF ≤ 12 1 ≤ BDF ≤ 8	Y = 4.6 - 0.5 ALR + 2.1 ALF + 2.2 BDF 1 ≤ ALR ≤ 17 1 ≤ ALF ≤ 11 1 ≤ BDF ≤ 10	Y = 1.8 + 2.2 ALF + 2.1 BDF 1 ≤ ALR ≤ 21 1 ≤ ALF ≤ 17 1 ≤ BDF ≤ 87
Cash and change, local bus	B1: BDF			
	Number of observations	26	No data	97
	Coefficient of determination	0.90	No data	0.85
	Standard error of estimate	0.72	No data	0.62
	Equation, passenger service time	Y = -2.0 + 4.5 BDF 1 ≤ BDF ≤ 10	No data	Y = 1.7 + 3.6 BDF 1 ≤ BDF ≤ 20
	A1: ALF			
	Number of observations	29	No data	18
	Coefficient of determination	0.83	No data	0.60
	Standard error of estimate	0.24	No data	0.35
	Equation, passenger service time	Y = 2.6 + 1.5 ALF 1 ≤ ALF ≤ 7	No data	Y = 3.0 + 1.4 ALF 1 ≤ ALF ≤ 6
	A2: ALR			
	Number of observations	8	No data	No data
	Coefficient of determination	0.89	No data	No data
	Standard error of estimate	0.84	No data	No data
	Equation, passenger service time	Y = 0.5 + 2.2 ALR 1 ≤ ALR ≤ 4	No data	No data
	A3: ALF and ALR			
	Number of observations	37	No data	5
	Coefficient of determination	0.66	No data	0.91
	Standard error of estimate	0.26	No data	0.73
	Equation, passenger service time	Y = 3.5 + 1.0 ALFR 1 ≤ ALR ≤ 7 1 ≤ ALF ≤ 7 2 ≤ ALFR ≤ 11	No data	Y = 4.5 + 0.8 ALFR 1 ≤ ALR ≤ 8 1 ≤ ALF ≤ 5 2 ≤ ALFR ≤ 13
	S1: BDF and ALF			
	Number of observations	Insufficient data	No data	23
	Coefficient of determination	Insufficient data	No data	0.95
	Standard error of estimate	Insufficient data	No data	0.55
	Equation, passenger service time	Insufficient data	No data	Y = 4.0 + 4.3 BDF 1 ≤ ALF ≤ 2 1 ≤ BDF ≤ 13
	S4: BDF and ALR			
	Number of observations	Insufficient data	No data	Insufficient data
	Coefficient of determination	Insufficient data	No data	Insufficient data
	Standard error of estimate	Insufficient data	No data	Insufficient data
	Equation, passenger service time	Insufficient data	No data	Insufficient data
	S5: BDF, ALF, and ALR			
	Number of observations	Insufficient data	No data	6
	Coefficient of determination	Insufficient data	No data	0.81
	Standard error of estimate	Insufficient data	No data	1.90
	Equation, passenger service time	Insufficient data	No data	Y = 4.5 + 3.5 ALR + 2.7 BDF 1 ≤ ALR ≤ 5 1 ≤ ALF ≤ 4 1 ≤ BDF ≤ 6

Table 2. Predictive equations.

System	Category	A.M. Peak	Midday	P.M. Peak
Exact fare, local bus	Alighting only			
	Number of observations	170	119	66
	Coefficient of determination	0.68	0.62	0.65
	Standard error of estimate	0.18	0.31	0.34
	Equation, passenger service time	Y = 2.3 + 1.0 A	Y = 2.5 + 1.4 A	Y = 2.5 + 1.1 A
		1 ≤ A ≤ 19	1 ≤ A ≤ 20	1 ≤ A ≤ 37
	Boarding only			
	Number of observations	50	94	257
	Coefficient of determination	0.94	0.89	0.90
	Standard error of estimate	0.34	0.41	0.40
	Equation, passenger service time	Y = 1.5 + 1.9 B	Y = 0.7 + 2.7 B	Y = 2.4 + 2.2 B
		1 ≤ B ≤ 25	1 ≤ B ≤ 20	1 ≤ B ≤ 56
	Simultaneous boarding and alighting			
	Number of observations	69	91	158
	Coefficient of determination	0.83	0.83	0.92
	Standard error of estimate	0.36	0.54	0.46
	Equation, passenger service time	Y = 0.5 + 1.3 A + 2.2 B	Y = 0.8 + 1.4 A	Y = 2.4 + 1.1 A + 2.1 B
		-0.1 (A • B)	+ 2.9 B	1 ≤ A ≤ 38
		1 ≤ A ≤ 14	- 0.1 (A • B)	1 ≤ B ≤ 87
		1 ≤ B ≤ 15	1 ≤ A ≤ 25	
			1 ≤ B ≤ 25	
Exact fare, trolleybus	Alighting only			
	Number of observations	No data	No data	No data
	Coefficient of determination	No data	No data	No data
	Standard error of estimate	No data	No data	No data
	Equation, passenger service time	No data	No data	No data
	Boarding only			
	Number of observations	No data	Insufficient data	13
	Coefficient of determination	No data	Insufficient data	0.97
	Standard error of estimate	No data	Insufficient data	0.49
	Equation, passenger service time	No data	Insufficient data	Y = -1.8 + 1.7 B
				1 ≤ B ≤ 20
	Simultaneous boarding and alighting			
	Number of observations	No data	13	15
	Coefficient of determination	No data	0.89	0.85
	Standard error of estimate	No data	0.70	0.65
	Equation, passenger service time	No data	Y = 2.8 + 1.6 B	Y = 1.3 + 0.7 A + 1.7 B
			1 ≤ B ≤ 15	1 ≤ A ≤ 8
			1 ≤ A ≤ 8	1 ≤ B ≤ 12
Exact fare, trolley car	Alighting only			
	Number of observations	No data	No data	No data
	Coefficient of determination	No data	No data	No data
	Standard error of estimate	No data	No data	No data
	Equation, passenger service time	No data	No data	No data
	Boarding only			
	Number of observations	No data	Insufficient data	7
	Coefficient of determination	No data	Insufficient data	0.64
	Standard error of estimate	No data	Insufficient data	0.90
	Equation, passenger service time	No data	Insufficient data	Y = 3.4 + 0.9 B
				1 ≤ B ≤ 13
	Simultaneous boarding and alighting			
	Number of observations	No data	11	5
	Coefficient of determination	No data	0.80	0.94
	Standard error of estimate	No data	1.67	1.50
	Equation, passenger service time	No data	Y = -4.2 + 4.1 A	Y = -4.0 + 2.0 B
			+ 2.0 B	1 ≤ A ≤ 8
			- 0.3 (A • B)	6 ≤ B ≤ 21
			1 ≤ A ≤ 13	
			2 ≤ B ≤ 20	
Cash and change, local bus	Alighting only			
	Number of observations	75	No data	27
	Coefficient of determination	0.76	No data	0.82
	Standard error of estimate	0.18	No data	0.29
	Equation, passenger service time	Y = 3.2 + 1.1 A	No data	Y = 3.8 + 0.9 A
		1 ≤ A ≤ 11		1 ≤ A ≤ 13
	Boarding only			
	Number of observations	26	Insufficient data	96
	Coefficient of determination	0.90	Insufficient data	0.85
	Standard error of estimate	0.72	Insufficient data	0.62
	Equation, passenger service time	Y = -2.0 + 4.5 B	Insufficient data	Y = 1.7 + 3.6 B
		1 ≤ B ≤ 10		1 ≤ B ≤ 20
	Simultaneous boarding and alighting			
	Number of observations	14	No data	36
	Coefficient of determination	0.80	No data	0.91
	Standard error of estimate	0.74	No data	0.55
	Equation, passenger service time	Y = 5.3 + 1.5 (A • B)	No data	Y = -0.1 + 2.2 A + 4.9 B
		1 ≤ A ≤ 7		-0.5 (A • B)
		1 ≤ B ≤ 3		1 ≤ A ≤ 8
				1 ≤ B ≤ 13
No fare, double-deck bus	Alighting only			
	Number of observations	No data	10	No data
	Coefficient of determination	No data	0.92	No data
	Standard error of estimate	No data	0.75	No data
	Equation, passenger service time	No data	Y = -1.8 + 2.3 A	No data
			2 ≤ A ≤ 12	
	Boarding only			
	Number of observations	No data	15	No data
	Coefficient of determination	No data	0.87	No data
	Standard error of estimate	No data	0.30	No data
	Equation, passenger service	No data	Y = 1.0 + 2.0 B	No data
			1 ≤ B ≤ 7	
	Simultaneous boarding and alighting			
	Number of observations	No data	12	No data
	Coefficient of determination	No data	0.82	No data
	Standard error of estimate	No data	3.48	No data
	Equation, passenger service	No data	Y = -8.9 + 3.5 A	No data
			+ 3.8 B	
			1 ≤ A ≤ 10	
			1 ≤ B ≤ 14	
No fare, local bus	Alighting only			
	Number of observations			11
	Coefficient of determination			0.97
	Standard error of estimate			0.65
	Equation, passenger service			Y = 3.1 + 1.4 A
				1 ≤ A ≤ 25
Various fares, intercity bus	Alighting only			
	Number of observations	30	53	
	Coefficient of determination	0.90	0.63	
	Standard error of estimate	1.4	0.91	
	Equation, passenger service	Y = 4.5 + 1.7 A	Y = 5.7 + 2.1A	
		4 ≤ A ≤ 57	4 ≤ A ≤ 69	
Cash and change, intercity bus	Boarding only			
	Number of observations		10	27
	Coefficient of determination		0.81	0.99
	Standard error of estimate		19.05	2.55
	Equation, passenger service		Y = -19.5 + 6.1 B	Y = -13.4 + 6.6 B
			8 ≤ B ≤ 63	1 ≤ B ≤ 52
Pay leave, intercity bus	Boarding only			
	Number of observations			18
	Coefficient of determination			0.90
	Standard error of estimate			2.29
	Equation, passenger service			Y = 3.2 + 3.9 B
				33 ≤ B ≤ 64

Figure 3. Time differences for boarding only, p.m. peak.

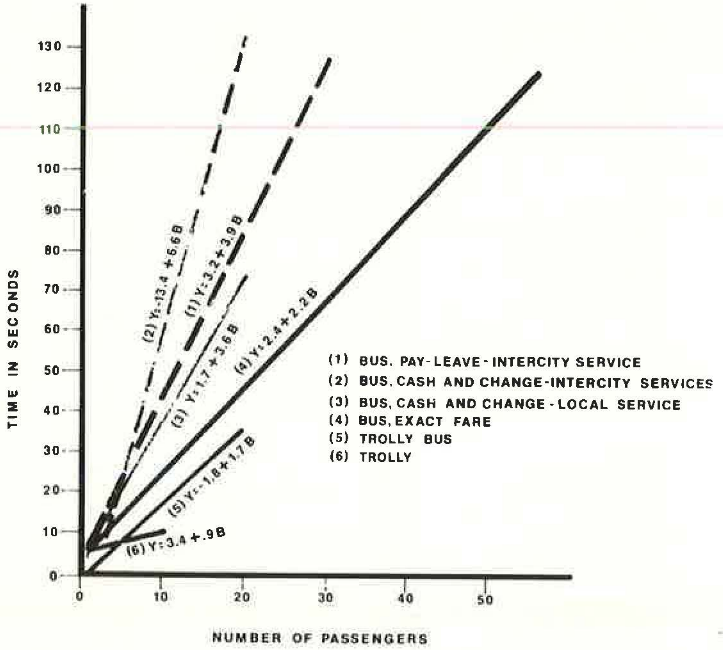
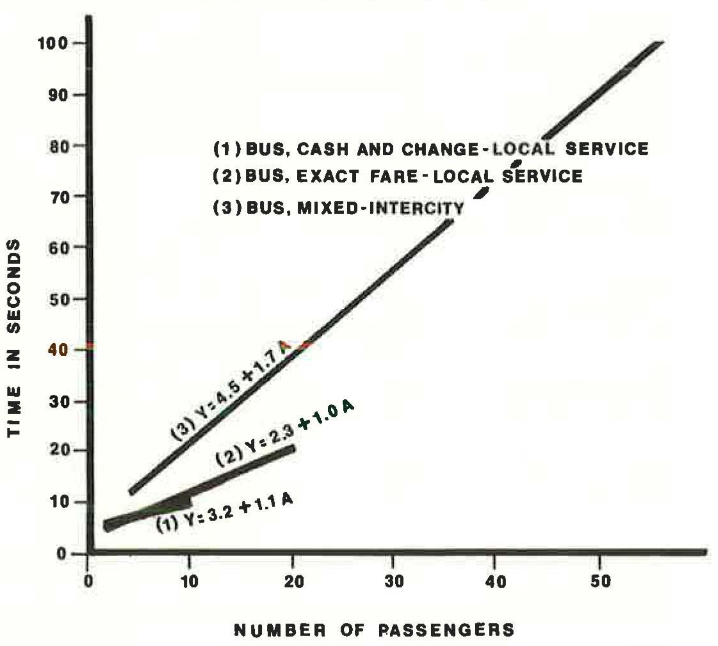


Figure 4. Time differences for alighting only, a.m. peak.



5. Time requirements for trolley cars and trolleybuses having double doors are less than those for buses with single doors; and
6. The exact-fare method of fare collection provides faster passenger service time than does the cash-and-change method.

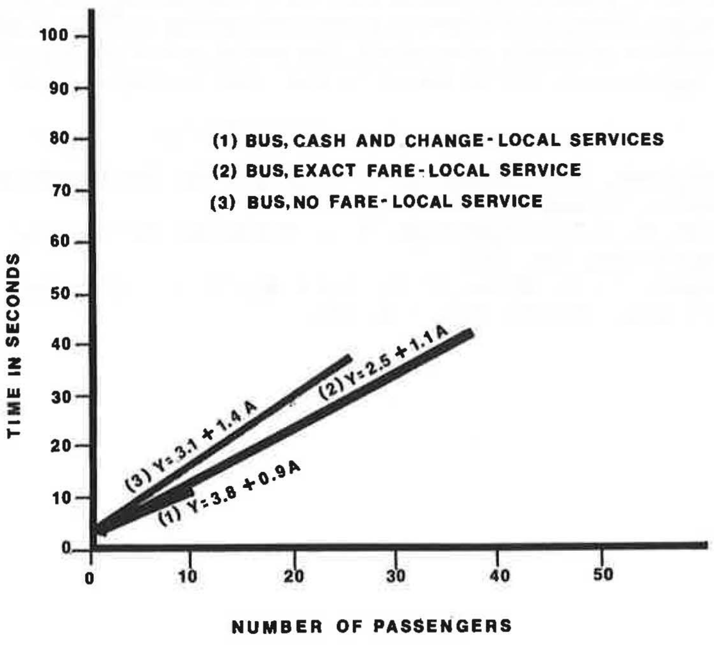
Figure 2 shows the difference between the exact-fare system and the cash-and-change system for boarding during the a.m. peak period. It shows a time savings of 2.6 seconds per passenger for the exact-fare system. This difference is reduced to 1.4 seconds per passenger during the p.m. peak period as shown in Figure 3. A time savings of 0.6 second per passenger for all time periods was indicated in NCHRP Report 113. Because sufficient data were not collected for the midday time period, further analysis and interpretation could not be made. Figure 3 also shows sizable differences in time requirements for local service and intercity service. In all cases intercity service required considerably more time. This may have resulted from the following:

1. Intercity passengers ask more questions;
2. Passengers inside the bus store their coats and luggage on overhead racks and delay boarding operations; and
3. Intercity passengers exit from the bus to wait for another when all seats are occupied.

Internal congestion or platform queuing frequently had an effect on the operation of all vehicles. This condition was noticeable for trolley car and trolleybus passengers as observed on Market Street in San Francisco. The loading platform was approximately 5 ft wide and located between the trolley car and trolleybus lanes. Frequently the crowding on the platform delayed passengers alighting from the trolley cars. Furthermore, congestion inside the trolley cars and trolleybuses frequently delayed boarding passengers. These conditions probably accounted for some of the higher than expected service times for the vehicles with double doors.

Figure 4 shows alighting only during the a.m. peak period for buses. As expected, there was almost no difference between the methods of fare collection for local service. Results do indicate, however, that intercity service requires more time than local ser-

Figure 5. Time differences for alighting only, p.m. peak.



vice. The internal congestion and higher floor height of intercity vehicles may account for this.

Figure 5 shows alighting only during the p.m. peak period for buses. Again, there is little difference between the cash-and-change and the exact-fare systems. The no-fare system seems to require slightly greater service time, but this is probably not significant. The no-fare data were collected at Rutgers—The State University in New Brunswick, New Jersey; the characteristics of the university passenger may differ from those of the downtown transit commuter and thereby have affected the results.

CONCLUSIONS

Many factors influence passenger service time of street transit systems. Those found to be most significant in this study include

1. Time of day—a.m. and p.m. peak periods are similar, but midday passenger service time requirements are greater than those for peak periods;
2. Type of service—local transit service requires less loading and unloading time than does intercity service;
3. Type of vehicle—double-door vehicles consume less passenger service time than single-door vehicles (vehicles with greater distance between the floor of the vehicle and the ground and those with narrower doors and aisles and tight seating configurations require more boarding and alighting time);
4. Method of fare collection—for local service, the exact-fare system saves between 1.4 and 2.6 seconds per passenger; and
5. Type of passenger—elderly people, handicapped people, and commuters exhibit distinctly different characteristics.

These results form the framework from which quantitative analyses can be performed, that is, the translation of loading and unloading time into terminal space and design criteria. Analyses of this type will become more and more critical in the future, particularly in view of increasing land costs in urban areas and reduced fuel allocations, which cause greater dependence on public transportation.

ACKNOWLEDGMENTS

This study was done as independent research by the authors using data collected by the authors, students at Newark College of Engineering, and personnel of the San Francisco Division of Traffic Engineering and the Chicago Department of Public Works. The authors gratefully acknowledge the assistance of those providing data and express their appreciation for the use of the computer facilities of Edwards and Kelcey, Inc.

REFERENCES

1. Boardman, T. J., and Kraft, W. H. Predicting Bus Passenger Service Time—Part II. Traffic Engineering, Feb. 1970.
2. Kraft, W. H., and Boardman, T. J. Predicting Bus Passenger Service Time. Traffic Engineering, Oct. 1969.
3. Pontier, W. E., Miller, P. W., and Kraft, W. H. Optimizing Flow on Existing Street Networks. NCHRP Rept. 113, 1971.