A Basic Method for Estimating Future Faregate Requirements

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ABSTRACT

The Bay Area Rapid Transit (BART) system may need to add faregates to its stations as patronage increases and headways are reduced in the future. A basic objective at BART has been the prevention of extended backlogs at the faregates. Essentially, patrons should be processed through the faregates at the same rate at which they arrive by train, or faster. This means that patrons from one train should be out of the station paid area before the next train arrives, that is, within the existing headway. To estimate the number of faregates needed in 1989 when patronage will have increased by 33 percent and headways are reduced to 2.25 min, the following steps were applied: (a) estimate the peak patron flows that will occur during the commute period, (b) calculate the time required for all passengers to exit each station, (c) develop exit time standards for different patronage levels and faregate conditions, and (d) calculate an index that weights the times a station does not meet the exit time standards. The index provides a single number to determine which stations will have the greater problems with patron delays. The study indicated that, based on 1980 patronage data, between 30 and 54 more aisles will be needed in 1989. However, depending on the type of equipment obtained, the actual number of faregate consoles required could be much greater.

Two important concepts to understand in reading this paper are the BART faregate consoles and the BART station centroids. A typical BART faregate array is shown in Figure 1. As indicated by the dashed lines, two faregate consoles make up one passenger aisle. The middle aisle is bidirectional and can be set by station agents for entry or exit, depending on the patron flow pattern. A centroid is a mezzanine area enclosed by faregates, service gates, railings, and a station agent booth. Stations within the BART system may have one, two, or three centroids.

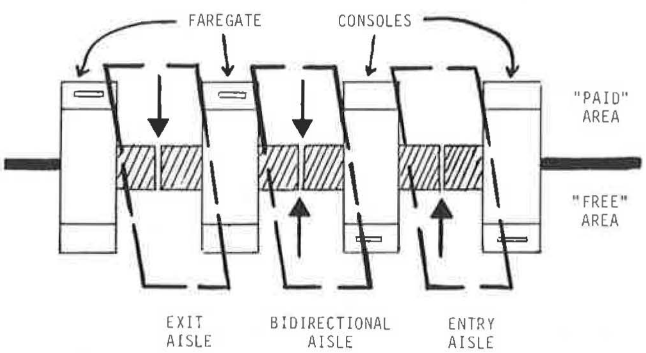

FIGURE 1 Typical BART faregate array.

BART is projecting that its patronage will increase by 33 percent in the next 5 years. At the same time, BART is planning to reduce its headways to 2.25 min in 1989. These two events will probably force BART to add faregates to its stations in order to process patrons within the headway time and thereby avoid long patron delays. The primary goal is to process patrons through the faregates at the same rate at which they arrive by train or at a faster rate. Patrons from one train should be out of the station paid area before the next train arrives.

Even with the current headways, some of the stations do not have enough aisles to process patrons in a timely manner, especially if two or three faregates are out of service. Conditions at the busy downtown stations and some of the end-of-line stations can become congested when a large crowd gets off the train during the commute periods. Shorter headways will therefore increase the need for more faregates. The purpose of the study was to estimate the number of faregates needed when shorter headways are implemented in 1989.

The actual number of faregates needed to avoid long patron delays was determined based on the following factors:

1. The projected peak number of patrons exiting a station from one trainload,
2. The time required to clear a station of all exiting patrons from one trainload,
3. The proposed time limits for clearing a station, and
4. An index for determining which stations have the more serious delay problems.

The index is a weighting factor of the occasions on which the exit time standards are exceeded and gives more importance to those occasions that are more frequent (e.g., all faregates operational). This report describes the four steps of the faregate analysis and shows how the number of faregates needed to avoid excessive patron delays at the faregates was estimated.

BACKGROUND

After several years of operation, It was found that some BART stations had significant delays at the faregates while other stations seemed to have no delays at all. One cause to which these differences can be attributed is that the patronage projections, on which the decision to install the automatic fare collection (AFC) equipment was based, were outdated--they had been made before the system opened in 1972. In many cases, the number of patrons using the stations was much greater or much less than the original estimate. A second cause can be attributed to reliability problems with certain AFC equipment installed in the busier stations. If two or three faregates were out of service, the patron delays would be extremely long. Sometimes the congestion became so bad that station agents would have to allow patrons to exit free, thus resulting in a loss of revenue for BART.

To ensure optimum use of all fare collection equipment and to reduce patron delays, the Management Services Division conducted a study in 1980 of BART's AFC equipment. Their objective was to develop a plan for relocating the AFC equipment in order to reduce patron delays at the busier stations. A secondary purpose was to reduce the number of unreliable faregate models used in the system.

A simple method was developed for analyzing the faregate requirements of each station. Exiting patron data was analyzed to obtain peak patron flow figures. Faregate capacities were determined and exit times were calculated for each station and centroid. Exit time criteria were also established. A special index was then developed as a tool for comparing the excess processing times. The study found that 10 stations did not comply with the exit standards. To eliminate all the instances of exit time criteria violations while at the same time removing most of the unreliable equipment, BART staff had to relocate nearly 100 faregate consoles. Sixty-nine consoles were moved to other stations and 27 were taken out of service. After the relocation project was completed, the number of failures per transaction dropped by 50 percent. The same methodology used in the 1980 study was used to estimate faregate requirements for the future. The following four sections of this paper describe each of the four steps of this method.

Patron Flow Rates

The first step in the determination of faregate requirements was to determine the peak patron flow rates that would occur during the commute period at each centroid. [These peaks occur when two rush-hour trains arrive at the station from opposite directions. Because all patrons are off-loaded almost simultaneously, the exit rush (7:00-9:00 a.m. at downtown stations, 4:00-6:00 p.m. at suburban stations) is considered to be a more critical case than the entrance rush.] In the 1980 study, the number of patrons whose tickets must be processed during these peak situations was determined using Data Acquisition System (DAS) 5-min traffic reports. Data from the 2-hr exit rush period was analyzed to determine both the highest patronage (worst case) and the 95th percentile for each station. The worst case patronage represented the largest number of patrons exiting during a 5-min period at each station during the days analyzed, while the 95th percentile was the level that was not exceeded 95 percent of the time during the 2-hr exit rush. These peak patron flows were used in the 1980 relocation design because the peaks were not expected to get much worse.

A complete reevaluation of projected patron flows is considered necessary, however, to provide a better basis for determining faregate requirements for 1989. The Research Division at BART has been requested to do a study of projected patron flows through the stations and through each centroid. Until those data are available, the 1980 data have to be used to provide a preliminary estimate of the magnitude of the problem.

Station Exit Time

By using the patron flow rates, the time required for all passengers to exit each station centroid can be calculated if the faregate capacity (number of patrons that can be processed per minute) is known. To establish the capacity of a faregate, stopwatch studies were conducted at Montgomery and Embarcadero stations (these are the two busiest stations in the BART system) to measure the flow rate of patrons through a faregate under queue conditions. The average processing rate measured for faregate equipment was slightly over 25 patrons per minute. Because this was determined from field observation, it is an actual rate that includes delays resulting from people inserting their tickets incorrectly or being underpaid and having to return to the addfare machine. The exit time was then calculated by dividing the patron flow rates by the centroid faregate capacity (number of aisles one-way multiplied by 25 patrons per minute per aisle). The calculated exit times for all station centroids are shown in Table 1. Exit times were also calculated with one faregate out of service at each centroid. This condition was analyzed to ensure that sufficient equipment redundancy exists at each centroid to prevent serious queuing problems from developing when equipment failures occur.

Exit Time Criteria

To provide a reference for evaluation of the calculated exit times for each station, exit time standards were developed. The exit time criteria given in the following table are based on anticipated headways in 1989.

	Time for Patrons to Exit (min)	
	95th % 2-Hr Rush	Worst Case
All Faregates Operational for All Lines	2.0	2.2
One Faregate Out of Service		
M Line (San Francisco-Daly City)	2.2	2.2
K Line (downtown Oakland)	2.2	2.2
A Line (Fremont)	2.2	3.0
C Line (Concord)	2.2	3.0
R Line (Richmond)	2.2	3.0

The basic standard was set at 2.0 min. This is the maximum desirable exit time with all gates operational for the 95th percentile patronage level. The 2.25-min headways on the M and K lines and intermittently on the R line were the basis for the 2.2-min standards. The longer headways on the A, C, and R lines allow the maximum permissible exit time to be set at 3.0 min. Although the headways on the A and C lines will actually be 4.0 min or greater, the need for equity on all lines favors using the 3.0-min standard for the A, C, and R lines. The possibility does exist, however, of changing the standards on these lines, especially if management feels the number of faregates mandated by these stringent standards is excessive.

Noncompliance Index

As a further tool, a noncompliance index (NCI) was formulated to provide a numerical tool for compari-

TABLE 1 Station Exit Times

	Exit Time (min)				
		All Faregates Working		1 Faregate Out of Service	
Station/Centroid	Aisles 1 Way	95 Percent Patron Level	Worst-Case Patron Level	95 Percent Patron Level	Worst-Case Patron Level
Lake Merritt	4	.7	.9	.9	1.2
Fruitvale	3	1.6	2.3	2.3	3.5
Coliseum	9	.3	.3	.3	.4
San Leandro	3	1.2	2.2	1.7	3.3
Bayfair	4	1.5	2.3	2.0	3.1
Hayward	3	1.6	2.2	2.4	3.3
South Hayward	2	1.9	3.2	3.8	6.4
Union City	4	1.5	2.0	2.0	2.7
Fremont	6	1.2	1.7	1.5	2.0
Rockridge	2	2.1	2.6	4.1	5.2
Orinda	3	1.5	2.6	2.2	3.8
Lafayette	4	1.4	2.1	1.9	2.8
Walnut Creek	5	1.8	2.5	2.3	3.1
Pleasant Hill	4	2.8	3.6	3.7	4.8
Concord	5	2.8	3.5	3.5	4.4
12th Street					
North	2	.7	1.1	1.6	2.2
Central	4	.9	1.3	1.1	1.7
South	2	.4	.6	.8	1.2
19th Street					
North	4	1.5	2.4	1.9	3.2
Central	2	1.4	2.4	2.9	4.8
South	2	.6	1.0	1.2	2.0
MacArthur	2	1.4	1.6	2.8	3.3
Oakland West	2	1.6	2.8	3.3	5.6
Embarcadero					
East	6	2.1	3.0	2.6	3.5
West	7	2.3	3.2	2.7	3.7
Montgomery					
East	8	1.5	1.7	1.7	1.9
West	10	2.3	2.6	2.5	2.9
Powell					
East	4	.5	.7	.7	.9
West	4	2.0	2.4	2.7	3.2
Civic Center					
East	4	1.2	1.9	1.5	2.6
West	4	1.6	2.6	2.1	3.5
16th/Mission	3	1.0	1.6	1.6	2.4
24th/Mission	4	1.6	2.6	2.1	3.4
Glen Park	5	1.7	2.5	2.2	3.1
Balboa Park	5	1.6	2.7	2.0	3.4
Daly City	8	2.5	3.2	2.9	3.7
Ashby	2	.8	1.3	1.7	2.5
Berkeley					
North	2	.1	.2	.2	.3
Central	4	.9	1.5	1.1	2.0
South	–	–	–	–	–
North Berkeley	2	1.0	1.9	2.1	3.5
El Cerrito	2	1.7	3.1	3.4	6.2
Del Norte	4	1.6	2.4	2.1	3.3
Richmond	2	1.4	2.3	2.9	4.5

son of exit time criteria violations. The NCI was developed by applying a weight factor to the exit time criteria violations. The weight factor is used to give a higher importance to the criteria violations that occur most frequently. Because the 95th percentile patronage level occurs more frequently than the worst case and all faregates are normally operating, this condition was arbitrarily given a weight of 4. Conversely, the situation in which the worst case patronage level is reached when one gate is out of service is the least likely condition and therefore was given a weight of 1. Obviously, the higher the NCI the more serious the exit time criteria violations. NCI is calculated by subtracting the exit time criteria (in minutes) from the station exit time (in minutes) and multiplying that by a weighting factor. The following calculation is for all faregates operational at the Pleasant Hill station:

95 percentile patronage:

(2.8-2.0) x 4 = 3.2.

Worst-Case patronage:

(3.6-2.2) x 3 = 4.2.

The following calculation is for one faregate out of service at the Pleasant Hill station:

95 percentile patronage:

(3.7-2.2) x 2 = 3.0.

Worst-case patronage:

(4.8-3.0) x 1 = 1.8.

The total NCI factor for the Pleasant Hill station, thus, is 12.2.

The NCI for the 26 stations expected to be in violation of the 1989 exit time criteria and the projected system total are given in Table 2. Although every station on the M line registers an NCI, the worst problems are expected at the Pleasant Hill and Concord stations. The system NCI of 110.7 gives an indication of the magnitude of the problems anticipated to occur in 1989 with the increased patronage and shorter headways. In the 1980 AFC Relocation Study, the NCI was found to be 22.4.

TABLE 2 Stations Not Complying with Exit Time Criteria

Station/Centroid	Noncompliance Index
Fruitvale	1.0
San Leandro	.3
Bayfair	.4
Hayward	.7
South Hayward	9.6
Rockridge	7.6
Orinda	2.0
Walnut Creek	1.2
Pleasant Hill	12.2
Concord	11.1
19th Street	
North	1.6
Central	4.6
MacArthur	2.3
Oakland West	7.4
Embarcadero	
East	4.9
West	6.7
Montgomery	
West	3.7
Powell	
West	2.6
Civic Center	
East	.4
West	2.5
16th/Mission	.2
24th/Mission	2.4
Glen Park	1.8
Balboa Park	2.7
Daly City	7.9
North Berkeley	.5
El Cerrito	8.3
Del Norte	.9
Richmond	3.2
System total	110.7

NUMBER OF FAREGATES NEEDED

The estimation of the number of faregates needed depends on the amount of reduction desired for the system NCI. For example, two levels of reduction are given in Table 3--(a) completely eliminate the NCI and (b) reduce the total NCI to less than 10.0. Fifty-four aisles are required to eliminate the NCI, while only 30 aisles are required to reduce the NCI to less than 10. The plot of faregates needed to reduce the system NCI is shown in Figure 2. As can be seen from Figure 1, 10 additional faregates could reduce the NCI to almost 50, and 40 additional faregates would only reduce the NCI to approximately 5. The plot graphically shows that adding more faregates has a decreasing impact on reducing the NCI. Again, the critical issue is what level BART wants to reduce the NCI to. Or, in other words, what degree of patron delays at faregates is BART willing to accept? As previously indicated, the exit time criteria could be made less stringent for the A, C, and R lines and thereby reduce the number of faregates needed on the system.

An important consideration in determining the number of faregates needed is the type of faregates to be added. BART would seek to find AFC equipment that would be compatible with the current system and that would also have high reliability. The critical issues would be the flexibility of the equipment and the number of consoles required to achieve single aisles. For example, the use of two faregate consoles for each initial aisle added to a station could almost double the number of equipment pieces needed. Twice the equipment needs means twice the cost.

TABLE 3 Estimated Number of Aisles Needed to Eliminate or Reduce the System Noncompliance Index (NCI)

	No. of Aisles Required	
Station/Centroid	To Eliminate All NCI Factors	To Reduce System NCI to Less Than 10.0
Lake Merritt	–	–
Fruitvale	1	–
Coliseum	–	–
San Leandro	1	–
Bayfair	1	–
Hayward	1	–
South Hayward	2	1
Union City	–	–
Fremont	–	–
Rockridge	1	1
Orinda	1	1
Lafayette	–	–
Walnut Creek	1	1
Pleasant Hill	3	2
Concord	3	3
12th Street		
North	–	–
Central	–	–
South	–	–
19th Street		
North	2	1
Central	2	1
South	–	–
MacArthur	1	1
Oakland West	2	1
Embarcadero		
East	3	2
West	4	3
Montgomery		
East	–	–
West	3	2
Powell		
East	–	–
West	2	1
Civic Center		
East	1	–
West	2	1
16th/Mission	1	–
24th/Mission	2	1
Glen Park	2	1
Balboa Park	2	1
Daly City	5	3
Ashby	–	–
Berkeley		
North	–	–
Central	–	–
South	–	–
North Berkeley	1	–
El Cerrito	2	1
Del Norte	1	–
Richmond	1	1
Total	54	30

CONCLUSIONS

The increased patronage and the shorter headways to be implemented in 1989 will create the need for additional faregates. These additional faregates will help to eliminate or reduce the patron delays at the gate arrays. The primary objective is to

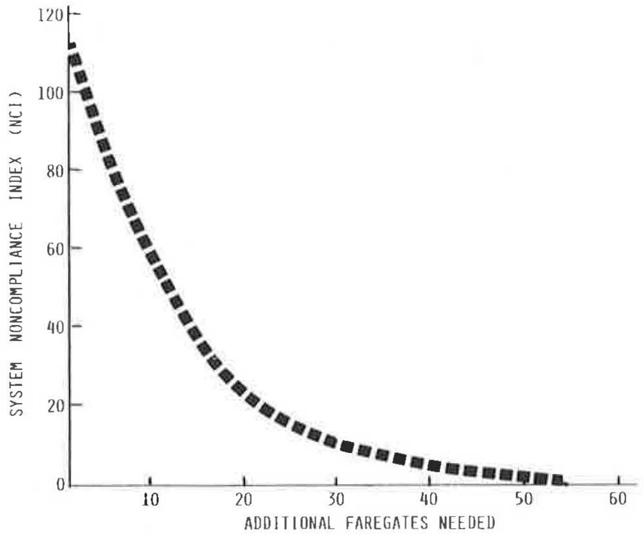

FIGURE 2 Additional faregates needed to reduce system noncompliance index.

ensure that the delays at the faregates do not exceed the headways. Based on the 1980 data, the estimated number of additional aisles needed to avoid patron delays in 1989 will probably be between 30 and 54. The actual number of faregate consoles required will be affected by the revised patronage projections for 1989 and the type of AFC equipment selected to augment the present system. These two factors could easily cause the required number of faregate consoles to double. At the same time, the exit time criteria established for the various lines have a significant impact on the number of additional faregates needed. Fairly stringent criteria were used in the current analysis to maintain equitable conditions for all the lines. Changing the exit time criteria on those lines with longer headways would reduce the number of faregates needed on the system by 20 percent or more.

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Planning an Integrated Regional Rail Network: Philadelphia Case

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ABSTRACT

Regional (commuter) rail systems, which serve the growing suburban areas, have had increasing ridership in many cities. In response to this growing need for high-quality regional transit service, many European and Japanese cities have upgraded their old commuter lines into regional rail systems with diametrical networks, regular schedules, and services integrated with local transit. Completion of the Center City Tunnel in Philadelphia in late 1984 connected two previously separate sets of lines (Western--formerly Pennsylvania and Northern--formerly Reading), combining them into an integrated regional rail system. The methodology, process, and major results of the planning for the regional rail systems are presented in this paper both in general terms and in their application to the Philadelphia system. Analysis of passenger requirements, operational factors, and economics has shown that the radial lines should be converted into diametrical (through) lines with fixed train routings and clear designations (such as R-1, R-2, and so forth). Extensive data concerning the system's physical characteristics, operations, and passenger volumes were collected and presented in many tables, charts, and diagrams. An elaborate methodology for selecting line pairs was developed. The guidelines for pairing included balancing of capacities and frequencies, minimizing track path conflicts, considerations of potential for through travel, capacity of tracks on the trunk section, operational characteristics of the two connected lines, and so forth. The recommended set of lines is presented with the basic data concerning its lines including their lengths, cycle times, headways, and train consists for peak and off-peak hours.