Southern California Rapid Transit District

Transit Research Unit
Operations Planning Section

Scheduling and Operations Planning Department

RTD

Southern California Rapid Transit District

DETECTING OPERATIONAL PROBLEMS ON HIGH FREQUENCY BUS LINES USING POINT CHECK DATA: A PROTOTYPIC METHODOLOGY

TRU Paper No.: FY93-03

by

Robert L. Jackson, Ph.D.
Timothy Mengle
Andy Galindez

Transit Research Unit
Operations Planning Section
Scheduling and Operations Planning Department
Southern California Rapid Transit District

Transportation Research Board
72nd Annual Meeting
Washington, DC

The authors would like to thank Meryl Schildkraut and Ricardo Aguirre for their assistance. The authors would also like to thank Stephen Parry, Ashok Kumar, Jon Hillmer and Frank Schroder who provided many helpful suggestions and insights.

Detecting Operational Problems on High Frequency Bus Lines

Using Point Check Data: A Prototypic Methodology

by

Robert Jackson, Timothy Mengle, and Andy Galindez

Abstract

Transit operators have long used point checks to, among other things, monitor on-time performance. Despite several important limitations inherent in point check data, it is possible to use these data to derive any number of informative and reliable indicators of transit operations other than on-time performance, such as gaps in service and bunching of vehicles. Moreover, by organizing a set of point checks as a time series, recurrent problems that might affect a line's operation can be detected. This paper describes a simple, prototypic methodology that was developed by Southern California Rapid Transit District (SCRTD) staff to assess changes in a line's relative operating effectiveness over time, using a series of point checks. As a demonstration, the method is used to evaluate the impact of schedule adjustments that were recently implemented on the operational effectiveness of two high frequency bus lines serving Downtown Los Angeles (viz., SCRTD Lines 16 and 30). The method is also applied to a third high demand line which did not undergo a schedule adjustment (viz., SCRTD Line 18). The analysis is restricted to the a.m. peak rush. To encourage the use of the prototypic method by other transit analysts, the paper features a step-by-step application of the technique. A summary of the benefits and limitations of the methodology is also provided.

Detecting Operational Problems on High Frequency Bus Lines Using Point Check Data: A Prototypic Methodology

by

Robert Jackson, Timothy Mengle, and Andy Galindez

I. INTRODUCTION

Despite the emergence of advanced service monitoring technologies such as Automated Vehicle Locating Systems (AVLs) and Automatic Passenger Counters (APCs), point checks remain a key source of service data for many transit operators, both large and small, including the Southern California Rapid Transit District (SCRTD). Nearly one-fourth of SCRTD's checking resources are currently allocated to the collection of point-check data. Point checks are most commonly used to track schedule adherence and monitor passenger loads at designated locations along the route of a line. At SCRTD, point checks are often made before and after a schedule adjustment (e.g., a reduction in the headway), which enables scheduling personnel to evaluate the impact of the adjustment on on-time performance and load ratios.

One major drawback attendant to using point checks for assessing service quality is that they describe passenger and/or vehicle activity at a single point on a line. Even if the "peak point" is checked, the data obtained may not provide much insight into service quality on other segments of the line. There are also drawbacks to using multiple point checks to evaluate running time quality because such checks provide little or no information about schedule quality between data collection points. Measurement error, due to checker estimation bias, recording errors, and so forth, can also be problematic. These and other well-known problems not withstanding, any number of reliable indicators of transit operations, in addition to schedule adherence, can be derived from point-check data.

This paper describes a simple prototypic methodology developed by SCRTD staff that utilizes multiple measures of operational effectiveness extracted from point checks to detect operational problems on a bus line. The method primarily involves creating increasingly detailed diagnostic graphs of selected bus operations indicators such as schedule adherence, gaps in service, and bus bunching. The diagnostic graphs are then used to: 1) assess the independent contribution of various operational factors to overall operational effectiveness; 2) pinpoint the time period where recurrent problems occur; 3) detect specific bus runs that create persistent operational problems; and 4) suggest remedial actions.

For expository purposes, the prototypic point-check diagnostic technique is used to evaluate the operational impacts of scheduling adjustments that were implemented on June 28, 1992, as part of the SCRTD's systemwide service change program. To encourage the use of the technique by other transit analysts, a step-by-step delineation of the methodology is presented for SCRTD Line 30. Additional applied examples of the technique are then provided for two other high frequency lines (namely, SCRTD Lines 16 and 18). Although the focus of the present paper is on the operational aspects of Lines 16, 18, and 30, some attention is given to factors that determine service effectiveness from the passengers' perspective (e.g., overcrowding). The paper concludes with a brief discussion of the strengths and limitations of the technique.

II. CREATING A POINT-CHECK DATABASE FOR DIAGNOSTIC ANALYSES

The prototypic point-check diagnostic technique involves four main steps. The first three steps, which taken together yield a time-series database required for graphing are as follows: 1) identify and define appropriate indicators to be extracted from the point check data; 2) edit raw point-check data and complete daily point check summary matrices; and 3) enter the raw data summaries into a personal computer spreadsheet and compute z-scores. A demonstration of Steps 1 through 3 is presented immediately below. Step 4, which involves graphing the point-check data summaries and interpreting the results, is discussed in the context of the three line-specific examples presented later in the paper.

To demonstrate Steps 1 through 3, a time series was constructed consisting of fifteen point checks conducted during the past year-and-a-half on SCRTD Line 30. Table 1 shows the dates of the point checks. The eight checks conducted during 1991 were considered "archival" and are included to demonstrate how the prototypic methodology can reveal long-term trends in operational effectiveness. The four checks conducted between January, 1992 and June 22, 1992, were treated as "pre" service change data. The three checks conducted in July 1992 are considered "post" service change data. Pico Boulevard and Figueroa Street, which is effectively the a.m. peak point location, was used to conduct all of the point checks (see Figure 1). A description of Line 30's operating characteristics is presented in Part III.

Table 1

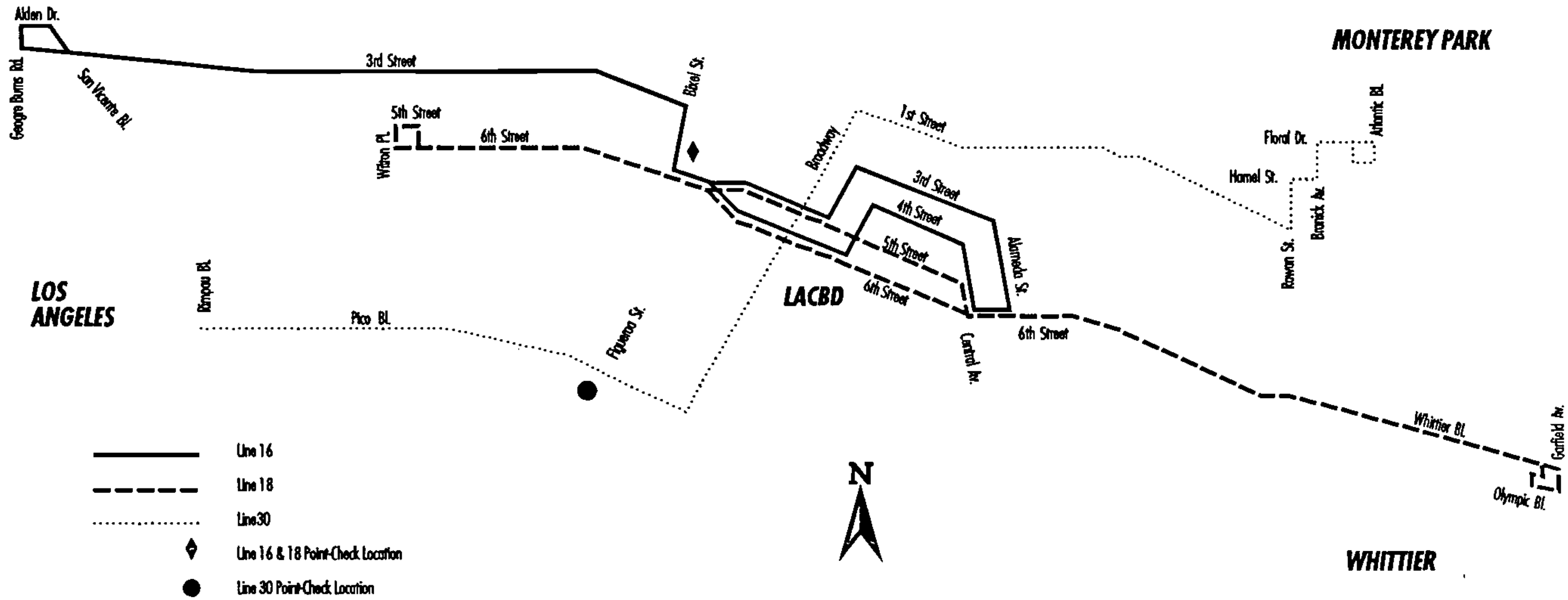
Line 30 Point Check Dates -- Pico Blvd. & Figueroa St.

(Northbound--6:30 - 8:00 A.M.)

Archival Data		Pre-6/28/92 Service Change	Post-6/28/92 Service Change
2/05/91	10/16/91	1/13/92	7/15/92
3/28/91	11/15/91	1/29/92	7/22/92
4/25/91	11/26/91	5/15/92	7/28/92
9/16/91	12/11/91	6/22/92	

FIGURE 1

Map of SCRTD Lines 16, 18, 30



210:141830

RTD

Prepared by Planning Dept. Graphics
for Scheduling and Operations Planning

July 1992

Step 1: Select and Define Operational Effectiveness Indicators

It is conceptually useful to categorize indicators extracted from point checks as either "passenger-related," "operational-related," or both. Categorizing indicators in this manner is important for diagnostic purposes because the two classes of indicators are not always strongly correlated. For example, a line may have adequate capacity (a factor of concern to passengers), but be operating poorly as measured by late buses and bunching. Also, whether a factor is considered "passenger-related" or "operational-related" will depend in large part on the type of line that is being studied (namely, high frequency versus low frequency). For example, on a high frequency line an "early bus" might be considered an operational problem, whereas on a low frequency line an "early bus" might be considered both an operational problem and a passenger-related problem.

For the present demonstration, a total of five "operational-related" service indicators were identified as appropriate for assessing the impact of the June, 1992 schedule adjustments on operational effectiveness: 1) bunched buses; 2) underloaded buses; 3) late buses; 4) gaps in service; and 5) buses out of sequence. The specific definition given to each measure is shown in Table 2.

In addition to the five operational indicators, two indicators of service quality that are of concern to passengers were examined (namely, overloaded buses and pass-up potential buses). Overloaded buses were defined as buses for which a schedule checker estimated that there were 68 or more passengers on board at the point check location. For Line 30, arriving loads were used since they tended to be higher than departing loads at the point check location (departing loads were used for Lines 16 and 18). A "pass-up potential" bus was defined as a vehicle having an arriving load of 75 or more passengers on Line 30 (a departing load of 75 or more passengers for Lines 16 and 18). It was felt that a bus carrying a load this size would have a very high probability of passing up passengers.

Table 2

Operational and Passenger Indicators Extracted from Point Checks

Conducted on SCRTD Lines 16, 18, and 30

Indicator	Type	Definition
Bunched Buses	Operational	Buses leaving point-check location within one minute of each other
Late Buses	Operational	Buses departing 4 or more minutes after scheduled time (3 or more on Line 30 only)
Buses Out of Sequence	Operational	Buses passing the point-check location in an order not consistent with the basic operating schedule
Underloads	Operational	Buses carrying less than a full-seated load (i.e., less than 43 passengers)
Gaps in Service	Operational	Incidences of buses spaced eight or more minutes apart (six or more minutes apart on Line 30 only)
Overloaded Buses	Passenger	Buses carrying 68 or more passengers (departing load for Lines 16 and 18; arriving load for Line 30)
Passup-Potential Buses	Passenger	Buses carrying 75 or more passengers (departing load for Lines 16 and 18; arriving load for Line 30)

It should be noted that at SCRTD, during the a.m. peak, high frequency local lines are scheduled for average maximum loads of 63 passengers which reflects a 1.45 loading standard on 43-seat vehicles.

Step 2: Edit Data and Complete Daily Point Check Summary Matrices

Once the specific outcome measures are selected and defined, the next step in creating a point-check based database involves calculating the number of incidences of each factor for each day in the series. One useful strategy for accomplishing this is to construct a matrix summarizing the key information. A sample point-check summary matrix, which was constructed for one of the days in the Line 30 time series (namely, July 15, 1992--a.m. peak Northbound) is shown in Table 3. The matrix includes basic point-check information such as estimated loads and departing times as well as columns for all of the aforementioned indicators. For the purposes of this demonstration, the a.m. peak is defined as 6:30am to 8:00am.

To complete the summary matrix for a single day, each trip is evaluated in terms of whether it satisfies the definition given to each of the various "passenger" and/or "operational" indicators. For those trips that satisfy the definition, a mark is placed in the appropriate column in the matrix. Finally, the total number of incidences of each factor is entered at the bottom of the matrix form (see Table 3). The same procedure is repeated for all the days in the series. Prior to completing the summary matrix, it is important to review the raw point-check data for "reasonableness" and completeness. Incomplete or inaccurate checks should be edited or eliminated prior to analysis since missing data and systematic estimation errors can yield misleading results and complicate the interpretation of the diagnostic graphs.

Table 3

Point Check Daily Data Summary Matrix

Line 30 -- Pico Boulevard and Figueroa Street -- 7/15/92 (6:30am-8:00am Northbound)

Point-Check Data					Operational Indicators					Passenger Factors	
Bus Run	Sched. Time	Depart. Time	Est. Passgr. Load	Bus Seq.	Service Gaps	Late Buses	Bunched Buses	Buses Out of Sequence	Under-loaded Buses	Over-loaded Buses	Pass-up Potential Buses
17	632	632	67	1							
15	636	637	59	2							
19	640	640	77	3						**	**
30	643	643	47	4							
16	647	646	41	5					**		
34	650	653	87	6	**	**				**	**
20	654	655	76	7						**	**
2	658	657	52	8							
18	706	706	76	10	**		**	**		**	**
31	702	707	65	9		**	**				
36	710	709	59	11							
28	714	714	46	12							
1	718	720	77	13	**		**			**	**
3	722	721	55	14			**				
23	725	725	84	15						**	**
5	729	728	32	16					**		
21	732	730	64	17							
24	736	735	64	18							
32	739	740	76	19						**	**
26	743	743	62	20							
4	747	749	83	21	**		**			**	**
7	751	750	28	22			**		**		
37	755	755	63	23							
9	759	757	23	24					**		
	Totals:	1,463			4	2	6	1	4	8	8

Step 3: Enter Sums Into a Personal Computer Spreadsheet and Compute Z-Scores

The summary data at the bottom of each daily matrix is then entered into a computer spreadsheet for analysis and graphing. To track changes in ridership and service levels over time, it is also useful to include the mean loads and the number of trips in the data layout. Table 4 shows the completed spreadsheet for the Line 30 example. The bottom portion of the spreadsheet shows the raw summary counts converted to z-scores. The conversion of raw scores to z-scores enables the comparison of indicators having different variances. Positive z-scores indicate better than usual performance and negative z-scores indicate worse than usual performance. A z-score of zero indicates average performance.

After completing Steps 1 through 3 of the prototypic point-check method, various diagnostic graphs can be generated and the results interpreted (i.e., Step 4 of the method). A description of the graphs that were produced as part of the present demonstration, as well as the interpretation of those graphs, is presented in the context of the three line-specific analyses below.

IV. SCRTD LINE 30 ANALYSIS

Line 30 Background

Line 30 operates from East Los Angeles, through Downtown Los Angeles, and terminates southeast of the Hollywood District (see Figure 1). The line has a total of 12.3 one-way miles. Line 30 is one of the heaviest lines in the SCRTD system, and carries about 40,000 riders per day. There are currently 38 a.m. peak buses assigned to the line. The a.m. peak headway is 3-4 minutes. As part of the June 28, 1992 service change program, the a.m. peak schedule on Line 30 was adjusted by, among other things, increasing the average headway between 6:30am and 8:00am from 3.6 minutes to 3.75 minutes. That is, the number of trips operated during this period was reduced from 25 to 24. The prototypic point-check diagnostic method was specifically used to see whether this change resulted in a short-term improvement or worsening of the line's operational effectiveness.

Table 4

Summary Counts and Z-Scores for Operational and Passenger Indicators Extracted from Point Checks
SCRTO Line 30 (6:30 AM - 8:00 AM)

	ARCHIVAL								PRE				POST		
	2/5/91	3/28	4/25	9/16	10/16	11/15	11/26	12/11	1/13	1/29	5/15	6/22	7/15*	7/22*	7/28/92*
Raw Data Summaries															
Operational Indicators															
Bunched Buses	6	7	4	14	11	10	7	8	6	2	6	9	6	6	3
Late Buses	1	1	2	6	5	8	1	2	3	2	2	1	2	1	2
Out of Sequence	0	0	0	0	2	2	0	1	0	0	1	1	1	0	0
Underloads	1	3	2	6	8	5	6	4	2	4	5	2	4	2	3
Service Gaps	4	3	3	4	5	4	4	3	7	3	3	3	4	4	4
Passenger Indicators															
Overloads	13	12	8	10	8	13	9	7	10	11	10	10	8	10	12
Pass-up Potential	8	7	5	8	6	8	3	4	5	6	7	4	8	7	11
Computed Z-Scores															
Operational Indicators															
Bunched Buses	0.33	0.00	1.00	-2.34	-1.34	-1.00	0.00	-0.33	0.33	1.67	0.33	-0.67	0.33	0.33	1.34
Late Buses	0.79	0.79	0.30	-1.68	-1.18	-2.66	0.79	0.30	-0.20	0.30	0.30	0.79	0.30	0.79	0.30
Out of Sequence	0.74	0.74	0.74	0.74	-2.04	-2.04	0.74	-0.65	0.74	0.74	-0.65	-0.65	-0.65	0.74	0.74
Underloads	1.50	0.43	0.96	-1.18	-2.25	-0.64	-1.18	-0.11	0.96	-0.11	-0.64	0.96	-0.11	0.96	0.43
Service Gaps	-0.13	0.85	0.85	-0.13	-1.11	-0.13	-0.13	0.85	-3.06	0.85	0.85	0.85	-0.13	-0.13	-0.13
Passenger Indicators															
Overloads	-1.62	-1.07	1.14	0.04	1.14	-1.62	0.59	1.70	0.04	-0.52	0.04	0.04	1.14	0.04	-1.07
Pass-up Potential	-0.77	-0.27	0.73	-0.77	0.23	-0.77	1.74	1.24	0.73	0.23	-0.27	1.24	-0.77	-0.27	-2.27
Z-Score Averages															
Operator Indicators	0.65	0.56	0.77	-0.92	-1.58	-1.30	0.05	0.01	-0.24	0.69	0.04	0.26	-0.05	0.54	0.53
Passenger Indicators	-1.20	-0.67	0.94	-0.37	0.69	-1.20	1.16	1.47	0.39	-0.14	-0.12	0.64	0.19	-0.12	-1.67
All Indicators	0.12	0.21	0.82	-0.76	-0.93	-1.27	0.36	0.43	-0.06	0.45	-0.01	0.36	0.02	0.35	-0.10
Ridership Variables															
Estimated Ridership	1605	1542	1483	1619	1502	1528	1497	1527	1465	1554	1452	1556	1463	1548	1611
Mean	66.9	64.3	61.8	57.8	53.6	58.8	57.6	58.7	61.0	62.2	60.5	62.2	61.0	64.9	67.1
No. of Trips	24	24	24	28	28	26	26	26	24	25	24	25	24	24	24

Notes: (1) Point Check Location: Pico Boulevard and Figueroa Street (Northbound)
(2) An asterisk indicates that the check was conducted after the 6/28/92 service change

Line 30 Results

Using widely available spreadsheet software, several diagnostic graphs were prepared in an effort to assess the impact of the June, 1992 schedule adjustment. Figure 2 shows mean estimated a.m. peak passenger loads arriving at Pico and Figueroa on Line 30, northbound, for the period February, 1991 through July, 1992. Figure 3 shows estimated ridership at the same location. Most of the variability in the mean load series can be attributed to changes in service levels. However, beginning subsequent to the schedule adjustment, there does appear to be a slight upward trend in ridership developing on the line; additional point checks will have to be conducted to confirm this possibility.[a]

As a preliminary global assessment of changes in operational effectiveness on Line 30 following the implementation of the June, 1992 schedule change (namely, decreasing service by one trip during the a.m. peak), a graph summarizing the five "operational-related" factors was generated (see Figure 4). The graph was produced by simply summing and averaging the z-scores for all five "operational" factors. It can be seen from this graph that service quality, from an operational perspective, has improved considerably since the period September-November, 1991. More pertinently, it <u>appears</u> that, with effective scheduling, increasing the headway slightly during the a.m. peak in June, 1992 did not have an adverse impact on the line's overall operational effectiveness.

---

[a]It is important to note that on June 1, 1992, SCRTD implemented a special four-month "50-Cent Discounted Bus Ticket Program" in response to the widespread civil unrest that occurred in Los Angeles in late April and early May, 1992. The 50-cent fares were available only through the advance purchase of ticket books. Discounted tickets are sold in books of 10 at a cost of $5.00 per book; the regular adult local fare on SCRTD lines is $1.10. Senior Citizens and physically handicapped riders were able to buy books of 20 tickets for $5.00, or 25 cents per ticket. All lines in the system that accept local fares were involved in the program. An examination of the point check data for Line 30 suggests that patronage did not increase measurably (at least during the a.m. peak) as a result of the discounted ticket program. It is very likely, however, that the fare mix may have changed and that ridership increased during other times of the day (or in the off-peak direction) when there is more available capacity. These possibilities are being investigated as part of a separate analysis being conducted by District staff.

SCRTD Line 30 Mean Loads
Pico/Figueroa 6:30-8:00am Northbound

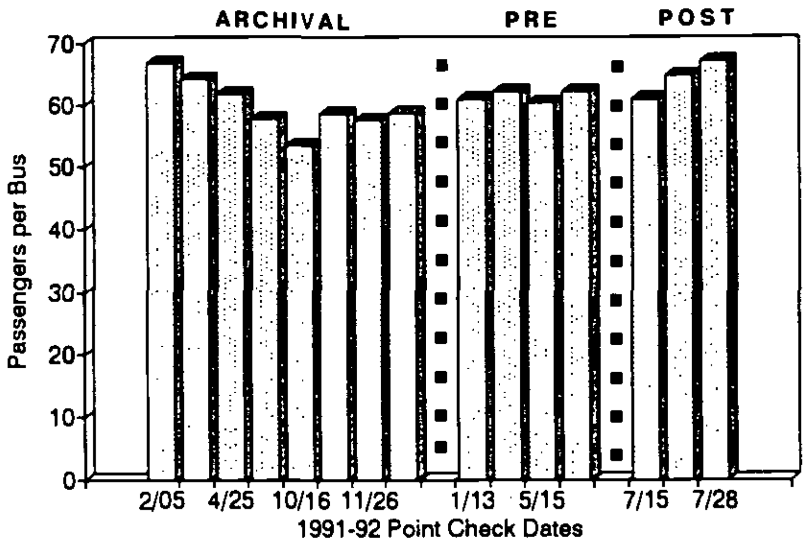


FIGURE 2

SCRTD Line 30 Total Ridership
Pico/Figueroa 6:30-8:00am Northbound

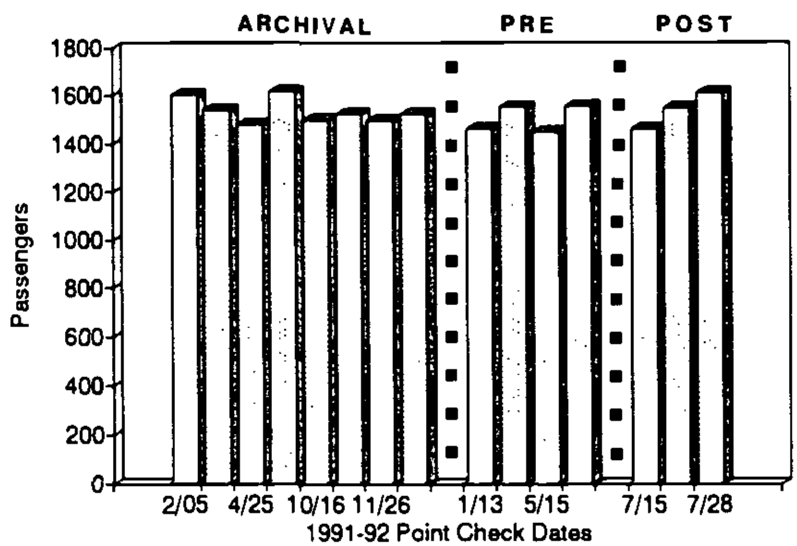
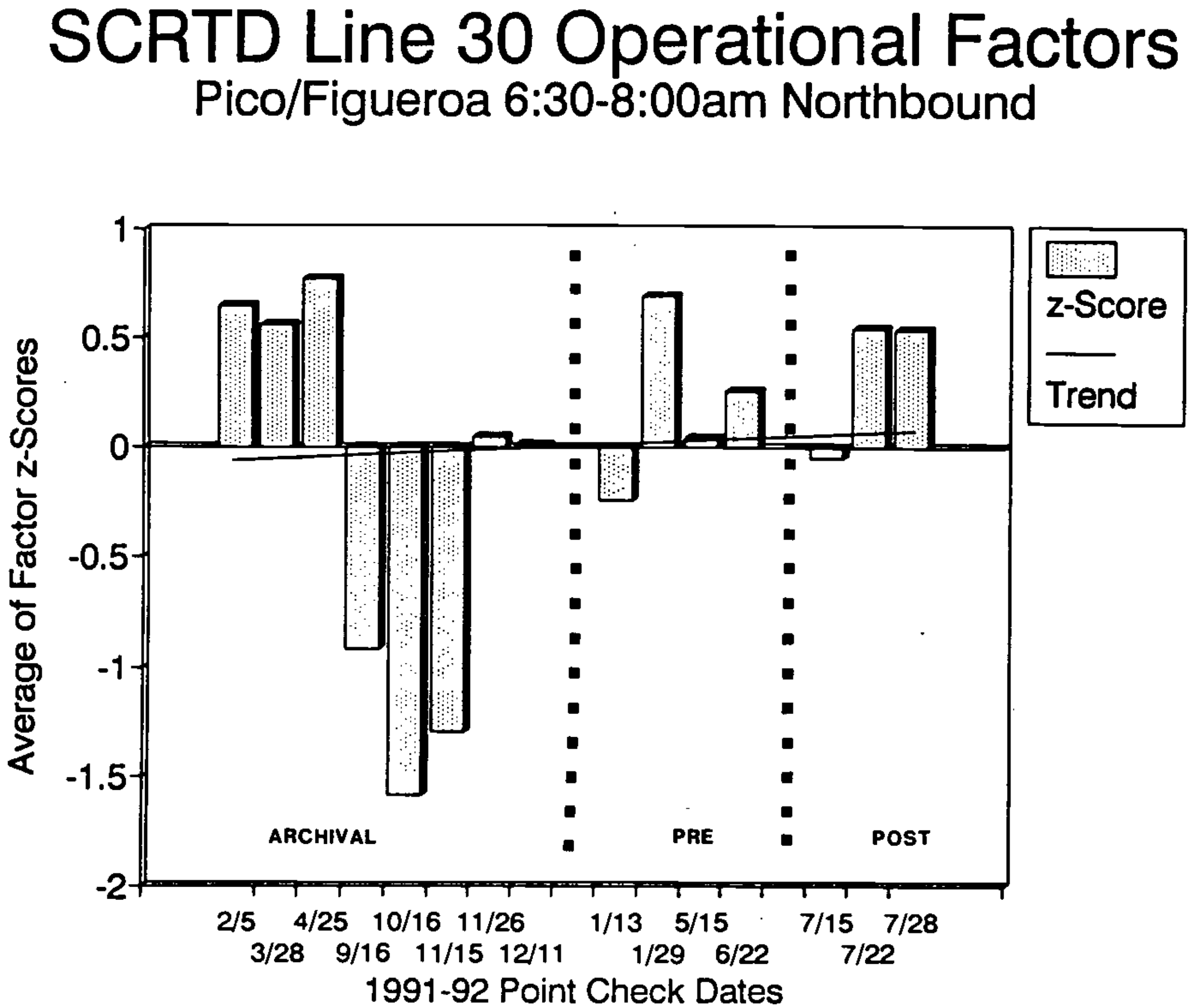


FIGURE 3

FIGURE 4


SCRTD Line 30 Operational Factors
Pico/Figueroa 6:30-8:00am Northbound
1
0.5
0
-0.5
-1
-1.5
-2
Average of Factor z-Scores
z-Score
Trend
ARCHIVAL
PRE
POST
2/5
3/28
4/25
9/16
10/16
11/15
11/26
12/11
1/13
1/29
5/15
6/22
7/15
7/22
7/28
1991-92 Point Check Dates

Although the summary diagnostic graph presented in Figure 4 is sufficient for revealing general trends in operational conditions on a line, it does not show the relative contribution of each indicator to overall operational effectiveness. To simultaneously assess the relative contribution (positive or negative) of multiple factors, the z-scores of all the operational factors can be plotted as a composite stacked-bar graph. The composite graph shown in Figure 5 suggests that in relative terms, the major problems causing poor line operation on Line 30 during September-November, 1991 were late buses, bunched buses, and buses out of sequence--symptomatic of a running time problem. There were also more underloads during September-November, 1991 due, in part, to increased available capacity. Service adjustments made in December 1991 seem to have effectively dealt with these problems.

Concerning the June, 1992 service change, none of the operational factors systematically deteriorated from the "pre" service-change period (January-June 22, 1992; see Figure 5). In fact, on balance, it would appear that, from an operational perspective, the line was running more smoothly following the schedule adjustment than was the case prior to the service change, indicating good schedule quality and/or improved operator adherence to the schedule.

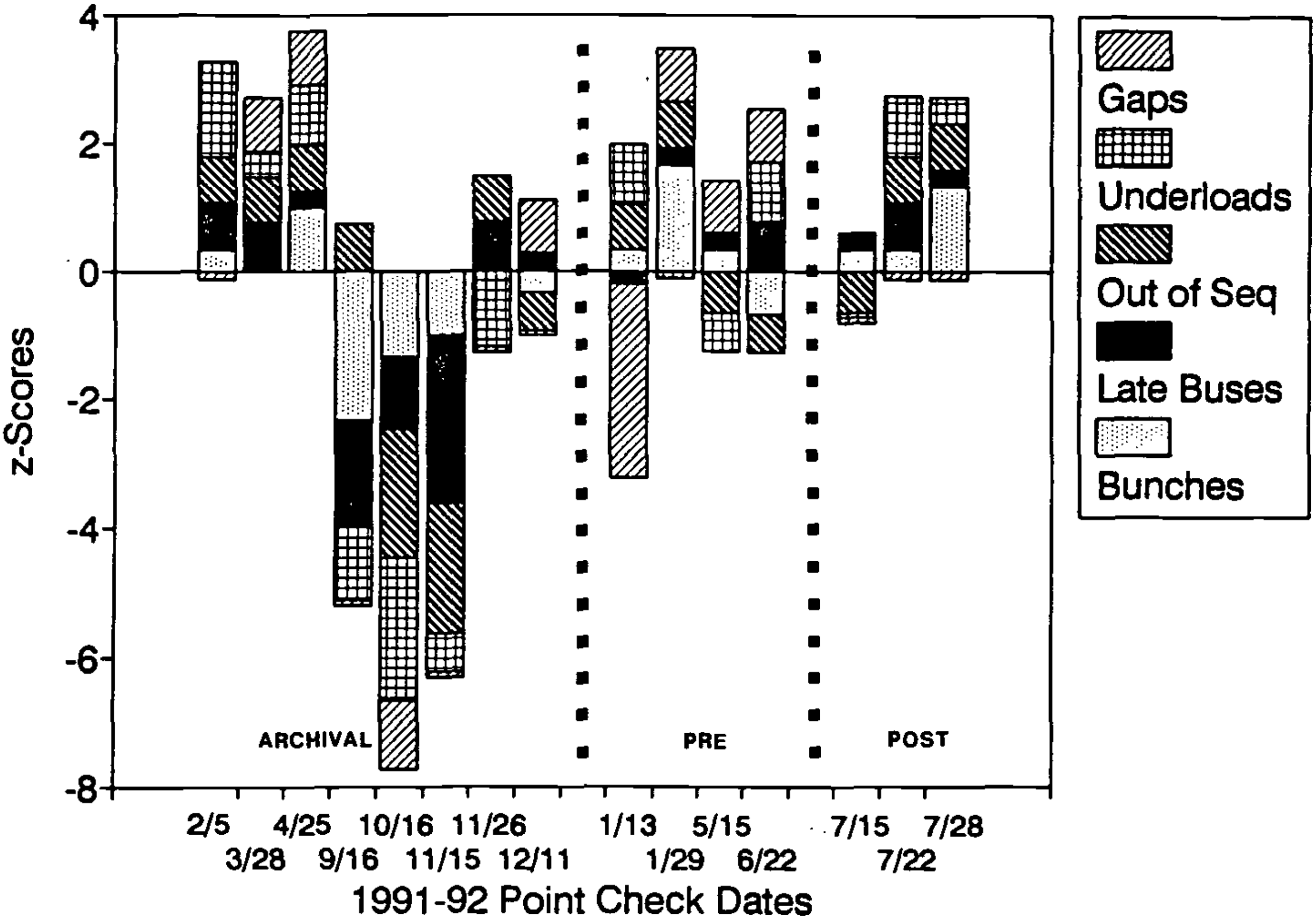
Because the data in Figures 4 and 5 reflect an 18-month time frame, it was possible that the archival data (i.e., 1991) in the series may have been obfuscating the true effect of the June, 1992 service change. To test this possibility, we excluded the 1991 data from the series and recomputed the z-scores. The resulting composite graph of operational factors is shown in Figure 6. As can be seen, the major finding remains the same. From an operational perspective, overall service quality appears to have improved somewhat with the implementation of a new schedule in June, 1992.

Although increasing the headway slightly during the a.m. peak did not seem to have an adverse impact on Line 30's operation (at least at the peak load

FIGURE 5

SCRTD Line 30 Operational Factors

Pico/Figueroa 6:30-8:00am Northbound



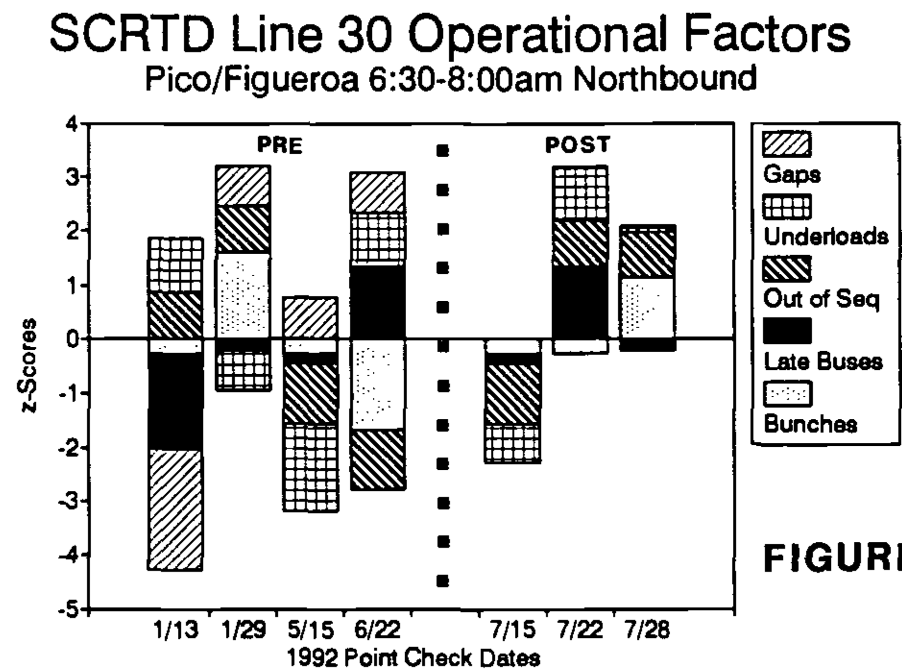


FIGURE 6

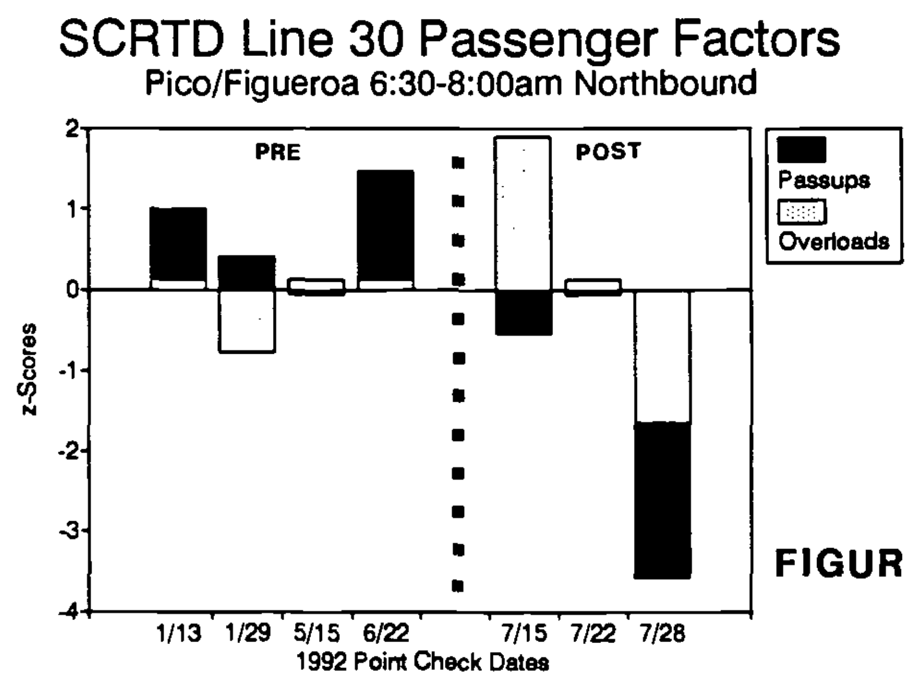


FIGURE 7

point), it was very possible that the net decrease in capacity had a negative impact on the line from the passengers' perspective. Figure 7 shows the composite graph of the two "passenger-factors." The pattern suggests that service quality on Line 30, from the passengers' perspective did, in fact, deteriorate somewhat, apparently as a sequela to the service change. Average pre- versus post-loads increased from 62 to 64, respectively, resulting in an increase in overloaded buses and pass-up potential buses.

One feature of the prototypic point-check methodology is that increasingly detailed graphs can be generated to study a line's operation. The most detailed graphs we have developed, to date, are minute-by-minute plots of time-series data, which provide a unique diagnostic tool for tracking individual bus runs and isolating operational problems on a line. Figure 8 shows a minute-by-minute graph of actual bus sequences for the 15 days in the Line 30 sample. By plotting the data in this manner, incidences of bus bunching and service gaps are also revealed. The plot was created using unedited computerized point check data stored on SCRTD's mainframe and, therefore, may deviate slightly from the edited data shown in Table 4. The format was programed using a subroutine contained in a widely available statistical software package.

Among the potential problems revealed by Figure 8 are:

- o the period 7:40-7:50 a.m. shows a worsening in bunching, service gaps and overloading as compared with the previous period--whether this is due to the schedule, changes in demand patterns, or other factors is not clear from the data; and
- o the ninth bus in the scheduled sequence is among the most erratic, operating very late on 7/15 and early on 7/28.

FIGURE 8

LINE 30 MINUTE-BY-MINUTE BUS SEQUENCE PLOT

POINTS CHECKS AT PICO ANO FIGUERDA -- NORTHBOUND

DEPARTING TIME	2/5/91	3/28	4/25	9/16	10/16	11/15	11/26	12/11	1/13/92	1/29	5/15	6/22	7/15	7/22	7/28
630						1	1	1							
631									1	1		1			
632				1							1		1		1
633			1	2										1	
634															
635							2			2	2			2	
636	1	1	2									2			2
637				3	2	2							2		
638					1	3		2	2						
639	2						3	3		3					3
640		2			3								3		
641		3	3								3	3		3	4
642					4	4	4	4	3			4			
643				4					4		4		4		
644															
645	3			5	5		5			4				4	
646				6					5				5	5	
647										5	5				
648			4									5			
649				7		5		5							5
650	4					6		6							
651		4	5							6				6	6
652		5		8							6	6			
653	5	6					6		6				6	7	
654	6				7	7		8							
655					6				7				7		7
656				9	8	8						7			
657	7		6		9		7	7		7		8	8		
658		7					8				7	9			
659	8		7	10			9		8	8					8
700									9		9			8	
701		8	8					9		9	10				9
702					10					10				9	
703						9						10			
704						10									
705		9		11						11					
706	9						10	10	10				10		
707	10		9			11	11					11	9		
708			10	12	11						11			10	10
709		10		13	12			11	11				11		
710								12		12				11	
711		11		14			12		12						11
712	11		11									12			
713					13						12				
714	12							13		13	13		12	12	
715		12	12		14							13			
716				15		14	13	14							12
717				16	15		14				14				
718		13							13						
719						15	15	15	14						13
720	13		13		16	13						15	13	13	
721	14	14		17					15	14		14	14	14	
722			14								15				14
723	15	15	15							15					
724						16	16	16	16			16			
725						12				16			15	15	15
726											16				
727	16	16	16				17								
728				18	17	17		17	17	17		17	16	16	16
729				19	18			18			17				
730	17				19	18	18				18	18	17		
731		17	17	20						18				17	
732						19	19								
733		18	18												17
734								19	18						
735	18			21	20					19	19		18		
736			19			20		20	19					18	
737	19				21		20					19			18
738				22								20			
739		19				21	21			20					19
740		20	20		22			21					19	19	
741	20						22								
742				23		22									
743										21	21		20		
744					23			22				21			
745		21	21												
746	21						23		21		20	22			
747						23		23		22				20	
748							24		22		22			21	20
749		22		24	24			24					21		21
750	22		22	25					23	23	23	23	22		22
751					25	24									
752														22	
753	23		23			25		25							
754		23			26		25			24				23	
755				26	27						24	24	23		
756				27					24						23
757			24										24		
758	24	24			28	26	26	26			25	25		24	24
759				28					25	25					

Once a seemingly recurrent problem has been detected, additional point checks can be conducted and/or remedial actions can be undertaken (e.g., enhanced road supervision and discussions with the specific operators involved and/or with the schedule maker assigned to the line) to determine the root cause of the problem.

In summary, this step-by-step analysis of point checks taken before and after the June 28, 1992 service change demonstrated the utility of the prototypic diagnostic technique for impact analysis, especially for detecting operational problems on a high-frequency line. The various diagnostic graphs, taken together, support the following tentative conclusions concerning the operational effective and overall service quality on Line 30 following the June, 1992 service change:

- the schedule adjustment was effective in that widening the headway from 3.6 minutes to 3.75 minutes did not adversely impact the line's performance during the a.m. peak rush
- the schedule adjustment has contributed to increased overloaded buses and pass-up potential buses during the a.m. peak rush, and this condition should be closely monitored;
- there are a few isolated, but ostensibly recurrent, problems that surfaced subsequent to the June, 1992 schedule change that should be investigated, such as "bunching" between 7:40am and 7:50am.

V. SCRTD LINE 16 ANALYSIS

The second demonstration of the point-check diagnostic methodology examines the impact of the June, 1992 service change on the operational effectiveness of SCRTD Line 16. Point-check data were available for seven dates (four "pre" and three "post"). The point checks were conducted at 6th St. and St. Paul Ave. (eastbound). The dates of the checks on Line 16 (and Line 18) are as follows:

PRE SERVICE CHANGE	3/18/92
	5/29/92
	6/5/92
	6/16/92
POST SERVICE CHANGE	6/30/92
	7/14/92
	7/28/92

Line 16 Background

Line 16 (W. Third Street) operates through Downtown Los Angeles and terminates southwest of the Hollywood District. The line has a total of 9.3 one-way miles, and carries about 25,000 riders per day, on a four-minute peak headway. Currently there are 23 a.m. peak buses assigned to the line. The location used to monitor the line is 6th Street and St. Paul Avenue, which is the maximum load location (see Figure 1). Among other things, Line 16 had been experiencing excessive overloading during the a.m. peak rush. Loads at the a.m. peak point average nearly 66 per bus during the period prior to the service change. Unlike Line 30 in the previous example, which experienced a net reduction of one trip during the a.m. peak (6:30am-8:00am), two trips were added to Line 16 during the a.m. peak as part of the June, 1992 service change program. Accordingly, the primary purpose in applying the prototypic point-check methodology to Line 16 was to assess the impact of the new schedule on the line's operational effectiveness.

Following the procedures delineated above, summary matrices were prepared for the four "pre" and the three "post-intervention" point checks. The raw data totals for seven indicators (5 operational and 2 passenger) were then entered into a spreadsheet and the corresponding z-scores computed. Table 6 shows these data. Finally, various diagnostic graphs were generated. The results of the analysis are summarized below.

Line 16 Results

Figure 9 shows the mean loads on the line at Sixth Street and St. Paul Avenue before and after the intervention. Figure 10 shows the pattern of ridership during this same period. The data suggest that the additional service did result in a reduction in mean loads but that the added capacity has been accompanied by an increase in passenger demand with estimated ridership higher during the last two point checks in the series than all previous checks.

Table 6

Summary Counts and Z-Scores for Operational and Passenger Indicators Extracted from Point Checks SCRTD Line 16 (6:30 AM - 8:00 AM)

	PRE				POST		
	3/18	5/29	6/05	6/16	6/30	7/14	7/28
Raw Data Summaries							
Operational Indicators							
Bunched Buses	6	5	2	2	9	7	6
Late Buses	1	4	3	0	0	2	3
Out of Sequence	0	1	0	0	0	1	1
Underloads	1	1	2	3	6	3	3
Service Gaps	3	4	4	0	1	3	2
Passenger Indicators							
Overloads	11	13	12	9	7	12	11
Pass-up Potential	8	9	7	5	2	5	6
Computed Z-Scores							
Operational Indicators							
Bunched Buses	-0.30	0.12	1.38	1.38	-1.57	-0.72	-0.30
Late Buses	0.59	-1.47	-0.78	1.27	1.27	-0.10	-0.78
Out of Sequence	0.87	-1.15	0.87	0.87	0.87	-1.15	-1.15
Underloads	1.09	1.09	0.45	-0.18	-2.08	-0.18	-0.18
Service Gaps	-0.41	-1.12	-1.12	1.74	1.02	-0.41	0.31
Passenger Indicators							
Overloads	-0.15	-1.20	-0.67	0.90	1.95	-0.67	-0.15
Pass-up Potential	-0.94	-1.40	-0.47	0.47	1.87	0.47	0.00
Z-Score Averages							
Operator Indicators	0.37	-0.51	0.16	1.02	-0.10	-0.51	-0.42
Passenger Indicators	-0.54	-1.30	-0.57	0.68	1.91	-0.10	-0.07
All Indicators	0.11	-0.73	-0.05	0.92	0.48	-0.40	-0.32
Ridership Variables							
Estimated Ridership	1427	1413	1395	1279	1266	1445	1448
Mean	68.0	67.3	66.4	60.9	55.0	62.8	63.0
No. of Trips	21	21	21	21	23	23	23

Notes: (1) Point Check Location: 6th Street and Saint Paul Avenue (Eastbound)

(2) All checks were conducted in 1992

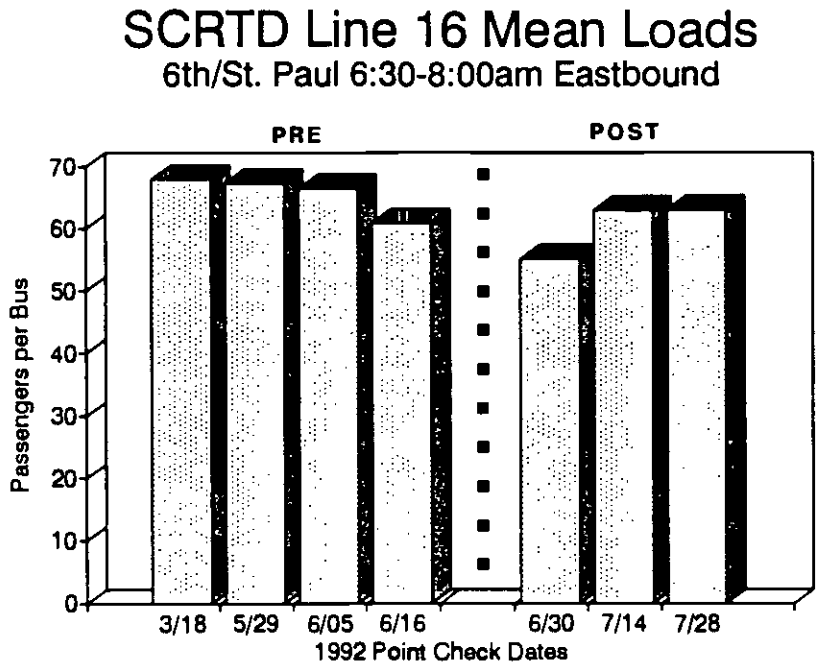


FIGURE 9

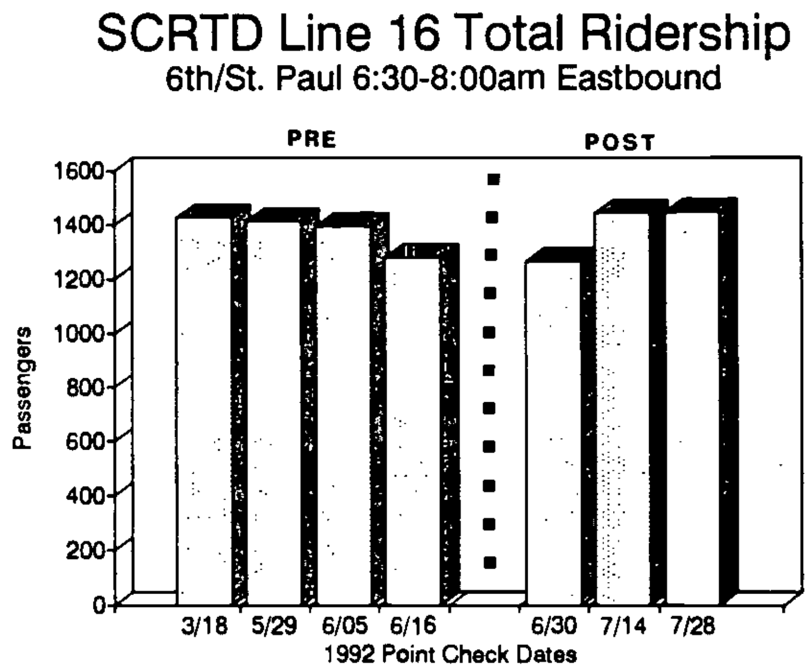


FIGURE 10

Figures 11 and 12 show the composite diagnostic graphs for "operational" and "passenger" factors, respectively. A minute-by-minute plot of bus sequence and departing loads by actual departing times is shown in Figure 13.

The following conclusions concerning the impact of the June service change on Line 16 a.m. peak performance are supported by the graphs:

- an increase in ridership lagged the increase in service by 2-3 weeks, which may indicate adaptive behavior on the part of the riders;
- initial adverse operational impacts that accompanied the introduction of the new schedule (viz., bus bunching) seem to have subsided, which suggests that operators have now adapted to the reduced headways;
- service quality, from the passenger's perspective, has improved since the schedule change was implemented.

VI. SCRTD LINE 18 ANALYSIS

The final applied example of the point-check based analytical method involves SCRTD Line 18, which did not experience any change in service levels during the a.m. peak as part of the June 28, 1992 service change program. Accordingly, our general hypothesis for this line was that there would be no major changes in the operational effectiveness of the line after June 28.

Line 18 Background

Line 18 (W. Sixth Street - Whittier Boulevard) operates from East Los Angeles, through Downtown Los Angeles, and terminates in Koreatown northwest of Downtown Los Angeles (see Figure 1). The line has a total of 11.8 one-way miles. West of the LACBD, Line 18 operates parallel to Line 16 for a distance of approximately three miles. Line 16 and 18 enter the LACBD on W. 6th Street. Line 18 carries about 30,000 riders per day, on a four-minute peak headway. Currently there are 26 a.m. peak buses assigned to the line. The location used to monitor the line was 6th St. and St. Paul Ave., (same as Line 16), which is the a.m. peak load location for the line.

SCRTD Line 16 Operational Factors

6th/St. Paul 6:30-8:00am Eastbound

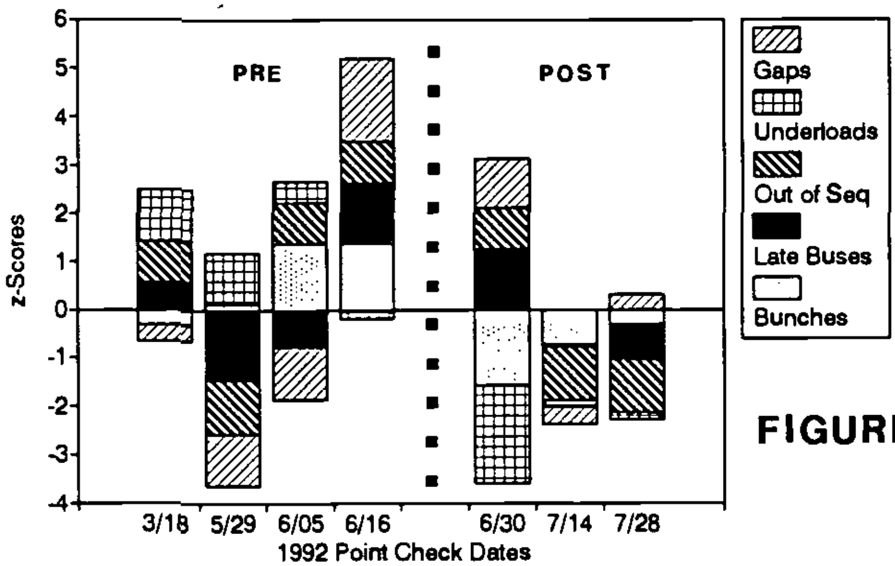


FIGURE 11

SCRTD Line 16 Passenger Factors

6th/St. Paul 6:30-8:00am Eastbound

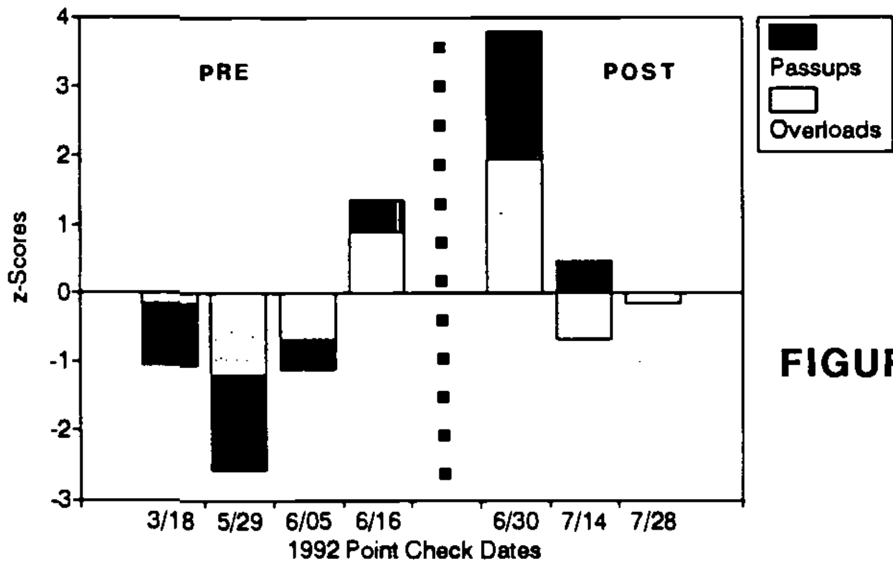


FIGURE 12

FIGURE 13

LINE 16 MINUTE-BY-MINUTE BUS SEQUENCE AND DEPARTING LOADS PLOTS

POINTS CHECKS AT SIXTH AND ST. PAUL -- EASTBOUND

DEPARTING TIME	3/18/92	5/29	6/5	6/16	6/30	7/14	7/28	3/18/92	5/29	6/5	6/16	6/30	7/14	7/28
630														
631														
632					1							67		
633														
634							1							81
635					2							40		
636			2	2		2				79	77		70	
637		2				1	2		84				69	67
638														
639	2							78						
640	3							66						
641						3	3						74	70
642		3	3	3	3				75	57	71	81		
643					4							64		
644														
645	4						4	85						74
646				4		4					85		57	
647		4				5			77				52	
648														
649					5							69		
650		5	4	5	6	6			79	81	79	49	51	
651					7		5					48		81
652	5							69						
653														
654	6					7	6	79					69	78
655														
656				6			7				71			74
657			5							81				
658			6							71				
659		6			8				87			50		
700		7	7			8			76	72			47	
701	7	8		7			8	87	35		80			51
702			8							79				
703				8	9						60	70		
704														
705														
706	8		9			9		80		55			78	
707		9							72					
708							9							66
709	9			9		10		74			78		79	
710					10		11					59		31
711					11	11	10					17	39	78
712	10							72						
713			10	10	12					80	71	54		
714						12							46	
715	11		11					64		69				
716							12							70
717		10		11					79		59			
718			12							49				
719		11			13				78			71		
720				12							62			
721														
722			13							54				
723		13				13			45				86	
724	12	12			14	14	13	64	69			80	79	71
725	13			13	15	15		49			45	42	40	
726				14			14				17			85
727	14	14						33	66					
728			14				15			6				76
729														
730		15		15	16				66		44	72		
731			15			16	16			59			73	47
732					17							36		
733	15	16	16			17	17	75	46	47			50	44
734														
735	16			16				57			61			
736					18							49		
737														
738					19							41		
739			17	17		18	18			68	59		72	58
740	17							67						
741							19							56
742		17			20	19			68			52	76	
743														
744														
745				18		20					65		39	
746	18	18			21			62	82			31		
747	19		18				20	45		67				60
748							21							39
749		19	19	19		21			70	77	40		64	
750														
751														
752				20	22						62	74		
753						22							61	
754														
755				21			22				22			32
756		20							56					
757	20							82						
758			20							81				
759					23	23	23					50	74	69

Line 18 Results

Table 7 shows the spreadsheet with z-scores for Line 18. Figure 14 shows the mean loads at Sixth Street and St. Paul Avenue for the period March, 1992 through July, 1992. Figure 15 shows total estimated ridership for each day in the series during this same period. As expected, given that no schedule adjustment were made on the Line, there do not appear be any consistent shifts in ridership or mean loads on Line 18 since the June 28, 1992 service change program. There is, however, what appears to be small increase in ridership during the first part of June which coincides with the discounted ticket program previously described.[a] Diagnostic graphs for Line 18, including minute-by-minute plots are shown in Figures 16, 17, and 18.

The following conclusions concerning trends in Line 18 a.m. peak performance are supported by the data;

- there is no clear pattern of change as regards passenger-related service indicators during the period studied--this was expected because service levels remained the same throughout
- operational indicators showed a downward trend, which was not expected. Bunched buses seem to the major problem since bunching consistently worsened over each of the last five checks in the series. This operational pejoration may be, in part, a function, of erratic summer traffic patterns that influence running times. Similar problems were observed on parallel Line 16. Additional data collected throughout the summer and into the fall will be required to assess this possibility.

---

[a]Assuming that the discounted ticket program did, in fact, attract some new riders to the line, then it seems reasonable to ask why there was an initial increase in ridership on Line 18, but no concomitant increase on parallel Line 16 (during the a.m. peak). One plausible explanation is that there was slightly more capacity available on Line 18 than on Line 16 when the discounted-ticket program was initiated. Specifically, based on the two pre-June 1 checks, Line 16 averaged 66.5 passengers as compared to Line 18 which averaged 64.3 passengers. Load estimation error is largely controlled by the fact the same person recorded data for both lines at the same location. Although this margin appears nominal, both the perception and the reality of potential Line 16 riders may have been that there was no available capacity on the line, while there was some marginal capacity on Line 18. This pattern also suggests that there is a ceiling of about 66 persons (average), at which point new riders will not use the system regardless of whether a reduced fare program is in effect. These suggestions, however, are purely speculative and serve as targets for future research.

Table 7

Summary Counts and Z-Scores for Operational and Passenger Indicators Extracted from Point Checks
SCRTD Line 18 (6:30 AM - 8:00 AM)

	PRE				POST		
	3/18	5/29	6/05	6/16	6/30	7/14	7/28
Raw Data Summaries							
Operational Indicators							
Bunched Buses	4	4	0	2	4	6	8
Late Buses	1	1	0	1	1	1	3
Out of Sequence	0	1	0	0	1	0	1
Underloads	3	0	1	1	2	3	1
Service Gaps	3	2	2	1	1	3	2
Passenger Indicators							
Overloads	15	8	14	12	11	14	9
Pass-up Potential	9	6	13	7	8	11	7
Computed Z-Scores							
Operational Indicators							
Bunched Buses	0.00	0.00	1.67	0.84	0.00	-0.84	-1.67
Late Buses	0.17	0.17	1.37	0.17	0.17	0.17	-2.23
Out of Sequence	0.87	-1.15	0.87	0.87	-1.15	0.87	-1.15
Underloads	-1.36	1.50	0.54	0.54	-0.41	-1.36	0.54
Service Gaps	-1.32	0.00	0.00	1.32	1.32	-1.32	0.00
Passenger Indicators							
Overloads	-1.27	1.56	-0.87	-0.06	0.35	-0.87	1.15
Pass-up Potential	-0.12	1.17	-1.85	0.74	0.31	-0.99	0.74
Z-Score Averages							
Operator Indicators	-0.33	0.10	0.89	0.75	-0.01	-0.50	-0.90
Passenger Indicators	-0.70	1.37	-1.36	0.34	0.33	-0.93	0.95
All Indicators	-0.43	0.46	0.25	0.63	0.08	-0.62	-0.37
Ridership Variables							
Estimated Ridership	1305	1322	1426	1335	1313	1367	1305
Mean	65.3	66.1	71.3	66.8	65.7	68.4	65.3
No. of Trips	20	20	20	20	20	20	20

Notes: (1) Point Check Location: 6th Street and Saint Paul Avenue (Eastbound)

(2) All checks were conducted in 1992

SCRTD Line 18 Mean Loads
6th/St. Paul 6:30-8:00am Eastbound

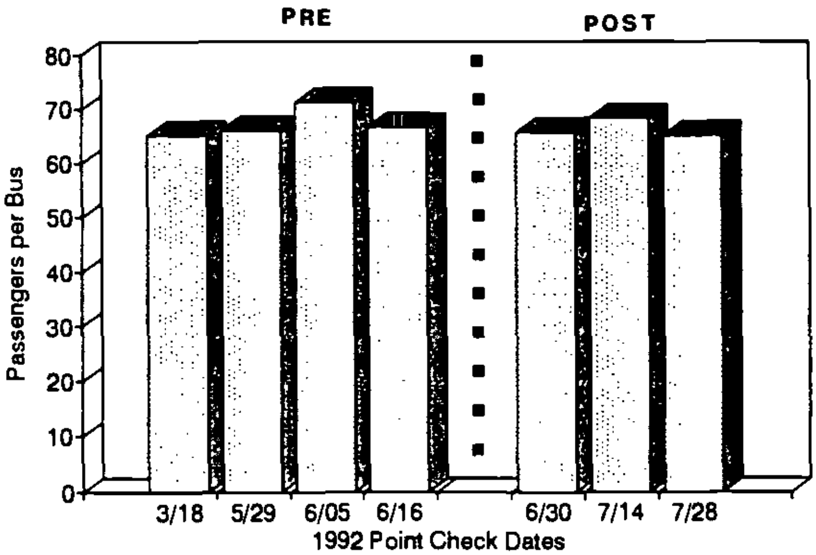


FIGURE 14

SCRTD Line 18 Total Ridership
6th/St. Paul 6:30-8:00am Eastbound

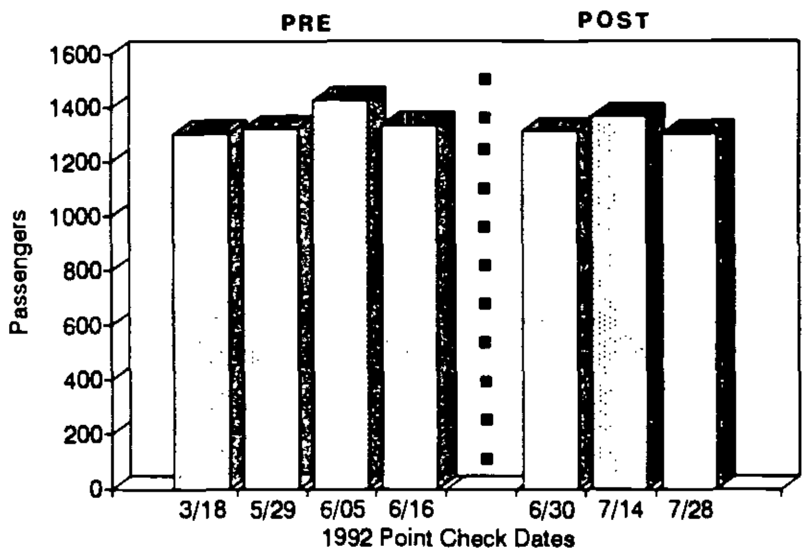


FIGURE 15

SCRTD Line 18 Operational Factors

6th/St. Paul 6:30-8:00am Eastbound

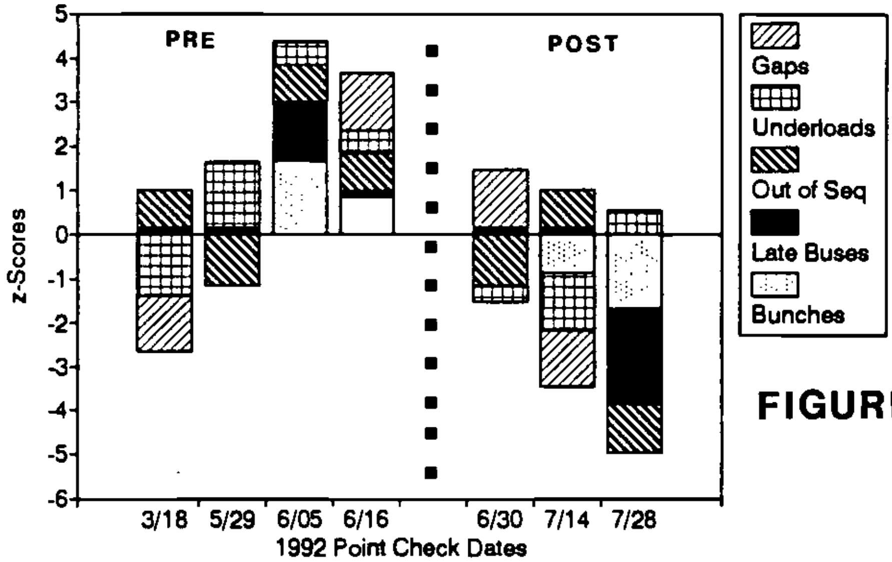


FIGURE 16

SCRTD Line 18 Passenger Factors

6th/St. Paul 6:30-8:00am Eastbound

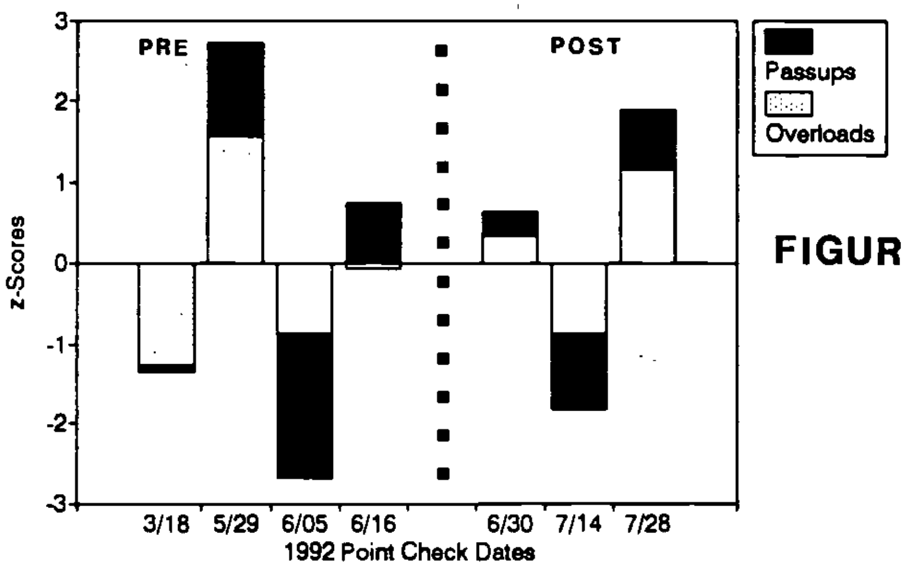


FIGURE 17

FIGURE 18

LINE 18 MINUTE-BY-MINUTE BUS SEQUENCE AND DEPARTING LOADS PLOTS

POINTS CHECKS AT SIXTH AND ST. PAUL -- EASTBOUND

DEPARTING TIME	3/18/92	5/29	6/5	6/16	6/30	7/14	7/28	3/18/92	5/29	6/5	6/16	6/30	7/14	7/28
630			1							82				
631		1					1		78					73
632														
633				1							85			
634														
635		2		2	2	2			70		78	78	81	
636														
637	2		2				2	85		80				66
638														
639	3							1						
640		3		3					79		74			
641			3							67				
642														
643			4		3	3	3			84		89	68	77
644	4			4				81			78			
645		4							81					
646						4	4						79	79
647														
648		5			4				80			87		
649			5	5						78	77			
650	5				5			88				68		
651			6			5				77			75	
652	6				6	6		71				47	41	
653														
654														
655		6	7				5		84	54				65
656		7		6			6		71		73			80
657	7			7				86			70			
658														
659					7	7	7					75	78	55
700	8	8	8	8			8	76	64	79	66			29
701					8							71		
702														
703						8							74	
704			9	9						34	61			
705	9					9		72					41	
706							9							82
707					10							37		
708		10	10		9				64	81		77		
709	10	9		10				77	55		75			
710						10							82	
711						11							46	
712		11		11					44		54			
713			11		11		10			76		64		82
714	11						11	74						65
715	12		12					27		82				
716		12		12					64		52			
717						12							81	
718					12							81		
719		13					12		57					69
720														
721			13	13						65	71			
722														
723		14	14	14	13	13	13		61	56	45	82	76	60
724	13				14			83				35		
725	14						14	69						49
726						14							78	
727														
728		15		15					53		41			
729	15		15					1		71				
730					15							59		
731	16	16		16		15	15	70	49		68		69	52
732			16		16	16	16			44		52	36	49
733														
734														
735														
736	17							65						
737			17		17	17				79		68	61	
738		17					17		77					57
739														
740				17							81			
741														
742														
743	18					18		78					82	
744					18		18					76		77
745				18							77			
746		18	18						65	81				
747														
748			19	19						78	55			
749														
750		19			19		20		66			59		77
751	19					19		77					55	
752														
753														
754				20							54			
755					20							53		
756	20	20	20					50	60	78				
757														
758														
759														

VII. SUMMARY AND CONCLUSION

This paper presented a simple, step-by-step procedure for organizing a point-check database and producing diagnostic graphs that can be used to detect operational problems on a transit line. The method was applied to three high frequency lines in the SCRTD system, two of which underwent schedule adjustments as part of a large-scale service change program in June, 1992. Taken together, the three applied analyses support the conclusion that point checks, when graphed as a time series, provide a unique diagnostic tool for studying and monitoring operational problems on a line before and after an intervention.

The prototypic point-check based diagnostic technique offers transit operators at least five specific benefits. First, unlike more costly ride checks, which typically reflect the operating conditions on a line for a single day, the point-check based method uses multiple checks that enable trend analysis. In fact, if the point-check database is maintained across years, then it can be used to detect, among other things, seasonal patterns. Second, by graphically displaying multiple-day data, specific problems in a schedule can be pinpointed and corrective actions suggested. Third, the method conceptually distinguishes between "passenger" and "operational" factors, which adds focus and insight to analysis. Fourth, the prototypic technique is flexible; the user can select and define <u>ad hoc</u> indicators depending upon the research objectives and the type of line being analyzed. Lastly, the technique is easy to implement since it only requires point check data, an IBM-compatible PC, and standard spreadsheet software.

It should be noted that the methodology described in this paper has yet to be tested on all types of transit services (e.g., express buses). Although the technique seems well-suited for high frequency bus lines, it may not be appropriate for all types of transit lines. Moreover, a key limitation of the method is that the data reflect passenger and operational activity at a single point on the line, which may not be representative of operational conditions on the rest of the line. Another concern that necessarily attaches to this, and other point-check based methods, is that non-time dependent indicators (e.g., passenger loads and pass-up potential buses) are subject to measurement errors that, if large enough, can seriously distort the results. However, with effective checker training and careful data editing, these errors can be kept to a minimum.

In conclusion, the prototypic point-check based method is a cost-effective diagnostic tool for detecting operational problems on a line. The method can be easily implemented by other transit operators. Refinements and further testing of the methodology are encouraged.