Service Reliability Program of the Southern California Rapid Transit District: A Test of the Short-Term Impacts on Line 26-51

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In mid-1989, the Southern California Rapid Transit District (SCRTD) implemented an innovative program designed to improve the performance of bus lines experiencing persistently poor service reliability. The Service Reliability Program (SRP) uses specially assigned road supervisors to intensively supervise problem lines and work closely with line operators and other District personnel to identify and resolve the underlying causes of the problems. A quasi-experimental test that was conducted in spring 1991 to quantify the short-term impacts of the SRP on the performance of Line 26-51 (Avalon Boulevard—7th Street—Virgil Avenue—Franklin Avenue) during the morning peak period. Line 38-71 (West Jefferson Boulevard—City Terrace), which did not receive any SRP treatment, was used as an experimental control to strengthen the pre/post design. The results of this test support the conclusion that intensive road supervision, coupled with team-oriented approaches to problem identification and resolution, can have a positive effect on service quality. Without adding service, and despite a small seasonal increase in ridership, improvements were found for various service reliability indicators on the target line (e.g., the number of bunched buses and pass-ups). The quantitative findings were generally corroborated by qualitative assessments made by both Line 26-51 customers and operators. Comparable service reliability improvements were not found on the control line.

The Southern California Rapid Transit District (SCRTD) began devising and testing innovative approaches to using road supervisors in resolving problems of poor service reliability on its bus lines in late 1988. In mid-1989, a large-scale project known as the Service Reliability Program (SRP) was formally implemented. Under this program, specially assigned mobile road supervisors interact with line operators to identify root causes of problems on a line, test alternative scheduling strategies in the field, and work with scheduling and operations planning personnel to adjust schedules or take other actions, as indicated. Once the underlying problems on a line are documented and corrective actions are either implemented or planned, ongoing supervision is maintained via a multiple-line "corridor-based" service management tactic.

An overview of SCRTD's SRP and the various steps involved in the SRP process is given. A special test that was conducted in spring 1991 to quantify the short-term effects of intensive, team-oriented supervision on service reliability, customer perceptions, and operator assessments is summarized. The test provides a much-needed demonstration of applied research in the area of nonautomated bus service management.

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SERVICE RELIABILITY PROGRAM

Background

The hypothetical causal model of poor service reliability that provided the conceptual underpinnings for SCRTD's SRP is shown in Figure 1. The model suggests that poor service reliability results from two general classes of factors. The first class consists of "transient shocks," all of the various nonregular, and largely unpredictable, occurrences that temporarily disrupt a line's operation (Path A). Inclement weather, detours, bus breakdowns, and accidents are examples of such transient shocks. The second class consists of "chronic problems," insufficient service levels, improper distribution of running time, and habitual rule infractions by one or more line operators (Path B). The model also implies that chronic problems on a line may lead to such operator-experienced outcomes as frustration, dissatisfaction, and apathy (Path C).

According to the hypothetical model, the causal relationship between transient and chronic antecedents and adverse operational outcomes is not necessarily direct. The overarching relationship may be mediated by various factors. In developing the SRP, "maladaptive responses" made by line operators in response to transient and chronic problems were considered important mediating factors. For example, if an operator opts to leave a time point early because of insufficient running time (perceived or real) and service reliability on the line is compromised, then this would be considered a maladaptive response (Paths D–E and F–E).

Following the logic of the model, it became apparent that if the underlying causes of poor service reliability on certain District lines were to be understood and effectively rectified, then a nontraditional approach to field service management would be required. In order to rectify poor service reliability, a rudimentary SRP was implemented on a single SCRTD line in December 1988. Specifically, four road supervisors (two during the morning and two at night) were assigned to intensively supervise SCRTD Line 16 (West 3rd Street Line). Instead of focusing on policing the line, a deliberate attempt

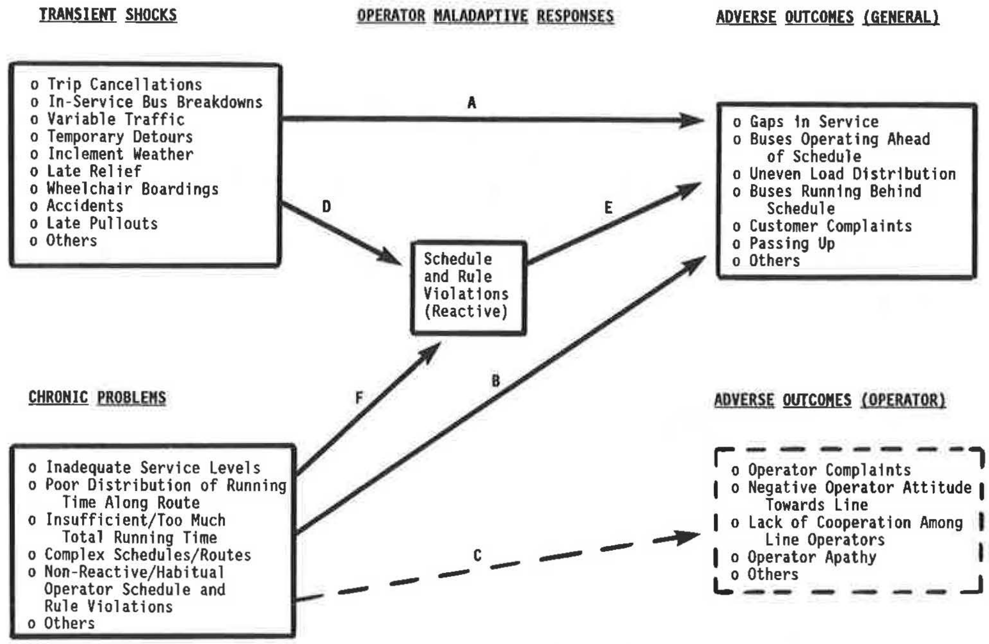

FIGURE 1 Hypothetical causal model of poor service reliability.

was made to work with the operators to identify and resolve any problems that might be contributing to poor service quality.

For example, supervisor interviews with Line 16 operators revealed that a single misplaced time point was causing most of them to run behind schedule leaving the Los Angeles-central business district (CBD). The problem was especially acute during the p.m. peak rush. A minority of operators adapted to this chronic problem by operating ahead of schedule, while the majority of operators adapted by operating late. Once the problematic time point was identified and removed, on-time performance improved from approximately 30 percent to nearly 85 percent during the p.m. peak period. The traditional approach in solving this problem might have been to simply cite those operators who were in violation of schedule rules.

Given the success of the pilot program, the Board of Directors of the SCRTD approved funding for an expanded and more structured SRP beginning July 1989. Since 1989, more than 40 lines have been targeted at various times by the SRP. These lines account for more than 60 percent of the District's total daily ridership. As of September 1991, 22 of SCRTD's 111 full-time road supervisors (20 percent) were assigned to the SRP.

General SRP Process

On the basis of lessons learned from evaluating alternative service management strategies during the past 2 years, a systematic procedure for implementing the SRP on a newly targeted line was adopted. Figure 2 shows the strategic plan known as the "SRP process." The key steps are summarized as follows:

Preimplementation Phase

Step 1: Publicize the Program Previous experience has shown that when the SRP is wel publicized, operators are much more willing to become actively involved. One strategy now used by SCRTD to publicize the program is to hang large SRP banners, posters, or both at the participating divisions.

Step 2: Collect Baseline Data An important feature of the SCRTD's SRP is that attempts are made to systematically evaluate program impacts. Depending on the objectives of the research, several types of evaluation data may be collected, such as point checks, operator opinions, and customer opinions.

Step 3: Conduct a Preimplementation Strategy Meeting Before SRP is implemented on a line, a team meeting between the road supervisors assigned to the line and the scheduling and operations planning personnel is usually held to develop a preliminary implementation strategy.

Implementation Phase

Step 4: Implement Program on Target Line During the first week on a target line, supervisors attempt to interview each operator. The interview is designed to provide operators additional details and objectives of SRP and to solicit comments and specific suggestions concerning problems on the line. A primary goal during the first week is to have operators accept the supervisor as a partner rather than an adversary,

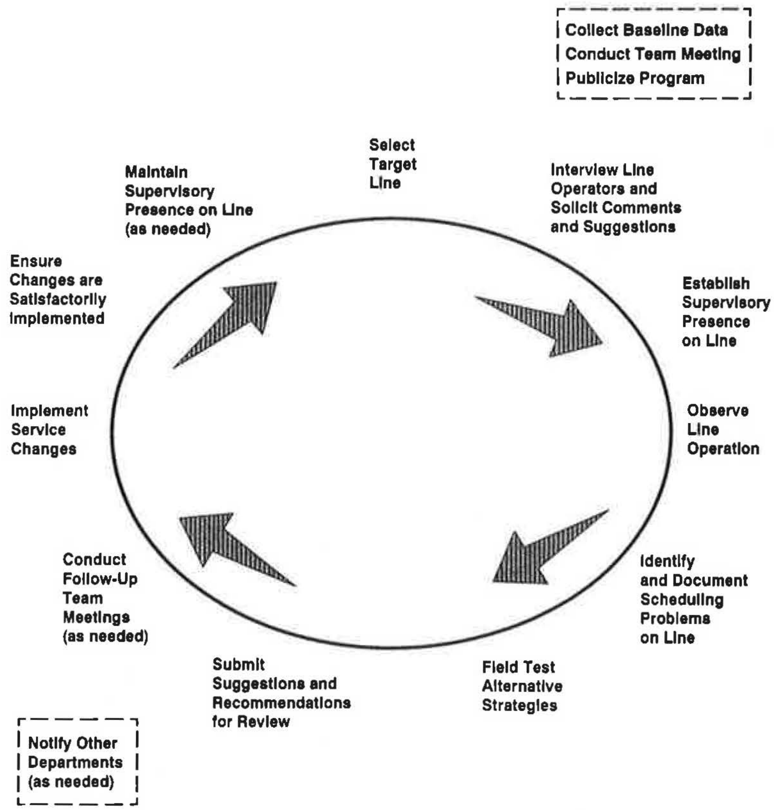

FIGURE 2 General SRP process.

who has a shared interest in resolving problems. Other supervisory activities during the first week include observing the line operation and identifying and correcting possible safety hazards.

Step 5: Devise and Test Strategies to Correct Persistent Problems During the second and subsequent weeks, road supervisors establish a highly visible supervisory presence on the targeted line. Teams of two supervisors (each in a mobile unit) are typically assigned to a line for the period 5:00 a.m. to 9:00 p.m. (two per shift). Once the current schedule is being operated as effectively as possible, road supervisors devise, test, and document alternative strategies to alleviate chronic problems. This unique feature of SRP encourages the road supervisor to both actively manage a line and test new ideas. Specific suggestions and recommendations are then submitted for review by staff in special weekly reports.

Step 6: Hold Follow-Up Team Meetings During the implementation period, follow-up team meetings are held with supervisors, operations control staff, and scheduling/operations planning staff as needed. The purpose of these meetings is to discuss and further refine recommendations made by the road supervisors. The meetings often result in planning or implementation of specific short-term and long-term actions. Changes such as minor running-time adjustments or additional pull-out time allocations are often implemented within 1 to 3 days, and a temporary schedule is issued. Supervisors attempt to keep line operators apprised of the status of pending long-term actions.

Step 7: Monitor Effects of Service Adjustments If schedule, route, or other types of adjustments are implemented, supervisors monitor the line to ensure that changes are working as planned, and the results are reported to scheduling/operations planning staff.

Postimplementation Phase

Step 8: Maintain Ongoing Supervisory Presence on Line Following the period of intensive supervision, SRP road supervisors maintain a long-term presence on the line through corridor-based service management. Under the SRP corridor concept of line management, multiple lines (usually three to five) operating within well-defined bus transit corridors are systematically visited. The goal is to sustain the effect of the initial intensive supervision effort in a cost-effective manner by promoting the perception among operators that a line is being regularly monitored.

The SRP is a nontraditional, team-oriented approach to strategic service management. A unique feature of the program is that it focuses on identifying and correcting underlying scheduling and operational problems that may lead to maladaptive responses by operators. The SRP has enhanced the District's capability to provide timely and effective responses to scheduling problems by expanding communications between road supervisors and scheduling/operations planning personnel. Previous assessments of the program's effectiveness have shown that when a line is being intensively supervised under the SRP, line operators become more actively involved in identifying problems and suggesting solutions to the problems, passenger loads generally become better distributed, schedule adherence improves, there is a reduction in schedule-related customer complaints, and interdriver cooperation increases (especially for lines operating out of multiple divisions).

TEST OF SRP ON LINE 26-51

To demonstrate the short-term effects of the SRP process on a line's performance, a special study of SCRTD Line 26-51 (Avalon Boulevard—7th Street—Virgil Avenue—Franklin Avenue) was undertaken in April 1991. The line, which carries approximately 26,000 passengers daily, became a candidate for the program when customer complaints, operator complaints, and point-check data indicated that the line was experiencing poor service reliability, including pass-ups.

Hypotheses

Figure 3 shows the previous hypothetical model of poor service reliability as applied to Line 26-51 (pre-SRP). The plus signs in the model indicate that implementing the SRP on Line 26-51 was expected to have a positive impact on all the theoretical links depicted. The factors in the model were derived in large part from information extracted from the preimplementation surveys of Line 26-51 customers and operators. Although the only major transient shock reported by Line 26-51 operators was variable traffic conditions, there were several chronic problems on the line, including a concern that a few operators were not adhering to the schedule. The following hypotheses were tested:

- Hypothesis 1: service reliability would improve on Line 26-51 following implementation of the SRP,
- Hypothesis 2: customer perceptions of the quality of service on Line 26-51 would improve as a result of the SRP,
- Hypothesis 3: Line 26-51 operators would perceive that key scheduling and operational improvements had occurred on their line following implementation of the SRP,
- Hypothesis 4: cooperation among Line 26-51 operators would improve once the SRP was implemented.

Study Design

To test the hypotheses, a pre/post design with an untreated nonequivalent control line was used. Before and during the period when SRP was implemented on Line 26-51 (target line), service reliability was simultaneously monitored on Line 38-71 (control line), which did not receive any SRP treatment. The general form of the design is as follows:

Target line (26-51)	0	0	SRP	0	0
Control line (38-71)	0	0		0	0

The above quasi-experimental design was considered superior to a simple pre/post test, since the use of an untreated control line minimizes the risk of attributing an effect to the SRP when the effect may have been due to more generally occurring phenomena.

Line 26-51 Characteristics (Target)

Line 26-51 consists of two lines that were combined at the end of 1988 in an attempt to eliminate duplicate service along a 3-mi segment and reduce operating costs. Line 26 is the

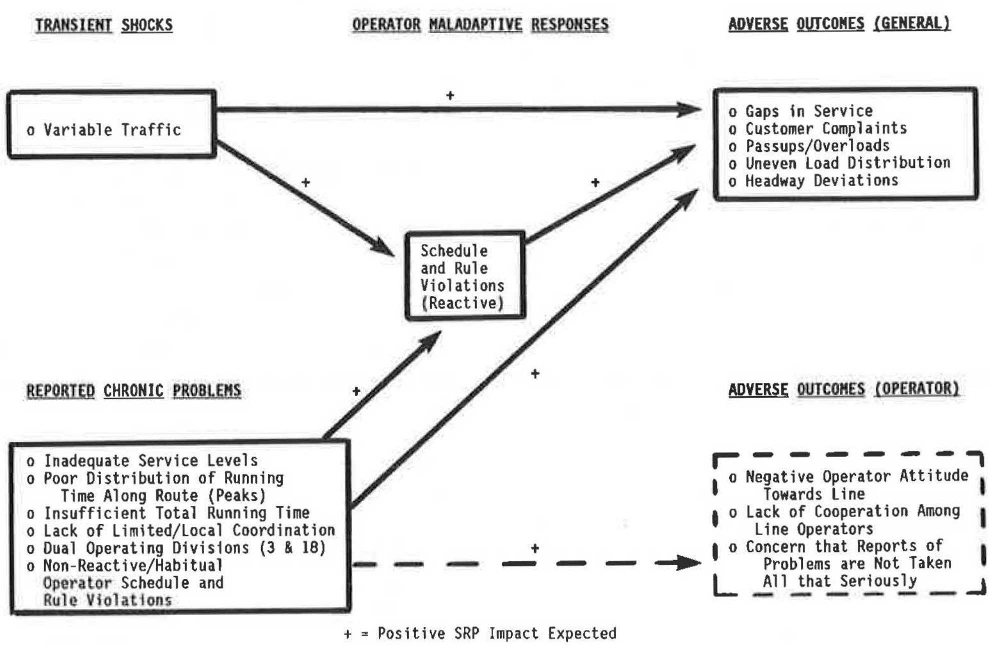

FIGURE 3 Hypothetical model of poor service reliability on SCRTD Line 26-51, a.m. peak.

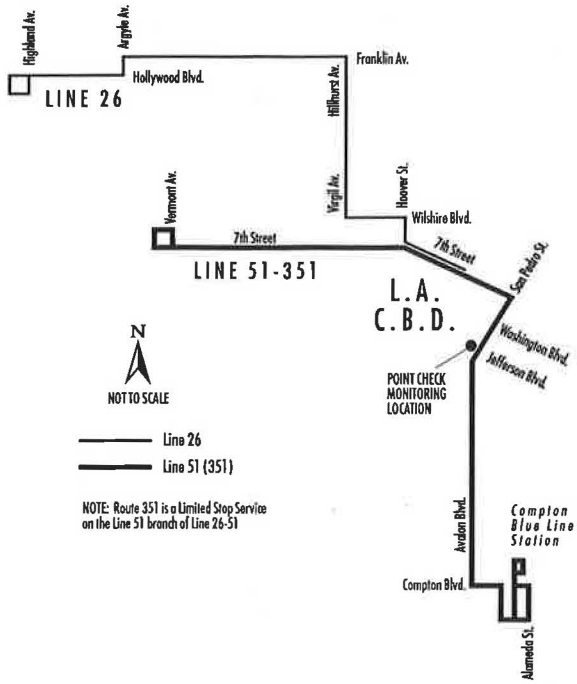

FIGURE 4 RTD Line 26-51 (351).

parent line and Line 51 serves as a branch. Line 26 operates between the Hollywood area and downtown Los Angeles (see Figure 4), while Line 51 operates between the city of Compton and the Los Angeles CBD. Line 26-51 operates out of two divisions and has a total of 26.2 one-way route miles. During the study period, 38 buses were assigned to the line during the a.m. peak. Certain trips on the Line 51 branch operated limited-stop service (via Route 351) along Avalon Boulevard to downtown Los Angeles.

Line 38-71 Characteristics (Control)

Selecting a suitable control line for this study was hampered by the fact that most other high-frequency local lines serving the Los Angeles CBD are either currently part of the SRP corridor service management plan or previously received intensive supervision under SRP. Among the few available candidate lines, Line 38-71 (W. Jefferson Boulevard—City Terrace) was ultimately chosen. Line 26-51 and Line 38-71 are similar in that both consist of two lines, operate through the Los Angeles CBD, and have demand headways and numerous short lines. Unlike Line 26-51, Line 38-71 operates out of a single division (Division 10) and has a longer headway (10 to 12 min during peaks).

Line 38, the parent line, operates from the West Los Angeles Transit Center east toward the Los Angeles CBD along Jefferson Avenue. Line 71, which serves as a branch of Line 38, primarily operates east of the CBD (see Figure 5). Line 38 and the Line 71 branch operate as a single bus route through the CBD, providing direct bus service between Southwest Los Angeles and the USC Medical Center. The combined routes total 18.2 one-way miles. Fifteen buses were assigned to the line during the a.m. peak rush. Line 38-71 carries about half as many patrons daily as the target line (approximately 13,000).

Scope of Study

The focus of this study was the weekday a.m. rush. Restricting the analysis to this period enabled the collection of passenger-waiting-time data and passenger surveys on both the target and control lines. A decision was made a priori to restrict the test to 7 weeks (April 25–June 14, 1991), since operators on both the target and the control lines were scheduled to bid new assignments, effective June 23, 1991, as part of a Districtwide "shakeup."

Outcome Measures

A total of 14 outcome measures were used to test these hypotheses. Simply assessing on-time performance or load variability or both, does not always provide insight into the true impact of an intervention such as the SRP. The specific outcome measures are listed below:

Service Reliability	*Customer Perceptions*	*Operator Perceptions*
Load differences	Overall service quality	Schedule improvements
Schedule deviations	Passing-up	Nonschedule improvements
Bunched buses	Waiting time	Supervisory presence
Gaps in service	Customer complaints	Attitude about working the line
Percentage passed up		
Mean waiting time		

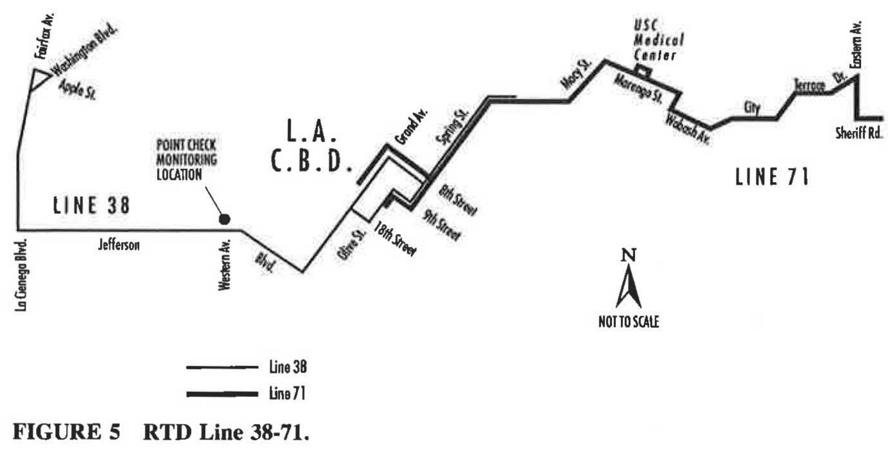

FIGURE 5 RTD Line 38-71.

With the exception of mean waiting time and percentage passed up, the service reliability measures were computed using regular point checks taken at the same location throughout the project. To obtain quantitative passenger waiting-time data and pass-up data (Avalon and Jefferson for the target line and Jefferson and Western for the control line), special checks were conducted at different locations. Specific definitions of the service reliability measures are provided in the next section.

Customer perceptions were made operational by conducting brief, structured interviews at the same location used to collect passenger waiting-time data. This enabled an assessment of whether customer perceptions were corroborated by actual measures of waiting time. Customer complaints were extracted from the complaint data base maintained by SCRTD. Finally, operator assessments of program impacts were obtained from an ad hoc operator opinion survey.

RESULTS

Service Reliability

The hypothesis that service reliability would improve on the target line (Line 26-51) following implementation of SRP, as supported by the data, received considerable support. Table 1 shows the results from the analysis of point checks taken at San Pedro and Washington on the target line before and during the 7-week SRP. Table 2 shows the results of the point-check analysis for the untreated control line (Line 38-71). Table 1 also shows that mean passenger loads on the target line increased from 57 to 61 per bus during the course of the study. This increase can be attributed to a generally occurring seasonal effect, and not necessarily to impact of the SRP.

Standard Deviation of Absolute Load Differences

Absolute load difference on the target line was defined as the unsigned difference in the number of passengers on the current bus versus the previous bus (at San Pedro and Washington). Taking the standard deviation of the absolute load differences gives insight into load variability. The standard deviation of absolute load differences averaged 14.3 during the preimplementation period. Throughout the various periods that the SRP was in place, the standard deviations averaged approximately 12.3 passengers (a reduction of about 16 percent). It was not appropriate to measure load differences at the designated monitoring location for the control line (i.e., Jefferson and 10th), since some of the buses passing the point were on short lines and had fewer passengers.

Standard Deviation of Absolute Schedule Difference

Absolute schedule deviation on the target line was defined as the unsigned number of minutes Line 26–51 buses deviated from the estimated scheduled time at San Pedro and Wash-

TABLE 1 SRP (TARGET) LINE 26-51 SERVICE RELIABILITY INDICATOR*

PERIOD	NO. TRIPS	MEAN DEPARTING LOAD	SD ABSOLUTE LOAD DIFFER.	**MEAN ABSOLUTE SCHEDULE DEVIATION (MINUTES)	**SD ABSOLUTE SCHEDULE DEVIATION (MINUTES)	NUMBER OF BUNCHED BUSES	***NUMBER OF SERVICE GAPS
Pre SRP Implementation							
4/17/91	20	59.8	13.4	3.8	3.1	15	2
4/18/91	21	55.1	13.7	3.5	3.7	13	2
4/19/91	22	56.0	17.8	3.3	2.2	18	3
4/22/91	21	55.6	12.3	3.9	3.2	14	3
Period Av:	21.0	56.6	14.3	3.6	3.1	15.0	2.5
Week 2 (SRP)							
5/7/91	21	58.5	10.9	4.0	2.5	16	3
5/8/91	23	58.3	15.5	4.1	2.4	15	2
5/9/91	22	56.1	10.7	3.1	2.4	12	3
5/10/91	23	61.4	11.4	2.8	2.6	13	3
Period Av:	22.3	58.6	12.1	3.5	2.5	14.0	2.8
Weeks 3-4 (SRP)							
5/15/91	22	62.2	8.8	2.5	2.5	9	2
5/16/91	23	58.4	15.7	3.5	2.0	14	2
5/22/91	22	57.8	9.1	3.7	2.7	10	2
5/23/91	21	63.0	9.3	2.8	2.8	8	2
5/24/91	22	56.6	15.8	2.2	1.6	8	2
Period Av:	22.0	59.6	11.7	2.9	2.3	9.8	2.0
Weeks 5-7 (SRP)							
5/31/91	22	60.8	10.9	3.4	2.1	10	2
6/5/91	20	63.2	13.2	4.1	3.4	8	2
6/6/91	21	59.5	13.6	3.0	2.2	7	0
6/11/91	22	59.4	9.8	4.4	3.6	11	1
Period Av:	21.3	60.7	11.9	3.7	2.8	9.0	1.3

NOTE: Results are based on point checks taken at San Pedro-Washington (6:00-7:45am northbound)

* 6:30-7:45am since headways are 7-8 minutes between 6:00-6:30am

** Not a time point -- estimated "scheduled" times used to obtain deviations

*** Gaps of 10+ minutes

TABLE 2 NON-SRP (CONTROL) LINE 38-71 SERVICE RELIABILITY INDICATORS*

PERIOD	NO. TRIPS	MEAN DEPARTING LOAD	MEAN ABSOLUTE SCHEDULE DEVIATION (MINUTES)	SD ABSOLUTE SCHEDULE DEVIATION (MINUTES)	NUMBER OF BUNCHED BUSES	**NUMBER OF SERVICE GAPS	NUMBER LATE OR EARLY BUSES
Pre SRP (on target line)							
4/17/91	10	43.9	4.2	3.2	2	1	4
4/18/91	10	43.9	3.0	2.5	2	1	2
4/19/91	10	46.3	3.2	2.7	6	1	3
Period Av:	10.0	44.7	3.5	2.8	3.3	1.0	3.0
Weeks 1-2							
5/1/91	8	***49.4	4.4	3.6	4	2	5
5/7/91	10	50.6	4.7	3.4	2	2	4
Period Av:	9.0	50.0	4.6	3.5	3.0	2.0	4.5
Weeks 3-4							
5/15/91	10	42.3	2.8	2.4	4	1	4
5/22/91	10	49.8	3.5	2.0	2	1	4
5/23/91	10	45.0	4.0	3.1	4	1	3
Period Av:	10.0	45.7	3.4	2.5	3.3	1.0	3.7

* Results based on point checks taken at Jefferson & 10th Avenue (6:15-8:15am westbound). Two of the ten scheduled trips terminate at this location. Passenger loads for these trips are zero and, therefore, were not included in the mean departing load variable. The two Jefferson & 10th shortline trips were, however, included in all of the schedule adherence indicators.

** Gaps of 15+ minutes, 7:00-8:00am only, to exclude short line trips.

*** Check began at 6:45am. As a consequence, the passenger load for Bus Run 8 (scheduled time 6:15am) was not available. For the purposes of this analysis, the load was estimated at 48, which is the mean load for Bus Run 8 across all other observations.

ington using estimates because the monitoring location was not a time point. Computing the standard deviation of these schedule differences provided an estimate of schedule variability. A similar measure was computed for the control line, where the monitoring location was a time point.

As Table 1 shows the standard deviation of absolute schedule differences was 3.1 min before implementation of SRP. During the first 4 weeks of the program on the line, this standard deviation was reduced to approximately 2.4 min (23 percent), and averaged 2.8 min during Weeks 5 to 7. The standard deviations for the control line were much more variable than those for the target line, and did not show any clear pattern of improvement (see Table 2). It seems reasonable to suggest that the SRP likely had a positive effect on schedule deviation, especially during the first 4 weeks of the program.

Bunched Buses

The number of bunched buses on the target line was defined as the sum of buses departing within 2 min of each other between 6:00 and 7:45 a.m. inbound at San Pedro and Washington. Table 1 shows that the average number of bunched buses on Line 26-51 decreased over time, whereas an average of 15 buses (71 percent), were involved in "bunching" before the program. During weeks 5 to 7 this average was reduced to nine (43 percent of total). The number of bunched buses on the control line was defined as the sum of buses departing within 5 min of each other between 6:15 and 8:15 a.m. westbound at Jefferson and 10th. On the control line the number of bunched buses remained on average approximately three throughout the study period (see Table 2).

Gaps in Service

A gap in service on Line 26-51 line was defined as any break between buses of 10 min or more between 6:30 and 7:45 a.m. at the monitoring location. For Line 38 (control), a 15-min criterion was used and the time period limited to between 7:00 to 8:00 a.m. because of longer headways before 7:00 a.m. and after 8:00 a.m. Table 1 shows that there was a small reduction in the mean number of service gaps on the target line during the course of the study. By Weeks 5 to 7, the number of gaps reduced to about one to two per day, versus two to three before the start of SRP. Although this finding is consistent with the hypothesis, the same general pattern was found for the control line (see Table 2). This finding must be interpreted cautiously, because the strongest effect was not found on the target line until Weeks 5 to 7, and data for this period on the control line were not available.

Percentage Passed Up

Table 3 shows the percentage of those passed up at Avalon and Jefferson (westbound) between 7:00 and 8:00 a.m. before and after implementation of the SRP. The percentage of those passed up on the target line at this location decreased considerably during the 2-week period following implementation of SRP on the line, whereas the average number of pass-ups for the two preimplementation days for which data were collected is 33 percent. The average for the 4 days when supervisors were intensively supervising the line was 8 percent. It should be noted that on the final day of counting pass-ups (May 7), 28 percent of the patrons were passed up. However, it would appear that passing-up reduced on the target line. It

TABLE 3 PASSENGER PASS-UPS AND WAITING TIME, LINE 26-51 VERSUS LINE 38-71, 7:00 TO 9:00 A.M., PRE/POST SRP IMPLEMENTATION

	MEAN HEADWAY (MIN.)	SD HEADWAY (MIN.)	NUMBER WAITING PASSENGERS	PERCENTAGE PASSENGERS PASSED-UP	MIN. UNTIL FIRST BUS ARRIVED	MEAN WAIT (MIN.)*
Line 26-51 (Target)						
Pre SRP Implementation						
Apr 17	4.3	4.6	59	30.5%	3.1	5.3
Apr 23	4.4	3.6	64	35.9%	3.1	4.2
Average:	4.4	4.1	61.5	33.2%	3.1	4.8
Post SRP Implementation						
Apr 30	4.3	2.8	54	0.0%	2.7	2.7
May 2	3.9	3.9	57	0.0%	3.5	3.5
May 6	4.8	4.3	62	4.8%	3.7	3.9
May 7	4.3	2.7	64	28.1%	3.3	4.4
Average:	4.3	3.4	59.3	8.2%	3.3	3.6
Line 38-71 (Control--No Treatment)						
Pre Implementation of SRP on Line 26-51						
Apr 17	9.5	4.2	44	n.a.	5.2	8.1
Average:	9.5	4.2	44.0	n.a.	5.2	8.1
Post Implementation SRP on Line 26-51						
Apr 29	11.5	7.4	44	n.a.	7.2	8.4
May 6	10.0	3.6	48	n.a.	3.9	7.2
May 7	10.5	7.6	52	n.a.	6.6	8.6
May 13	10.3	2.5	44	n.a.	5.1	8.3
Average:	10.6	5.3	47.0	n.a.	5.7	8.1

n.a. = information not available

Passenger Survey Locations: Line 26-51 Avalon & Jefferson (Westbound)
Line 38-71 Jefferson & Western (Westbound)

* For Line 26-51, the mean waiting time includes an estimate of additional time waited due to passing up (assumes simple queuing behavior). For Line 38-71, the mean waiting time includes additional time due to some persons not boarding short-line trips (assumes at least every other bus is a through bus).

was not possible to gauge pass-ups on the control line since some patrons voluntarily waited for a through bus.

Mean Waiting Time

Mean passenger waiting time decreased on Line 26-51 once the SRP was implemented (see Table 3). The limited data show that the mean waiting time was 4.8 min before implementation and 3.6 min subsequent to implementing SRP. The mean amount of time passengers waited for a bus to arrive actually increased during the implementation period, from 3.1 min preimplementation to 3.3 min subsequent to implementation. The reduction in mean waiting time was because of the fact that pass-ups decreased sharply at the monitoring location. Unlike the target line, there was no improvement in the total mean waiting time on the control line, 8.1 min pre- and post- as shown in Table 3.

Customer Perceptions

Overall Service Quality

The hypothesis that customers would perceive service quality to be improved on the target line following implementation of SRP received strong support from the data. A Kruskal-Wallis one-way analysis of variance (ANOVA) was used to test for changes in perceptions. A statistically significant difference in the ranks was found in the hypothesized direction—chi-square corrected for ties = 4.36, $p < .05$. Customers on Line 26-51 who were surveyed at the same location where passenger waiting-time checks were conducted perceived that there had been a significant improvement in the overall service quality on the line. For the control line, there was no meaningful change in the customers' perceptions of overall line quality. However, because the assessments on Line 38-71 clustered closer to the upper end of the scale and were more positive than those for the target line, the possibility of a "ceiling effect" cannot be ruled out.

Passing Up

A Kruskal-Wallis test was also used to determine whether Line 26-51 customers perceived that they had been passed up less frequently after the implementation of SRP. The resulting chi-square value was 4.03, which is significant at the .05 level. No comparable data were available for Line 38-71, since passing up due to overloaded buses was not a problem on the control line at the monitoring location.

Perceived Waiting Time

Perceived waiting time did not change on the target line during the study period, because the results suggested that Line 26-

51 customers believed that they waited, on average, just as many minutes after SRP was implemented as before. The general pattern of these findings is consistent with the results from the quantitative assessments of pass-ups and waiting time described earlier. Pass-ups decreased, whereas waiting time remained essentially the same. No change was reported for the control line in terms of perceived waiting time.

Customer Complaints

Table 4 shows the number of customer complaints reported on a weekly basis for Lines 26-51 and 38-71, for the period April 1–June 14. Complaints on the target line, which were more than twice those on the control line at the outset, averaged fewer than the control line by Weeks 5 to 7. This pattern of results is most compelling when a nonequivalent control group design is used.

Operator Perceptions

The hypothesis that operators would perceive that significant scheduling and operations-related improvements had occurred on their line following implementation of SRP was supported by the data. However, the hypothesis that cooperation would improve among operators on the line did not receive strong support. Only operators who participated in both the preimplementation and follow-up operator opinion surveys were included in the analysis ($n = 23$).

Assessments of Improvements (Scheduling)

As Table 5 shows, half of the operators on Line 26-51 who were surveyed prior to SRP and again after 5 weeks of implementation perceived that running time during the peaks had improved, at least slightly. The same general pattern of responses was found for all the other scheduling-related items. In contrast, nearly all of the operators on the control line perceived that there was no change in the scheduling-related areas surveyed. It is noteworthy that nearly half of the operators (45 percent) on the target line perceived that some service had been added, when in fact, none had.

Assessments of Improvements (Nonscheduling)

Table 5 also shows the operators' perception of change in factors not directly related to scheduling. Unlike scheduling-related factors, the pattern is muddled. A fair summary, however, would be that in the operators' view, with the exception of traffic, non-schedule-related factors changed very little on the target line, and improved somewhat on the control line. Operators on the target line generally did not directly perceive that cooperation among them had improved following the implementation of SRP.

Supervisory Presence

Table 6 shows the results of a comparison of the preimplementation versus postimplementation responses made by operators on the target line, and Table 7 shows similar information for control-line operators. As might be expected, a statistically significant difference was found for the frequency with which supervisors were observed on the target line ($t = -3.13$, $p < .01$). No statistically significant difference was found for the control on this measure.

Attitude About Working Line

There was also a significant difference, at the .10 level, in the responses made by Line 26-51 operators before and after SRP to the question, "During the past month, how often would you say you enjoyed working Line 26?" Taken together, operator responses were more positive at Time 2 than they were prior to SRP. A comparable change was not found for Line 38-71 operators.

Although the change for the question "How often is lack of cooperation among operators a problem?" was not statis-

TABLE 4 CUSTOMER COMPLAINTS BY WEEK, 5:00 TO 9:00 A.M., LINE 26-51 VERSUS LINE 38-71, PRE/POST SRP IMPLEMENTATION

	Pre SRP					2-4 weeks				5-7 weeks				
	1991					1991				1991				
	Apr 1	Apr 8	Apr 15	Apr 22	Mean	Apr 29	May 6	May 13	Mean	May 20	May 27	Jun 3	Jun 10	Mean
Line 26-51 (Target)														
Sched--AM Peak	3	4	1	2	2.5	4*	1	0	1.7	0	0	1	1	0.5
Total--AM Peak	3	6	1	3	3.3	4*	1	0	1.7	0	0	2	2	1.0
Line 38-71 (Control)														
Sched--AM Peak	0	1	0	2	0.8	0	3	2	1.7	0	3	1	1	1.3
Total--AM Peak	0	2	1	3	1.5	0	3	2	1.7	0	3	2	1	1.5

* Includes three no-show complaints near same location on the same day.

Sched = Scheduling and operations-related complaints such as passups, early bus, and late bus. Total complaints include such categories as operator discourtesy and accidents in addition to the scheduling and operations complaints (excludes fare-related complaints).

TABLE 5 OPERATOR PERCEPTIONS OF CHANGES ON LINE 26-51 VERSUS LINE 38-71

FACTOR	N	% IMPRVD. SIGNIF.	% IMPRVD. SLIGHTLY	% NO CHANGE	% WORSENED SOMEWHAT	% WORSENED SIGNIF.
Scheduling-related Factors						
Line 26-51 (Control)						
Running Time (Peak)	22	4.5	45.5	50.0	0.0	0.0
Distr. Running Time (Peak)	22	4.5	36.4	54.5	0.0	4.5
Amount of Service (Buses)	22	9.1	36.4	40.9	9.1	4.5
Passups Due to Overloads	23	8.7	34.8	39.1	13.0	4.3
Line 38-71 (Control)						
Running Time (Peak)	15	0.0	6.7	93.3	0.0	0.0
Distr. Running Time (Peak)	12	0.0	8.3	91.7	0.0	0.0
Amount of Service (Buses)	15	0.0	6.7	93.3	0.0	0.0
Passups Due to Overloads	16	0.0	12.5	87.5	0.0	0.0
Non-Scheduling Related Factors						
Line 26-51 (Target)						
Equipment	21	14.3	9.5	57.1	19.0	0.0
Cooperation Among Operators	23	8.7	21.7	47.8	17.4	4.3
Passenger Cooperation	23	17.4	8.7	56.5	13.0	4.3
Traffic	22	4.5	9.1	63.6	13.6	9.1
Line 38-71 (Control)						
Equipment	17	0.0	29.4	58.8	11.8	0.0
Cooperation Among Operators	16	18.8	18.8	62.5	0.0	0.0
Passenger Cooperation	16	6.3	37.5	50.0	6.3	0.0
Traffic	17	0.0	5.9	88.2	5.9	0.0

TABLE 6 OPERATOR PERCEPTIONS, SRP TARGET LINE 26-51, WILCOXON MATCHED-PAIRS SIGNED-RANKS TEST, PRE VERSUS POST

SURVEY ITEM	NO. MINUS (WORSE-ENED)	NO. PLUS (IMP-ROVED)	NO. TIES (NO CHANGE)	Z-SCORE	2-TAIL PROB.	t-VALUE
Enjoy Working Line	3	8	12	-1.73	.08*	-1.93*
Problem Getting Recovery Time	6	6	11	-0.11	.91	0.12
Comfortable Making Sugges. to Supv.	4	5	11	-0.41	.68	-0.37
How Often Supervisors Seen	4	15	4	-2.57	.01**	-3.13**
How Often Called Dispatcher	6	9	8	-0.80	.43	-0.65
How Often A Problem?						
Insuff. Running Time (Peaks)	8	3	9	-1.11	.26	1.28
Poor Distr. Running Time (Peaks)	7	3	11	-0.97	.33	1.10
Insuff. Running Time (Off-Peak)	4	3	13	-0.17	.86	0.00
Poor Distr. Running Time (Off-Peak)	4	1	14	-0.94	.35	1.07
Equipment Breakdowns	4	6	11	-0.56	.57	-0.62
Lack of Coop. Among Operators	5	11	7	-1.06	.29	-1.00
Not Enough Service	5	3	9	-0.70	.48	0.59
Unruly Passengers	3	3	17	0.00	1.00	0.00
Unpredictable Traffic	4	11	8	-1.59	.11	-1.80*
Passing Up Due to Overloads	5	5	13	-0.25	.15	0.22

* significant at .10, two-tailed test
** significant at .05, two-tailed test

t-values shown are from paired t-Test analyses (two-tailed test)

Pre Survey Dates = April 7-12, 1991

Post Survey Dates = May 21-26, 1991, and June 19-30, 1991

tically significant, it should be noted that nearly half (11 out of 23) of the operators on the target line viewed lack of cooperation among operators as less of a problem at Time 2, as shown in Table 6. One plausible reason that lack of cooperation among operators was perceived to be less of a problem, even though the same operators reported that cooperation had not improved, is that the need to engage in maladaptive responses diminished during SRP. The presence of supervisors on the line, along with minor scheduling adjustments, may have reduced the need to operate ahead of schedule or use other maladaptive responses. Although operators may have felt that there was no real change in the level of operator cooperation, the need for such cooperation seems to have lessened during the SRP.

CONCLUSION

Providing reliable bus service is a key goal of most transit agencies. Chronic problems and transient shocks on a line, however, often make achieving this goal difficult. In an effort to better understand the causal relationship between antecedent problems and subsequent poor service reliability, a conceptual model was proffered. The model postulates that

TABLE 7 OPERATOR PERCEPTIONS, CONTROL LINE 38-71, WILCOXON MATCHED-PAIRS SIGNED-RANKS TEST, PRE VERSUS POST

SURVEY ITEM	NO. MINUS (WORSE-ENED)	NO. PLUS (IMP-ROVED)	NO. TIES (NO CHANGE)	Z-SCORE	2-TAIL PROB.	t-VALUE
Enjoy Working Line	5	3	8	-0.35	.36	0.44
Problem Getting Recovery Time	2	8	6	-0.87	.39	-0.64
Comfortable Making Sugges. to Supv.	2	2	11	-0.00	1.00	0.00
How Often Supervisors Seen	2	5	9	-0.59	.55	-0.62
How Often Called Dispatcher	4	2	10	-0.73	.46	0.81
How Often A Problem?						
Insuff. Running Time (Peaks)	5	4	6	-0.23	.81	0.25
Poor Distr. Running Time (Peaks)	4	5	6	-0.77	.44	-0.89
Insuff. Running Time (Off-Peak)	0	6	8	-2.20	.03**	-2.59**
Poor Distr. Running Time (Off-Peak)	1	4	11	-1.48	.14	-1.60
Equipment Breakdowns	1	3	12	-0.54	.58	-0.62
Lack of Coop. Among Operators	0	2	13	-1.34	.18	-1.29
Not Enough Service	5	6	3	-0.71	.48	-0.84
Unruly Passengers	1	5	10	-1.46	.14	-1.73*
Unpredictable Traffic	6	3	6	-0.53	.59	0.56
Passing Up Due to Overloads	2	4	9	-0.94	.35	-1.00

* significant at .10, two-tailed test
** significant at .05, two-tailed test

t-values shown are from paired t-Test analyses (two-tailed test)

Pre Survey Dates = April 7-12, 1991

Post Survey Dates = May 21-26, 1991

the overarching relationship is mediated by, among other things, maladaptive operator responses.

Largely on the basis of the model's logic, SCRTD implemented an innovative program in mid-1989 to deal with the problem of poor service reliability, SRP. Under the program, road supervisors not only intensively supervise lines, but also work with District personnel, including line operators, to identify and resolve root causes. The step-by-step SRP process delineated in this paper can easily be adopted by other transit agencies.

To demonstrate the short-term impacts of the SRP, a pre/post test was conducted on SCRTD Line 26-51. The results from the test support the conclusion that intensive road supervision, coupled with team-oriented approaches to problem identification and resolution, can have a positive effect on service quality. Without adding service, and despite a small seasonal increase in ridership, improvements were found for various service reliability indicators on the target line (e.g., number of bunched buses and pass-ups). The quantitative findings were generally corroborated by qualitative assessments made by Line 26-51 customers and operators.

Although the Line 26-51 test should make an important contribution to the applied research literature on bus service reliability, several limitations must be noted. First, the control line differed in many respects from the target line (e.g., longer headways). This fact necessarily made certain result comparisons between the target and control lines untenable. Second, because of the restricted time frame available for this research, the amount of baseline data was limited. Third, the sample sizes of passenger surveys for each line were very small and taken at a single location. Fourth, the test was restricted to the a.m. peak rush. Whether the present findings can be generalized to the p.m. peak remains to be determined. These and other limiting factors notwithstanding, the results clearly suggest that innovative service management programs such as the SRP can have beneficial effects on line performance, at least in the short term. Future research will address such issues as how long the effect of SRP lasts once the program is removed, and how often the process must be repeated.

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