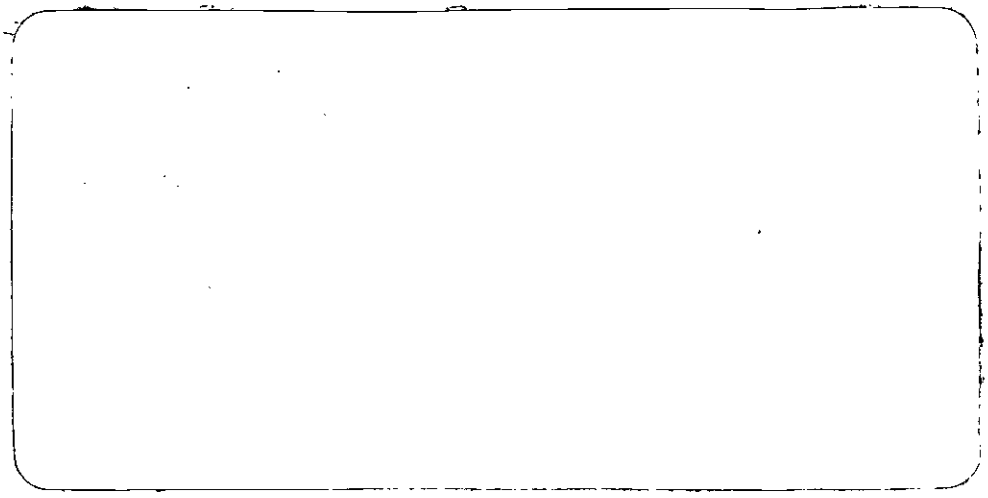
Southern California Rapid Transit District



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Southern California Rapid Transit District

A COMPARATIVE ANALYSIS OF METRO BLUE LINE PASSENGER INSPECTION RATES

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A COMPARATIVE ANALYSIS OF METRO BLUE LINE PASSENGER INSPECTION RATES

-- Executive Summary --

This report describes the results of a study that was recently conducted to investigate the discrepancy in the Metro Blue Line fare inspection rates reported by the Los Angeles Sheriff's Department (LASD) and the District's Service Inspection Unit (SIU). Based on a series of analyses, several conclusions concerning the underlying reasons for the discrepancy were drawn. Recommendations based on the study's findings, including alternative LASD and SIU deployment strategies, are offered. A rudimentary algorithm that estimates the probability of the same passenger being checked for proof of fare payment more than one time during a single trip is included as an appendix to the report.

Background

The Metro Blue Line is a 22-mile long light rail system linking Downtown Los Angeles with Downtown Long Beach. (A map of the Metro Blue Line is included as Appendix A). The system, which began operating in July, 1990, features a barrier-free fare environment. Since the opening of the Metro Blue Line, the Los Angeles Sheriff's Department has been contracted by the Southern California Rapid Transit District to, among other things, provide security and police protection and conduct fare inspections.

To ensure patrons pay the required fares, the Sheriff's Department is required to check approximately 25 percent of Metro Blue Line ridership for proof of fare payment. The inspection rates reported by the LASD represent the official numbers by which contract compliance is assessed. However, a separate inspection rate, based on the number of train trips on which SCRTD

undercover personnel are asked by a Deputy to provide proof of fare payment, is also routinely calculated by the District's Service Inspection Unit (SIU). When the rates reported by the two sources were compared for consistency in 1991, sizeable discrepancies were revealed.

Analyses

The present study involved three main analyses. The first compared the deployment strategies used by the LASD and the Service Inspection Unit, respectively. The purpose of the analysis was to determine if the Deputies and Inspectors were deployed in a manner consistent with known ridership patterns. The second analysis, which compared LASD passenger counts with District point-check data, was designed to determine the magnitude of over- or undercounting in the inspection data reported by the LASD. The third analysis was designed to estimate the number of Metro Blue Line riders who are asked to produce proof of fare payment more than once during a single train trip.

Conclusions

The following are among the major conclusions that were drawn from the results of the analyses:

- The Service Inspection Unit fare inspection rate will generally not be a valid indicator of the percentage of Metro Blue Line patrons who are inspected for proof of fare payment.
- The on-board passenger counts recorded by the Deputy Sheriffs appear to be reasonably accurate (although additional tests are required to strengthen this conclusion). The accuracy of the fixed-post counts remains to be rigorously tested.

- Fare inspection is conducted in a disproportionate manner on the line, creating "holes" in the inspection coverage. Certain segments/stations tend to be checked more frequently than others depending upon the LASD deployment strategy that is in place at any given time.

- Incidences of double-checking appear to occur relatively infrequently and, therefore, should not materially distort the fare inspection rates reported by the LASD. Based on a sample taken in March, 1992, it appears that an average of one and one-half percent of Metro Blue Line riders were involved in multiple fare inspections during the four days studied. The rate of double checking, however, is apt to vary significantly depending upon the LASD deployment scheme that is in place on any given day.

Recommendations

Based on the study's findings, we recommend the following:

- Eliminate all side-by-side comparisons of LASD and Service Inspector fare inspection rates because inappropriate conclusions may be drawn. If the data must be reported simultaneously, a clear rationale for the difference between the rates should accompany the information.

- The Service Inspection Unit should continue to report the fare inspection rate for internal use, and as a check of possible "holes" in LASD deployment.

- The LASD should routinely notify the Service Inspection Unit of on-board LASD deployment patterns so that the SIU can most effectively determine its own deployment strategy.

- Discontinue the policy of mostly end-to-end Service Inspector trips. Instead, implement specialized deployment strategies that assess the quality of service along particular line segments or during specific times of day.

- The rate at which duplicate fare inspections occur should be monitored, and new data collected whenever there is a change in LASD deployment.

- The LASD (perhaps with assistance from SCRTD staff) should conduct ongoing studies concerning the accuracy of both on-board and fixed-post fare inspection data.

- The LASD should consider requesting funds for a large-scale demonstration project for computer simulation of barrier-free rail systems. A possible funding source would be the Federal Transit Administration (FTA).

A COMPARATIVE ANALYSIS OF METRO BLUE LINE PASSENGER INSPECTION RATES

I. INTRODUCTION

The Metro Blue Line is a 22-mile long light rail system linking Downtown Los Angeles with Downtown Long Beach. The system, which began operating in July, 1990, features a barrier-free fare environment. Since the opening of the Metro Blue Line, the Los Angeles Sheriff's Department (LASD) has been contracted by the Southern California Rapid Transit District (SCRTD) to, among other things, (1) provide security and police protection and (2) conduct fare inspections. To ensure patrons pay the required fares, the Sheriff's Department is required to check approximately 25 percent of Metro Blue Line ridership for proof of fare payment. Specifically, the current District County Law Enforcement Service Agreement, dated July 1, 1992, states that:

> "The Sheriff shall perform fare enforcement activities as defined by the District consistent with industry standards. This will include inspections of approximately 25% (median) of the ridership. Fines and forfeitures shall be forwarded to District pursuant to applicable Penal Code Sections." (p. 2)

To help gauge whether the LASD is in compliance with the contract, each Deputy who engages in fare inspection activities completes a form describing the number of fares checked, the number of citations issued, and so forth, on a daily basis (a copy of this form is included in Appendix B). These figures are then compiled and reported to the SCRTD on a monthly basis. A fare inspection rate is calculated by dividing the total number of patrons reportedly inspected by

the Deputies by the total (estimated) ridership on the Metro Blue Line for the specified period.

The inspection rates reported by the LASD represent the official numbers by which contract compliance is assessed. However, a separate inspection rate, based on the number of train trips on which SCRTD Service Inspectors are asked by a Deputy to provide proof of fare payment, is also routinely calculated by the District's Service Inspection Unit (SIU). The SIU fare inspection rate is calculated by dividing the number of trips during which fares were inspected by the total number of trips that were ride checked during the same period (if two Service Inspectors ride the same trip then this is counted as two trips). It should be made clear that the SIU's fare inspection activities are only one part of the Service Inspectors' larger mission. The Service Inspectors generally ride selected train trips each month and record relevant information concerning various aspects of service quality on the Metro Blue Line. A "Service Inspector Blue Line Ride Check" form, a sample of which is included in Appendix C, is used to record their observations. The form includes space for the Service Inspectors to indicate whether a fare inspection was made on each trip they rode as well as the number of times an invalid fare (e.g., an expired transfer) was detected by a Deputy.

Once sufficient fare inspection data were available from both the LASD and the SIU, the rates reported by the two sources were compared for consistency. Table 1 shows the fare inspection rates reported by the two sources for the period January, 1991 through August, 1991. As can be seen, there were large discrepancies. The rates reported by the LASD were consistently higher than those reported by the SIU. For example, during the month of August, 1991, the LASD reported an inspection rate of 37% while the Service Inspectors reported being checked only 19% of the time. Although the methods used to determine the rates were different (the number of passengers versus the number of trips,

Table 1

Comparison of LASD and SIU Metro Blue Line Fare Inspection Rates

(January-September, 1991)

MONTH	LASD REPORTED INSPECTION RATE*	% TIMES SIU INSPECTED**
January	34%	11%
February	37%	12%
March	34%	16%
April	29%	16%
May	30%	21%
June	30%	18%
July	45%	33%
August	37%	19%
September	39%	23%

* Fare Enforcement Team Activity Reports (LASD)
** SCRTD Service Inspection Unit Monthly Reports

respectively), it seemed reasonable to expect smaller discrepancies than were actually found.

The purpose of the present analysis was to (1) determine the underlying reasons for the discrepancies in the two fare inspection rates and (2) make recommendations concerning alternative Service Inspector and LASD deployment strategies in an effort to minimize the persistent discrepancies. This report describes the results of the analysis. The report also includes a rudimentary algorithm that was developed to estimate the probability of the same passenger being checked (for proof of fare payment) more than one time during a single trip. This algorithm can be used to refine the fare inspection rates reported by LASD to reflect "unique" (non-duplicative) fare inspections. Future research possibilities concerning optimal LASD deployment strategies, including a possible simulation study, are also briefly discussed.

II. RESEARCH QUESTIONS

To enable a clear delineation of pertinent research questions, Transit Research Unit (TRU) staff made the (untested) assumption that both the LASD and the SIU fare inspection rates were essentially accurate. If this assumption were correct, then the discrepancy between the two rates would necessarily have to be attributed to factors other than differences in the method of calculation. That is, if we assume that both the Deputy Sheriffs and the Service Inspectors are deployed in a (statistically) random manner on the Metro Blue Line (i.e., by station, direction, and time period in proportion to ridership volumes), then, irrespective of how the rate is computed, Service Inspectors should be asked for proof of fare payment at the rate reported by the Sheriff (i.e., more than 25 percent of the time, on average). This assumes, of course, a large enough sample.

Following this logic, the first set of research questions we developed to account for the discrepancy in the two fare inspection rates focussed more on possible differences in the deployment patterns used by the LASD and the SIU than on measurement differences or data errors. We specifically wanted to know:

1. To what extent does the LASD deploy its Deputies assigned to the Metro Blue Line in a non-random manner? Alternatively asked, "Do the Deputies tend to concentrate on certain time periods, stations, and so forth, in a manner that does not necessarily reflect the true distribution of riders on the line?"

2. To what extent does the deployment of SCRTD's Service Inspectors comport with the Deputies' deployment pattern?

Although it was felt, a priori, that incompatible deployment strategies would likely account for a large proportion of the disparities in the inspection rates, there were other potential factors that we felt should be examined. One such factor was measurement error in the passenger counts provided by the LASD, from which the Sheriff's fare inspection rates are computed. Among the potential problems were: 1) systematic undercounting by individual Deputies; 2) systematic overcounting by individual Deputies; 3) significant, non-systematic counting errors on isolated trips; 4) inadvertent data recording errors (by Deputies or administrative staff); and so forth. Accordingly, the second set of research questions dealt with these issues. We specifically wanted to know:

3. How accurate and reliable are the on-board fare inspection counts made by the Deputy Sheriffs?

4. How accurate and reliable are the fare inspection counts made by the Deputy Sheriffs at fixed-post locations?

It should be noted that because the SIU does not use passenger estimates to compute its fare inspection rates, the issue of measurement error in the SIU rate was deemed moot and not investigated.

The final factor that we thought might help explain the discrepancy between the two fare inspection rates concerned the possibility of inadvertent "double-checking" by the LASD. When the LASD calculates the proportion of daily Blue Line ridership that has been inspected, the value reported actually represents the number of inspections which occurred, not the number of riders who were inspected. To clarify this point, suppose a Deputy inspects 10 riders at point A, and another Deputy inspects the same 10 riders at point B. In this case, 20 inspections have occurred, and will be reported, but only 10 riders will actually have been inspected. If these same 10 riders are involved in a third fare inspection, then the "double-checking" of individual riders is even greater (i.e., they will have been "triple-checked").

Multiple checking of the same patrons on a single trip is not necessarily a problem, per se, given the present language in the contractual agreement. Although the spirit of the contract may be that approximately 25 percent of all riders will be fare inspected once (per trip), there is no explicit language bearing on that point. The issue of double-checking is, nonetheless, relevant in the present context because it is possible that individual Service Inspectors were being checked multiple times on the same trip, but this fact was not being reflected in the SIU's reported fare inspection rate. As noted above, the SIU rate is based on the percentage of trips inspected and not the actual number of inspections that occur on a trip.

The specific research questions that we asked concerning double-checking were as follows:

5. What is the probability that an individual riding the Metro Blue Line will be required to provide proof of fare payment more than once on the same trip?

6. On average, what estimated number of Metro Blue Line riders are asked to provide proof of fare payment more than once on the same trip on a single weekday?

III. ANALYSES

Three main analyses were conducted in an attempt to shed light on the six research questions delineated above. The results are described in the sections below.

A. ANALYSIS 1: PRELIMINARY CONTRAST OF SIU AND LASD DEPLOYMENT STRATEGIES

Answering the first two questions concerning the randomness of both the LASD and the SIU deployment schemes was accomplished by conducting a simple comparison. Specifically, deployment data from both sources were plotted, by station, for the month of June, 1991. Figures 1, 2, and 3 show the resultant plots for the Service Inspectors, by a.m. peak, base, and p.m. peak time periods, respectively. Figure 4 shows a graph depicting the percentage of LASD on-board fare inspections, by line segment, for April 8-9, 1991.

It was immediately apparent from these figures that neither the Deputy Sheriffs nor the Service Inspectors were being deployed in a statistically random pattern that reflected known Blue Line ridership patterns. More importantly, the geographic concentration of personnel from the two sources was disparate. The Service Inspectors typically concentrated their effort on the area north of the 103rd St. Station while the Deputies tended to work south of the station. This general pattern was especially true for the a.m. peak and the base.

SCRTD SERVICE INSPECTORS DEPLOYMENT DISTRIBUTION
(A.M. PEAK)
Alighting Station

June 1991

Boarding Station

	LBTM	Pacific	1st /5th	Anaheim	PCH	Willow	Wardlow	Del Amo	Artesia	Compton	Imperial	103rd	Firestone	Florence	Slauson	Vernon	Washington	San Pedro	Grand	Pico	Metro
LBTM							1	1		1											
Pacific																					
5th / 1st																					
Anaheim											1	2	1								
PCH																					
Willow											1	1									
Wardlow																					1
Del Amo																				1	
Artesia																					
Compton																			2		1
Imperial																			3		5
103rd						1													3	1	6
Firestone																					3
Florence																					
Slauson																					
Vernon																					
Washington																					
San Pedro																					
Grand																					
Pico																					
Metro										1											

Southbound

Northbound

Figure 1

SCRTD SERVICE INSPECTORS DEPLOYMENT DISTRIBUTION
(A.M. PEAK)

Alighting Station

June 1991

Boarding Station

	LBTM	Pacific	1st /5th	Ana-heim	PCH	Willow	Ward-low	Del Amo	Artesia	Comp-ton	Imperial	103rd	Fire-stone	Florence	Slauson	Vernon	Washing-ton	San Pedro	Grand	Pico	Metro
LBTM							1	1		1											
Pacific																					
5th / 1st																					
Anaheim											1	2	1								
PCH																					
Willow											1	1									
Wardlow																					1
Del Amo																				1	
Artesia																					
Compton																			2		1
Imperial																			3		5
103rd						1													3	1	6
Firestone																					3
Florence																					
Slauson																					
Vernon																					
Washington																					
San Pedro																					
Grand																					
Pico																					
Metro										1											

Northbound

Southbound

Figure 1

SCRTD SERVICE INSPECTORS DEPLOYMENT DISTRIBUTION
(BASE PERIOD)

Alighting Station

June 1991

Boarding Station

	LBTM	Pacific	1st /5th	Ana-heim	PCH	Willow	Ward-low	Del Amo	Artesia	Comp-ton	Imperial	103rd	Flo-rence	Florence	Slauson	Vernon	Washing-ton	San Pedro	Grand	Pico	Metro
LBTM																					
Pacific																					
5th / 1st																					
Anaheim																					
PCH																					
Willow																					
Wardlow																1					
Del Amo																					
Artesia															1					1	1
Compton																				1	
Imperial				1															1	1	3
103rd																					1
Firestone																					1
Florence																				1	
Slauson																					
Vernon																					1
Washington																					
San Pedro																					
Grand												1									
Pico													1								
Metro							2		3	2	2	1		1	2			1			

Southbound

Northbound

Figure 2

SCRTD SERVICE INSPECTORS DEPLOYMENT DISTRIBUTION
(P.M. PEAK)
Alighting Station

June 1991

Boarding Station

	LBTM	Pacific	1st /5th	Ana-heim	PCH	Willow	Ward-low	Del Amo	Artesia	Comp-ton	Imperial	103rd	Fire-stone	Florence	Slauson	Vernon	Washing-ton	San Pedro	Grand	Pico	Metro
LBTM																					
Pacific																					
5th / 1st																					
Anaheim																					
PCH																					
Willow																					
Wardlow																					
Del Amo													1							2	
Artesia																					1
Compton																				2	
Imperial																					
103rd						1															
Firestone						1		1												1	1
Florence						1		2			1										
Slauson							1		1		1										1
Vernon																					
Washington									1												
San Pedro																					
Grand																					
Pico							1					1		3			1				
Metro							1		1		1	1	4	3	1						

Northbound

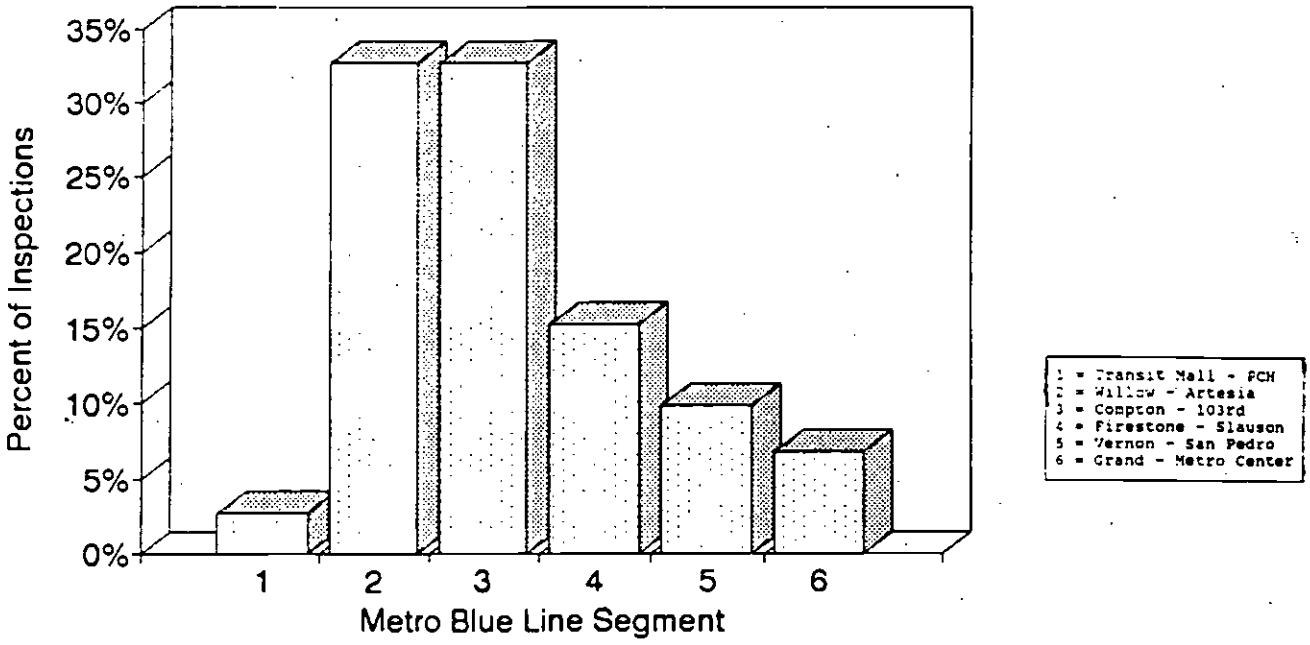
Southbound

Figure 3

Figure 4

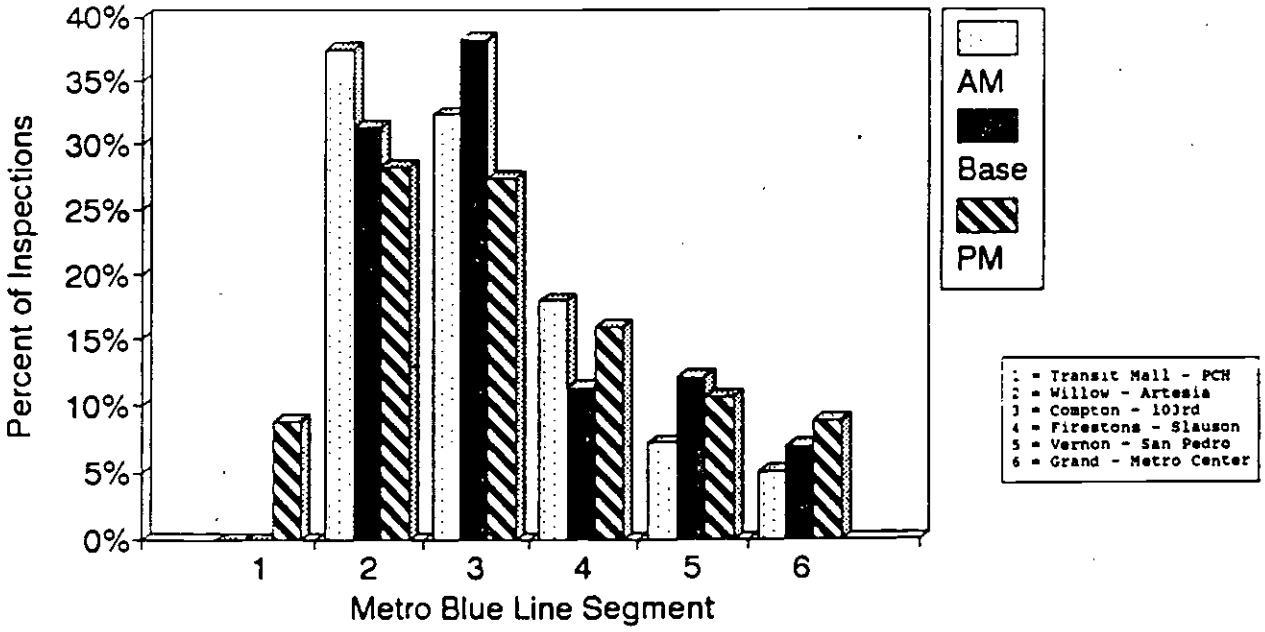
LASD On-Board Fare Inspections

By Line Segment (April, 1991)



LASD On-Board Fare Inspections

By Line Segment and Time of Day



Because the deployment schemes used by the two agencies were not only non-random but also disparate, it was very likely that, as suspected, much of the discrepancy in the two fare inspection rates could be accounted for by this fact alone. It was felt, therefore, that simply modifying the deployment pattern of the Service Inspectors to better reflect the pattern being used by the LASD would increase the likelihood of the inspectors being asked for proof of fare payment while on board a given trip.

To partially test this hypothesis, Transit Research Unit (TRU) staff recommended that the Service Inspectors begin riding the line end-to-end, as opposed to concentrating on the northern end of the line. This recommendation was implemented in October, 1991. A plot of these new deployment data is shown in Figure 5. Concomitantly, the Superintendent of Operations Staff instructed the Service Inspectors to concentrate more of their effort on the peak periods, when ridership is greatest (and, presumably, when LASD deployment is also greatest). The impact of these changes in SIU deployment during the period October-December, 1991 is shown in the table below:

Comparison of LASD and SIU Metro Blue Line Fare Inspection Rates
(October-December, 1991)

MONTH	LASD REPORTED INSPECTION RATE	% TIMES SIU INSPECTED
October	34%	40%
November	31%	n.a.
December	27%	44%

As can be seen, simply redeploying the Service Inspectors in a manner that more closely followed the deployment pattern being used by the LASD (at the time) actually reversed the direction of the discrepancies in the reported inspection rates. Although this situation is still obviously problematic, one could argue

SCRTD SERVICE INSPECTORS DEPLOYMENT DISTRIBUTION

(ALL DAY)

Alighting Station

October 1991

Boarding Station

	LBTM	Pacific	1st /5th	Anaheim	PCH	Willow	Wardlow	Del Amo	Artesia	Compton	Imperial	103rd	Firestone	Florence	Slauson	Vernon	Washington	San Pedro	Grand	Pico	Metro
LBTM												3									24
Pacific														1						2	
5th / 1st																					2
Anaheim																					
PCH																					
Willow																					
Wardlow																					
Del Amo																					
Artesia																					
Compton																					
Imperial			1		1																
103rd																					3
Firestone	1																				
Florence																					
Slauson																					
Vernon																					
Washington																					
San Pedro																					
Grand																					
Pico																					
Metro	22		6							1	2										

Northbound

Southbound

Figure 5

that the higher SIU fare inspection rates that have been obtained since October, 1991 essentially eliminate any of the concerns one might have about whether the LASD is, in fact, conducting fare inspections at the minimum rate specified in the contractual agreement.

Several tentative conclusions can be drawn from this simple analysis of LASD versus SIU deployment and the ensuing changes that were implemented:

- o LASD deployment schemes are not statistically random processes, but incorporate, in all likelihood, other important determinants of deployment patterns, including enforcement priorities and logistics;
- o relatively high SIU inspection rates can be achieved by having the Service Inspectors ride end-to-end and concentrate on those time periods when Deputy Sheriffs are apt to be on board in greater numbers -- however, the resulting SIU inspection rate will likely contain significant errors (tending towards the high side); and
- o the likelihood of the Service Inspectors precisely mimicking the Deputies' deployment pattern is very low, which means the SIU fare inspection rate will generally not be a valid indicator of the percentage of Metro Blue Line patrons who have their fares inspected.

B. ANALYSIS 2: ACCURACY OF LASD'S FARE INSPECTION COUNTS

The second analysis conducted as part of this study was designed to address the two questions we had concerning the reliability of the fare inspection data reported by the LASD, namely, how accurate are the Deputies' on-board and fixed-post passenger counts, respectively.

o <u>Accuracy of LASD On-board Counts</u>

To assess the accuracy of the LASD on-board counts, TRU staff took advantage of the availability of point checks conducted at either Imperial Station or

Florence Station as part of the District's ongoing strategy to statistically estimate Metro Blue Line ridership. The test essentially involved comparing the load counts recorded by Schedule Checkers at one of the aforementioned stations with the on-board counts reported by the LASD Deputies for the same (or proximal) stations. It should be noted that the data had to be extensively edited because many of the Deputies' passenger counts were based on a single car as opposed to both cars. Moreover, because the times recorded by Deputies are often approximations between stations, and train run numbers were not always available, TRU staff had to rely on judgement to match the data. Trips that staff could not agree were matches were eliminated from the analysis. The final sample consisted of 62 matched trips.

The results of the analysis are shown in Tables 2-5 and Figure 6. As can be seen, there was very little difference between the counts recorded by the Schedule Checkers and the Deputies, which suggests essentially no systematic bias (over or undercounting) by either group. For the 62 trips in the sample, taken together, the Schedule Checkers estimated a total of 4,611 passengers, whereas the Deputy Sheriffs indicated that they had checked 4,431 passengers on-board the trains (a difference of 3.9%). A comparison of the 33 trips for which there were exact station matches yields 2,519 passengers for the Schedule Checkers and 2,406 passengers for the Deputy Sheriffs (a difference of 4.5%).

These relatively small discrepancies are especially impressive given the variability generally associated with ridership estimates. The direction of the discrepancies is also noteworthy. As Tables 2-5 show, with one exception, the overall counts for the Deputies were <u>less</u> than those for the Schedule Checkers. This is precisely as expected, because, unlike the Schedule Checkers, it was very possible that some of the Deputies were not able to check every person on each train. We would expect the former's overall counts to be higher than the latter's.

Table 2

Comparison of LASD On-Board Fare Inspection

Counts with Florence Station Point Checks (Northbound)

Date	Trip #	LASD Fare Insp. Count	LASD Stations	Point Check (Florence)	Diff.
NORTHBOUND					
3/04/92	2260*	79	**Fire/Flor**	76	+3
	2480	20	Fire	25*	-5
	2520	29	Fire	38*	-9
	2540	30	Fire	32*	-2
	2800	57	103rd/Fire	79	-22
	2840*	27	**Flor**	27	0
	3040*	21	**Flor**	35	-14
3/20/92	2260	69	103rd/Fire	65	+4
	2280*	68	**Flor/Slau**	55	+13
	2340	79	Fire/Flor	45	+34
	2660	50	103rd/Fire	70	-20
	3180*	35	**Flor/Slau**	45	-10
Overall Total:		564		592	-28
Florence Station:		230		238	-8

* Florence Station Check (boldface type)

Note: One-half point check load used for single-car fare inspection counts

Table 3

Comparison of LASD On-Board Fare Inspection

Counts with Florence Station Point Checks (Southbound)

Date	Trip #	LASD Fare Insp. Count	LASD Stations	Point Check (Florence)	Diff.
SOUTHBOUND					
3/04/92	1710	20	Fire	20	0
	2250*	153	**Flor/Fire**	154	-1
	2310*	64	**Flor**	69	-5
	2430*	68	**Flor**	70	-2
	2690	82	Fire	80	+2
3/20/92	1310	62	Fire	31	+31
	1610	55	Fire/103rd	70	-15
	1870*	44	**Flor/Fire**	93	-49
	1910	41	Fire/103rd	70	-29
	2310*	58	**Flor**	63	-5
Overall Total:		647		720	-73
Florence Station:		387		449	-62

*Florence Station Check (boldface type)

Note: One-half point check load used for single-car fare inspection counts

Table 4

Comparison of LASD On-Board Fare Inspection

Counts with Imperial Station Point Checks (Northbound)

Date	Trip #	LASD Fare Insp. Count	LASD Stations	Point Check (Imperial)	Diff.
NORTHBOUND					
4/03/92	**1440***	80	**Impe**	100	-20
	1480	123	103rd	178	-55
	1560*	204	**Impe/103rd**	189	+15
	1600	120	Comp	116	+4
	1720	204	Comp/103rd	180	+24
	1800	62	Comp	87	-25
	1920*	87	**Impe**	66	+21
	1960	82	103rd	65	+17
	2220	46	Comp	40	+6
	2360	37	Comp	35	+2
	2480	158	Comp	159	-1
	2560*	110	**Impe/103rd**	129	-19
	2640*	55	**Impe**	61	-6
	2920	110	Comp	130	-20
	3040*	98	**Impe/103rd**	99	-1
	3240*	51	**Impe/103rd**	45	+6
	3960	60	Comp/Fire	57	+3
	4000*	37	**Impe**	28	+9
Overall Total:		**1,724**		**1,764**	**-40**
Imperial Station:		**722**		**717**	**+5**

*Imperial Station Check (boldface type)

Note: One-half point check load used for single-car fare inspection counts

Table 5

Comparison of LASD On-Board Fare Inspection

Counts with Imperial Station Point Checks (Southbound)

Date	Trip #	LASD Fare Insp. Count	LASD Stations	Point Check (Imperial)	Diff.
SOUTHBOUND					
4/03/92	1450*	98	Impe	92	+6
	1490*	159	Impe/Comp	170	-11
	1610	91	103rd/Impe	92	-1
	1730	42	103rd	39	+3
	1770*	32	Impe	40	-8
	1810*	80	Impe/Comp	76	+4
	1890*	28	Impe	24	+4
	1930	33	Comp	42	-9
	1970	33	103rd	39	-6
	2330	41	103rd	48	-7
	2370*	25	Impe	43	-18
	2410*	80	Impe/Comp	74	+6
	2450*	69	Impe/Comp	72	-3
	2530*	64	Impe	75	-11
	2650	99	Fire/103rd	87	+12
	2890*	52	Impe	49	+3
	3130*	110	Impe/Comp	113	-3
	3290*	64	Impe/Comp	80	-16
	3650*	80	Impe	78	+2
	4010*	90	Impe	86	+4
	4250	90	Comp/Arte	73	+17
	4490*	36	Impe	43	-7
Overall Total:		1,496		1,535	-39
Imperial Station:		1,067		1,115	-48

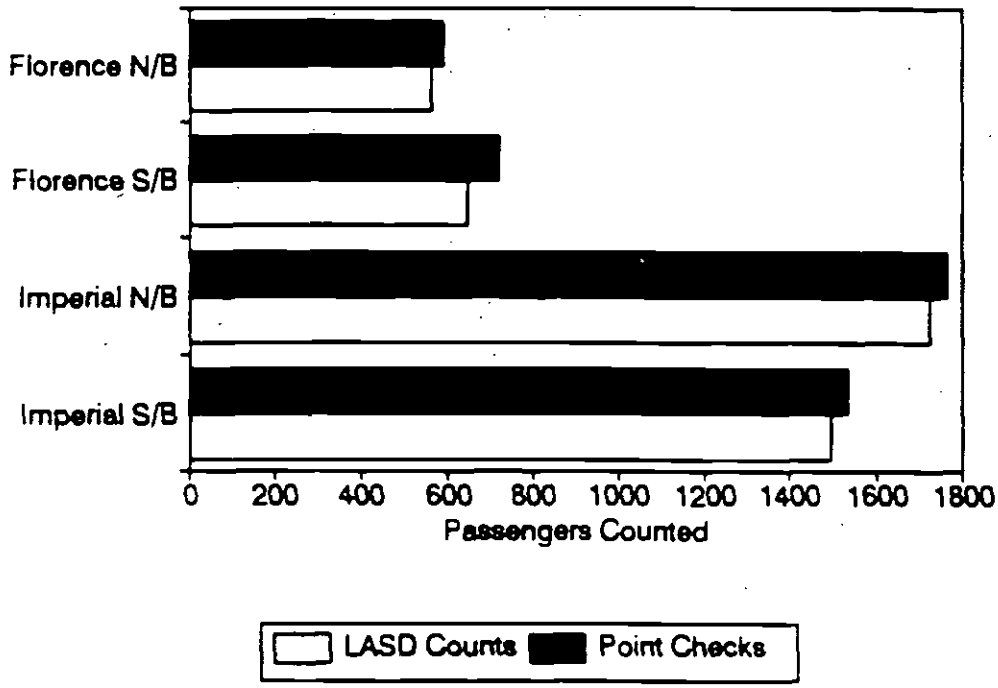
*Imperial Station Check (boldface type)

Note: One-half point check load used for single-car fare inspection counts

Figure 6

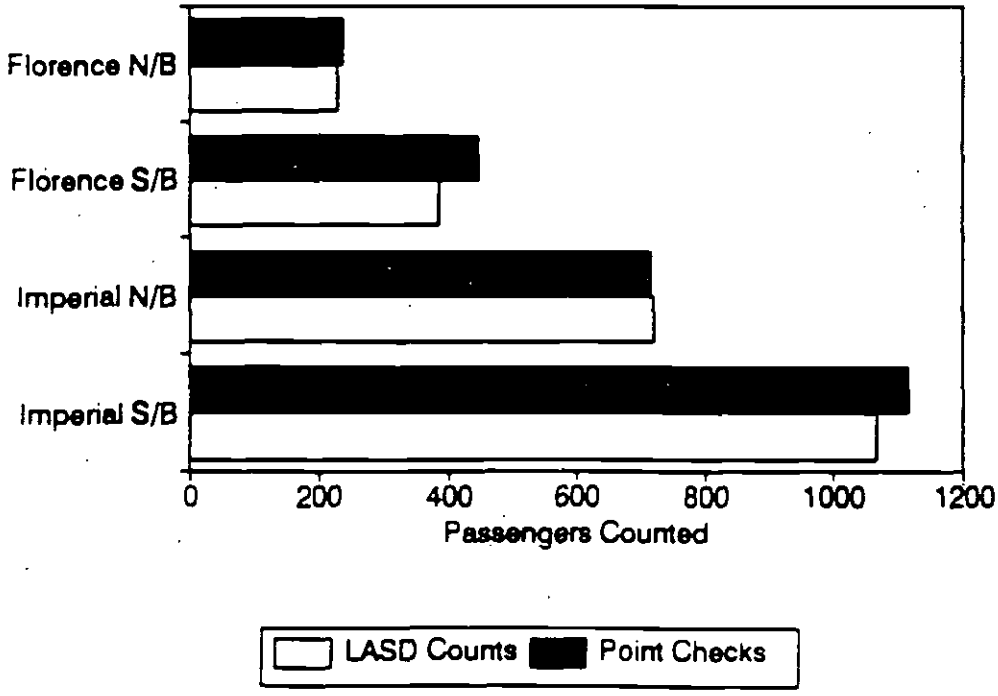
OVERALL COUNT COMPARISON

On-Board Fare Inspection vs. Point Checks



STATION-SPECIFIC COMPARISON

On-Board Fare Inspection vs. Point Checks



Despite the positive findings, it would be inappropriate to strongly conclude that the on-board passenger counts recorded by the LASD are completely without error. At least three caveats must be offered. First, although the overall counts are good, there are substantial discrepancies in the passenger estimates on many of the individual trips. The range of discrepancy, for the 33 exact station matches, was -49 to +21 passengers (it cannot be determined whether the errors were those of the Schedule Checkers, the Deputies, or some combination thereof). Second, the sample size was relatively small and may not be representative of the universe of LASD Deputies who work the Metro Blue Line. Third, these data do not provide any insight concerning the quality of the on-board inspections--e.g., were the fares checked carefully enough to detect nearly all fare evaders. In light of these caveats, we tentatively concluded that the LASD on-board passenger counts are generally reliable.

o Accuracy of LASD Fixed-Post Fare Inspection Counts

No part of this study was specifically designed to assess the accuracy of the LASD fixed-post fare inspection counts; therefore, we were largely unable to address this issue. It is worth noting, however, that as part of the development of the probabilistic model of "double-checking" presented later in this report, fare inspection counts recorded by the Deputy Sheriffs at several fixed-post locations in March, 1992 were compared with the SCRTD ride-check-based boardings profile for the same locations. On average, the counts recorded by the Deputies were approximately two-thirds the corresponding boardings shown in the ride check for the 30 comparisons that were made. It is important to note that this value is an estimate based on a very limited sample of data. In this sample, three of the 30 passenger counts recorded by the LASD showed out-of-range values (for example, one Deputy recorded 352 fare inspections when the boardings profile shows only 102 boarding passengers at that location). It is possible that some of these passenger counts included fare inspections of patrons who were alighting

from a train in addition to those passengers who were boarding. This might account for fare inspections exceeding boardings in certain locations.

On the basis of these very cursory comparisons, and in light of the accuracy exhibited by the Deputies in recording on-board inspection counts, we tentatively concluded that the fixed-post counts recorded by the Deputies appear to be reasonably accurate. A much more extensive ad hoc analysis would have to be conducted, however, to strengthen this conclusion. Moreover, as was the case with the on-board fare inspection counts, the fixed-post counts do not provide any insight into the quality of the inspections. We could not discern whether the counts recorded by the Deputies at fixed posts represented the actual number of persons who were approached by the Deputies and asked to produce proof of fare payment, the number of persons observed purchasing tickets, or some other condition.

C. ANALYSIS 3: ESTIMATING MULTIPLE FARE COUNTS ON SINGLE TRIPS

Given the deployment strategies used by the LASD, some passengers are necessarily asked to provide proof of fare more than once during a single train trip. A more precise estimate of the actual percentage of all riders who get fare inspected can be arrived at if the effect of these multiple inspections is taken into account. In order to accomplish this, it is first necessary to determine precisely how many potentially duplicate inspections occur on a given day, the locations of these inspections, and the direction and time of day at which each occurs. Once this information has been compiled, the number of passengers involved in each of these duplicate inspections must be estimated.

Towards that end, we devised a formula which allows us to calculate the probable number of passengers involved in any given duplicate fare inspection. The formula is presented in Appendix D, along with definitions of its components and an example of its application. In order to obtain some sense of the magnitude of the double-checking that results from duplicate fare inspections,

data from the Deputy Sheriffs' Daily Inspection reports for several days during the past year were analyzed. It must be noted that the estimates resulting from this effort are extremely preliminary, as only a small sample of data was included in the analysis.

It is also important to realize that, even with a current and reliable estimate, the value which results from application of the formula is not meant to represent the exact number of over-counts for a day. This value is probability based, and indicates that there is a high likelihood that this approximate amount of over counting occurred; the estimate should be close to the actual frequency for that day, though some variation from the true value is inevitable.

The current analysis examined data from April, 1991 and March, 1992. These two periods were chosen, in part, because the deployment strategies employed by the LASD Deputies during each were quite different. It was felt that an assessment of the effects of these differences on the rate of duplicate fare inspections would increase our knowledge of the effectiveness of different deployment strategies. Several summary tables of the data were prepared to facilitate comparisons between the two time periods. A brief explanation of the contents of the tables is necessary to clarify the information presented.

Table 6 shows the number of simple duplicate inspections that occurred during the a.m. peak, the base period, and the p.m. peak, for three days in April, 1991. Table 7 contains the same information for four days in March, 1992. The information is presented separately for duplicates involving only on-board inspections, and for those involving fixed-post inspections. These values do not indicate the number of passengers involved in double-counting. Rather, these are the number of times the trains were involved in duplicate inspections. The number of passengers actually involved will vary from

Table 6

Metro Blue Line Fare Inspection Project

Number of Occurrences of Duplicate Inspections

Period / Location	Dates					
	4/03/91		4/08/91		4/10/91	
	N/B	S/B	N/B	S/B	N/B	S/B
AM						
On-Board	8	13	13	7	8	7
Fixed-Post	9	16	0	0	0	0
Total	17	29	13	7	8	7
Base						
On-Board	1	5	1	1	10	2
Fixed-Post	0	0	2	0	0	0
Total	1	5	3	1	10	2
PM						
On-Board	4	4	1	0	17	11
Fixed-Post	0	0	0	0	0	0
Total	4	4	1	0	17	11
All Day						
On-Board	13	22	15	8	35	20
Fixed-Post	9	16	2	0	0	0
Total	22	38	17	8	35	20

Table 7

Metro Blue Line Fare Inspection Project

Number of Occurrences of Duplicate Inspections

Period / Location	Dates							
	3/04/92		3/18/92		3/20/92		3/23/92	
	N/B	S/B	N/B	S/B	N/B	S/B	N/B	S/B
AM								
On-Board	0	0	1	0	0	5	2	0
Fixed-Post	0	3	0	11	23	18	12	10
Total	0	3	1	11	23	23	14	10
Base								
On-Board	0	0	1	2	1	4	1	3
Fixed-Post	0	0	0	0	0	0	0	0
Total	0	0	1	2	1	4	1	3
PM								
On-Board	0	2	6	13	2	7	7	3
Fixed-Post	17	10	8	63	31	16	41	34
Total	17	12	14	76	33	23	48	37
All Day								
On-Board	0	2	8	15	3	16	10	6
Fixed-Post	17	13	8	74	54	34	53	44
Total	17	15	16	89	57	50	63	50

Table 8

Metro Blue Line Fare Inspection Project

Estimated Number of Double-Counted Inspections*

Period / Location	Dates					
	4/03/91		4/08/91		4/10/91	
	N/B	S/B	N/B	S/B	N/B	S/B
AM Peak						
On-board	159	118	250	6	198	61
Fixed-post	7	18	0	0	0	0
Total	166	136	250	6	198	61
Base						
On-board	11	124	4	36	191	36
Fixed-post	0	0	6	0	0	0
Total	11	124	10	36	191	36
PM Peak						
On-board	54	139	7	0	340	403
Fixed-post	0	0	0	0	0	0
Total	54	139	7	0	340	403
All Day						
On-board	224	381	261	42	729	500
Fixed-post	7	18	6	0	0	0
Total	231	399	267	42	729	500

* Calculations based on average daily ridership of 24,000

Table 9

Metro Blue Line Fare Inspection Project

Estimated Number of Double-Counted Inspections*

Period / Location	Dates							
	3/04/92		3/18/92		3/20/92		3/23/92	
	N/B	S/B	N/B	S/B	N/B	S/B	N/B	S/B
AM								
On-board	0	0	20	0	0	25	19	0
Fixed-post	0	0	0	61	121	9	23	13
Total	0	0	20	61	121	34	42	13
Base								
On-board	0	0	15	96	25	142	6	92
Fixed-post	0	0	0	0	0	0	0	0
Total	0	0	15	96	25	142	6	92
PM								
On-board	0	31	74	427	19	342	110	101
Fixed-post	40	12	8	68	44	82	7	29
Total	40	43	82	495	63	424	117	130
All Day								
On-board	0	31	109	523	44	509	135	193
Fixed-post	40	12	8	129	165	91	30	42
Total	40	43	117	652	209	600	165	235

* Calculations based on average daily ridership of 33,000

occurrence to occurrence. Examination of these tables reveals that the rate of duplicates, particularly those involving fixed-post fare inspections, is higher for the data from March, 1992. The estimated number of passengers affected by the duplicate inspections is presented in Table 8 for April, 1991 and Table 9 for March, 1992. As can be seen from Tables 8 and 9, we estimated that a total of approximately 2,168 patrons were double-checked during the three days in April, 1991 that were examined (mean = 723 per day) versus 2,061 patrons, total, during the four days in March, 1992 (mean = 515). That is, we estimated that double-checking decreased from about 3 percent of total daily riders to about 1.5 percent. Again, this reduction most likely reflects a change in LASD deployment strategy, especially given that ridership increased by about 9,000 passengers daily from April, 1991 to March, 1992. We cannot stress strongly enough that these are preliminary estimates based on a probabilistic mathematical model. In order to calculate a more reliable estimate, it would be necessary to examine considerably more data, including information from a more recent time frame than that which was available for the current analysis.

Several other items of interest can be seen by comparing the results in Tables 8 and 9. The data from April, 1991 indicate that northbound trains accounted for more duplicate inspections than did southbound trains, while precisely the opposite is true of the March, 1992 data. In the April data, the proportion of duplicates occurring during the a.m. peak and the p.m. peak were comparable; in the March data, the p.m. peak accounted for a large majority of the duplicate fare inspections.

The following <u>very</u> <u>tentative</u> conclusions can be drawn from this preliminary analysis of double-checking:

- o incidences of double-checking occur relatively infrequently and, therefore, should not materially affect the fare inspection rates reported by the LASD;
- o the LASD deployment strategy in place in April, 1991 yielded more double-counts, on average, than did the deployment strategy in place in March, 1992;
- o approximately two percent of Metro Blue Line (weekday) riders are subjected to multiple fare inspections, on average (as of March, 1992); and
- o adjusting the LASD fare inspection rate to account for double-checking is not necessary given that the percentage of persons subjected to multiple fare inspections is relatively small.

IV. ALTERNATIVE LASD DEPLOYMENT STRATEGIES IN A BARRIER-FREE ENVIRONMENT

As work progressed on this study, any number of interesting research questions emerged regarding how best to cost-effectively deploy Deputy Sheriffs to maximize such things as patron safety, station security, and fare inspections while minimizing other factors such as fare evasion, double-checking of fares, and personnel costs. Unfortunately, much of this research is clearly outside of the purview of the present study. Nonetheless, a few comments on this complex issue are warranted.

Although untested, it is our opinion that an effective deployment strategy would likely feature a strong fixed-post orientation. That is, most of the Deputies would inspect fares at designated stations. Deputies assigned to fixed posts might rotate among them, spending some time at one location and then going to an adjacent location, and so forth. This effort could be augmented by a few Deputies who "rove" on board to establish a presence. On-board fare inspections

would be kept to a minimum (just enough to ensure compliance with the contractual agreement). A possible method for testing the effectiveness of such a strategy is presented below.

TRU staff recently conducted a (non-exhaustive) literature search on the topic of minimizing fare evasion on barrier-free rail systems. The results were sparse. Perhaps the most promising paper we found was entitled, "Fare Evasion and Non-Compliance: A Simple Model" (Boyd, Martini, Rickard, and Russell, 1989) which presented the problem as a mathematical model amenable to validation by computer simulation. Following the general logic of Boyd, et al., we briefly describe how computer simulation might be used to evaluate alternative fare inspection deployment strategies by the Los Angeles Sheriff's Department.

A simulator is a mathematical model that imitates the essential characteristics of a process under investigation. The model identifies the important variables and how they are interrelated. To simulate a given LASD fare inspection deployment strategy, the pattern of fare evasion by the public and its detection by the LASD, a mathematical model that mimics the interaction between the LASD and the public on the Metro Blue Line is required. In this particular case we are interested in, among other things, ensuring the LASD is fulfilling its contractual obligation of inspecting approximately 25% of the Blue Line ridership for fare payment and detecting the maximum number of fare evaders.

The "process generator" in this simulation is an encounter between a Deputy and a member of the riding public. Several outcomes are possible in this encounter. The patron can have proof of correct fare payment, an incorrect fare (e.g., expired transfer), or no proof of fare payment in his/her possession. For the Deputy's part, he/she may elect not to fare-inspect the patron, inspect the patron and detect the fare evasion, or inspect the patron and not detect the incorrect fare payment. All these possible outcomes can have probabilities associated with them based

on the relative frequencies of their occurrence in historical data. Other variables necessary to complete the simulation are boarding patterns by station, direction, and time of day; rate of fare evasion; and deployment strategy (number of Deputies, time of day, fixed-post inspections versus on-board, and so forth).

The resulting simulation can be described as a huge log sheet where all the fare inspections and their results are entered by station, time of day, train run, direction, and Deputy. This simulation is a sample that describes one day of interaction between Deputies and the public and will generate values for fare inspection and fare evasion rates. By repeating the sampling procedure (simulation) over and over, it is possible to simulate the occurrence of the phenomenon as it actually happens in the real world. In fact, you can compute the number of simulation runs necessary to achieve a certain confidence level for the desired statistics.

To ascertain the efficacy of different deployment strategies, a simulation analysis would be required. The simulation analysis consists of a series of experiments designed to see what happens to a particular model under a variety of conditions and circumstances. Once the model has been validated, in that it accurately mimics LASD operations on the Blue Line, the deployment strategies and staffing levels can be modified to examine their effect on the fare inspection and fare evasion detection rates. Again, large enough samples should be obtained to get reliable estimates of the variables of interest. Many different deployment scenarios can be experimented with to test the sensitivity of fare evasion detection. The model can be further refined by the introduction of behavioral variables such as the socioeconomic characteristics of likely fare evaders and the aggressiveness of Deputies in the inspection effort. Recent Blue Line passenger origin and destination survey data can be used to pinpoint travel characteristics of probable fare evaders.

The deployment strategies utilized depend greatly on the objectives you wish to achieve. You might want to maximize fare evasion detection within budgetary and manpower constraints and fulfill the contractual inspection rate. Alternatively, you might want to maintain some minimum fare evasion detection rate while fulfilling the contractual inspection rate. It is important to note that the model does not indicate which strategy is optimal. It only shows what is likely to happen if a particular operating policy is put into effect.

The main advantages to using a simulation model to examine different fare inspection deployment strategies are:

- o tedious and repetitive computations are done by computer once the model has been constructed;
- o in the real world it would take at least one month to generate the value for the fare inspection and evasion detection rates for a given deployment strategy. With a model you can simulate a year of different deployment strategies in a matter of minutes; and
- o a representative simulation will provide important insights into the characteristics of a deployment strategy including multiple and erroneous counts.

The principal limitation to the use of any simulation model is the amount of time and effort necessary to construct and validate the model. However, the proliferation in recent years of many specialized simulation software packages has made this task somewhat easier.

In conclusion, simulation models are designed to be experimented with in order to learn the probable effects of a particular operating policy. Because the objective is not to arrive at a mathematical solution, simulation models can accommodate very complex and realistic conditions such as the interaction of the

LASD and the public during fare inspection activities on the Metro Blue Line. Simulation can provide information that would not otherwise be obtained unless different deployment strategies were experimented with in a trial-and-error fashion, which is a risky and non-optimal way to evaluate decision alternatives.

V. STUDY CONCLUSIONS

The primary purpose of this study was to determine the underlying reasons for the discrepancy between the fare inspection rate reported by the Los Angeles Sheriff's Department and the rate reported by SCRTD's Service Inspection Unit. By conducting several simple, but tedious, analyses this was satisfactorily accomplished. Our main conclusions, which are supported by the analyses, are summarized below:

(1) The LASD and SIU fare inspection rates differ not because of measurement error or differences in methods, but because the personnel deployment strategies used by the two agencies are (statistically) non-random and inherently different.

(2) Fully reconciling the rates is not feasible. It is not likely that the Service Inspectors will precisely mimic the deployment pattern used by the LASD in the foreseeable future.

(3) The SIU fare inspection rate will generally not be a valid indicator of the percentage of Metro Blue Line patrons who get fare inspected.

(4) Relatively high SIU inspection rates can be achieved by having the Service Inspectors ride end-to-end and concentrate on those time periods when Deputies are apt to be on board in greater numbers. However, this strategy yields artificially high rates that are not statistically reliable.

(5) Fare inspection is conducted in a disproportionate manner on the line, creating "holes" in the inspection coverage. Certain segments/stations tend to be checked more frequently than others depending upon the LASD deployment strategy that is in place at any given time.

(6) LASD on-board fare inspection counts, in the aggregate, appear to be reliable and accurate. This is also true of the fixed-post passenger inspection counts recorded by the Deputy Sheriffs (although additional tests are required to strengthen this conclusion).

(7) Incidences of double-checking appear to occur relatively infrequently and, therefore, should not materially affect the fare inspection rates reported by the LASD. Based on a sample taken in March, 1992, approximately one and one-half percent of Metro Blue Line riders are involved in multiple fare inspections on any given day. However, this finding should be tested using current data. The rate at which double checking occurs is influenced by whatever LASD deployment scheme is in place at the time. For this reason, the rate should be monitored, and new data collected whenever there is a change in deployment.

VI. RECOMMENDATIONS

The following recommendations follow from the study's conclusions:

(1) All side-by-side reporting of LASD and Service Inspection fare inspection rates should be eliminated. If the data must be simultaneously reported, a footnote discussing the methods and explaining the difference between the rates should accompany the information. For example, one might indicate that, because of differences in the deployment strategies of the two units, the computation method used by the Service Inspection Unit does not reliably estimate the rate reported by the Sheriff's Department.

(2) Because an important part of the Service Inspector's work is to see how non-payments (on-board) are handled, the LASD should routinely notify SIU of on-board deployment patterns in place. The strategy of deploying Service Inspectors in a manner similar to the Sheriff's Deputies could be used whenever opportunities for on-board inspections need to be maximized.

(3) The fare inspection rate reported by the LASD should be accepted as the official rate because the SIU rate is generally not a valid indicator of the true rate of fare inspections (due to differences in deployment strategies between the two tracking agencies). However, the LASD rates should be periodically checked for accuracy.

(4) Discontinue the policy of mostly end-to-end SIU trips. Instead, implement specialized deployment strategies that assess the quality of service along particular line segments or during specific times of day. Vary the "target" monthly. Service Inspectors should be randomly deployed across all days of the week unless the "target" for a particular month is a certain day (e.g., Wednesday).

(5) The LASD (perhaps with assistance from SCRTD staff) should conduct studies concerning the accuracy of fare inspection data. To facilitate this, current data collection forms should be carefully reviewed and modified, as needed. In the future, Deputies should indicate on the form whether the recorded fare inspection occurred at a fixed-post location or on-board a train. Also, more standardization with respect to data entry on forms would be helpful. The meaning of each entry should be clear and unambiguous.

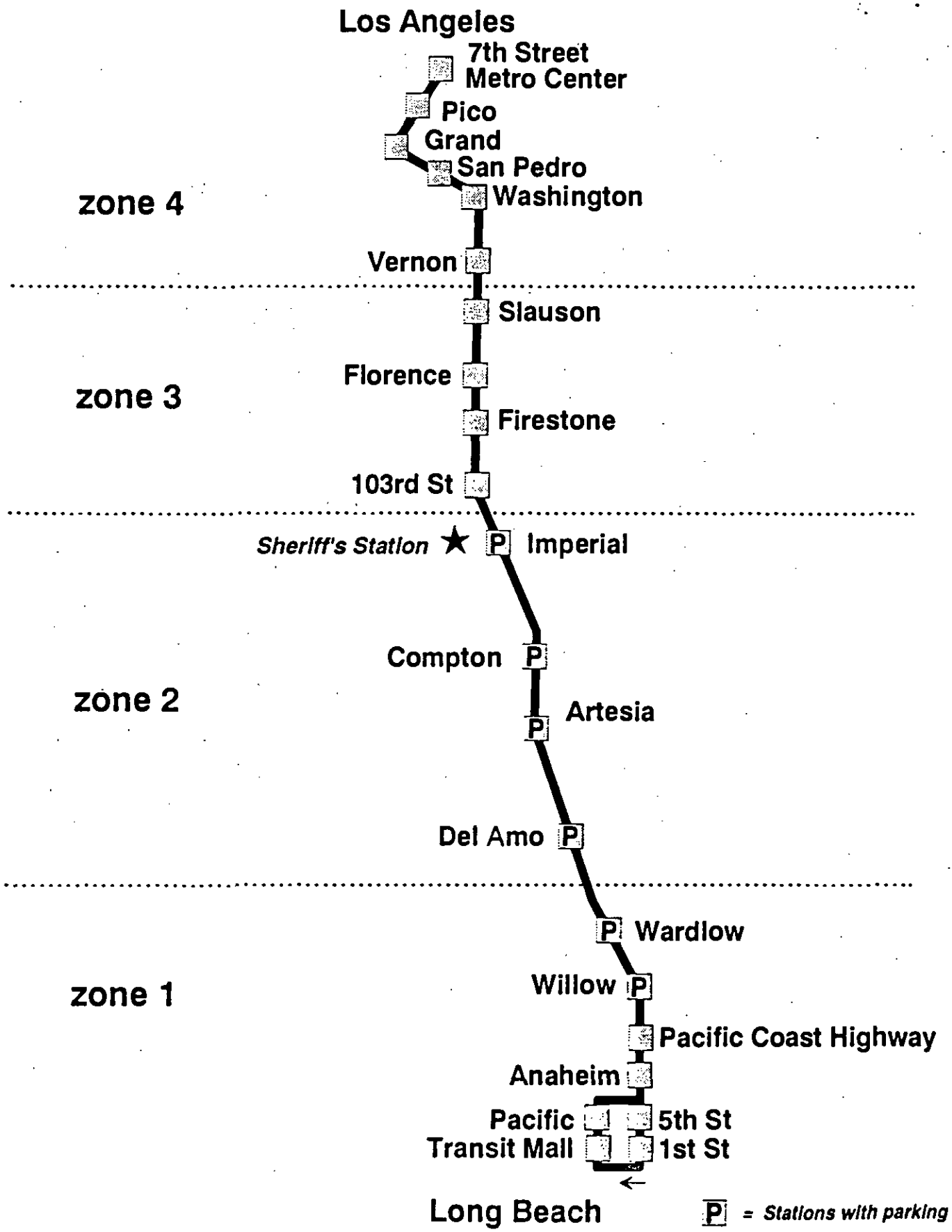
(6) The LASD should investigate the possibility of using hand-held computers (HHCs) for data collection. In addition to their use for fare inspection data, HHCs might also be utilized to record citation activity, and so forth.

(7) The LASD should consider requesting funds for a large-scale computer simulation demonstration project to test alternative deployment strategies in a barrier-free environment. One possible funding source would be the Federal Transit Administration (FTA).

REFERENCES

Boyd, C., Martini, C., Rickard, J., and Russell, A. (1989): "Fare evasion and non-compliance: a simple model." Journal of Transport Economics and Policy, May, 189-197.

Metro Blue Line
Los Angeles Sheriff's Department Deployment Zones



APPENDIX B

LASD Daily Fare Inspection Report Form

DAILY FARE INSPECTION REPORT PAGE __ OF __

TRANSIT SERVICES BUREAU

NAME:_____ DATE:_____

DAY:_____ ZONE: NORTH [ ]SOUTH [ ]OTHER [ ]

SHIFT:_____ CALL SIGN:_____ EMPLOYEE #:_____

TIME	M/S	PAX STATION	TRAIN CAR #	TOTAL PAX	NON PAYS	FARE EVASIONS	OTHER CITES	WARNING
TOTALS								

CITATIONS:
STARTING #_____
ENDING #_____

VENUE
ADULT (C.M.C.)_____
JUVY. L.A. _____
JUVY. L.B. _____

ARREST REPORTS ___
OTHER REPORTS ___
F.I.R.'S. ___
WARRANT CHECKS ___

VIOLATION TYPES
640 (a) _____
640 (b) _____
640 (c) _____
640 (d) _____
640 (e) _____
640 (f) _____
602.7 _____
others _____

APPENDIX C

SIU Metro Blue Line Ride Check Form

SERVICE INSPECTOR BLUE LINE RIDE CHECK

Trip#_____ Inspector_____ Date_____19___
Line 801 Car#_____ A B Run#___
Location On:_____ Time On: _____ AM PM
Location Off:_____ Time Off:_____ AM PM
Sheriff I.D._____ unable to see___

	Yes	No
Fare Inspection Made.....	___	___
Loc.of 1st check_____ # of passengers__ Time_____ AM PM		
Loc.of 2nd check_____ # of passengers__ Time_____ AM PM		
All Stations Announced.. Once___ Twice___..	___	___
Eating, Drinking,Smoking Etc. Announced.....	___	___
Public Address System-Audible & Intelligible	___	___
Interior Cleanliness.....	___	___
Exterior Cleanliness.....	___	___
Incidents of Passenger Misconduct.....	___	___
Visible Graffiti, Vandalism.....	___	___
Delays Associated With Defective TVM'S.....	___	___
Defective Door(s).....	___	___
Patrons Eating,Drinking,Smoking Etc.....	___	___
In Car ____ On Platform___		
Sheriff/Passenger Relations Observed.....	___	___

Size of Load.... 1/4___ 1/2___ 3/4___ Full___
(In Inspector's Car Only) Standees #___
Type of Fare Media in Possession:
Valid Proof- Ticket___ Transfer___ Pass___
Invalid Proof- No Fare___
Invalid Ticket___ Time Expired___
Invalid Transfer__ Wrong Date___
Wrong Direction___
Passes: Wrong Month___ Sch.___ Sr.___ Rdcd/Hndcp.____
Action Taken by L.A.S.D.- Citation__ Warning__ No Detection__
See Reverse Side For Comments Yes___ No___

APPENDIX D

Algorithm to Estimate the Rate of Duplicate Fare Inspections

The following formula has been derived to estimate the number of passengers involved in duplicate fare inspections on a single train trip. This algorithm contains many different components, two of which require some brief explanation before the formula can be applied. Moreover, the various situations which necessitate the use of the formula differ from each other somewhat. A discussion regarding the use of the formula under these different conditions follows.

When exactly two fare inspections occur during a single train trip, the formula can be applied in a straightforward manner and requires no additional clarification. However, when more than two fare inspections occur on a single train trip the situation becomes complex: some passengers may be inspected three (or more) times during the trip, while others on the same trip may be inspected twice. Take, for example, three inspections, occurring at stations labeled "A," "B," and "C." Those passengers who travel between stations A and C are inspected three times, while those riding from stations A to B are inspected twice. Another group of passengers, those who travel from stations B to C, are also inspected twice. It can be seen that, when more than two inspections occur during the same train trip, there are several pairs of duplicate fare inspections embedded within the larger cluster. It is not sufficient to simply calculate each of these pairs separately and then sum the resulting values; this procedure leads to an inflated estimate. In order to determine the total number of "double-checks" occurring in a cluster, it is only necessary to calculate the number of passengers involved in each of the double fare inspections, then sum the

results; ignore the triple and/or quadruple fare inspections. In the example given above, the duplicates from A to B and from B to C (double inspections) would be calculated and summed; the duplicate from station A to station C (triple inspection) would be ignored. One loses the specific information as to how many passengers were involved in the triple and each double, but the total value is the same.

Another issue which arises in situations such as the one just described concerns two of the terms used in the formula. Components "I" and "J" are defined as the zone in which the first inspection occurred, and the zone in which the second inspection occurred, respectively. These definitions require clarification, because, as was shown above, there will occasionally be a situation in which more than two inspections occur during the same train trip. Consequently, in such a situation, it is necessary to specify exactly which inspections will be considered as "first" and "second." This procedure is straightforward, and should not present any problems. In the example given above, two separate calculations would take place, and the results would be summed to arrive at the final answer. The first calculation would account for passengers involved in duplicate inspections at stations A and B. In this case, station A is the location of the first inspection, and station B is the location of the second inspection. The next calculation would account for passengers involved in inspections at stations B and C. Here, station B is the location of the first inspection, and station C the location of the second.

For purposes of deployment, the LASD has designated four separate zones along the route of the Metro Blue Line. Zone 1 includes the stations from the Long Beach Transit Mall through Wardlow station; zone 2 begins at Del Amo station and continues through Imperial station; zone 3 extends from the 103rd Street

station through Slauson station; and zone 4 begins at Vernon station and ends at the Seventh Street Metro Center. It should be noted that when the formula is used to assess duplicate fare inspections on southbound trips, the zone numbers need to be reversed such that zone 4 is designated as zone 1, zone 3 is designated as zone 2, and so forth.

$$\sum_{m=P}^{I}\left(\frac{A_k \times B_m}{C_k} \times \frac{F_m}{D_m} \times L_m \times \frac{H_m}{E_m} \times P\right) \times \left(\sum_{n=J}^{Z} \frac{E_n - H_n}{E_n} \times G_{mn}\right) \times (Av.\ Daily\ Ridership)$$

k — A given direction and time period

A_k — The proportion of daily ridership who travel in the k direction and time period

I — The zone in which the first inspection occurred

J — The zone in which the second inspection occurred

Z — The numbers of zones

P — If the first inspection occurred at a fixed-post, P=I; if the first inspection occurred on board a train, P=1

m — The zone being examined for boardings

n — The zone being examined for alightings

B_m — The proportion of all riders travelling k who board in zone m

C_k — The number of train runs in k

D_m — The number of stations in zone m

F_m — Set to 1 if m=I and inspection occurred at a fixed post, and equal to D_m in all other cases

H_m — If m=I, H_m = (The number of inspections in zone m which occurred prior to the current inspection on the same train run as the current inspection) + 1
Else, $H_m = 1$

E_m — If m=I, E_m = (The number of inspections occurring within zone m on a single train run) + 1
Else, $E_m = 1$

L_m — Set to 1 if m=I and inspection occurred on board a train, and equal to E_m/H_m in all other cases

P — The proportion of all riders boarding at a given station who have had their fares inspected at that fixed post (in the current data this value is 0.67); if no fixed-post inspection occurred, P = 1

H_n — If n=J, H_n = (The number of inspections in zone n which occurred prior to the current inspection on the same train run as the current inspection) + 1
Else, $H_n = 0$

E_n If n=J, E_n = (The number of inspections occurring within zone n on a single train run) + 1
else, E_n = 1

G_{mn} The proportion of riders who, having boarded in zone m, alight in zone n

APPENDIX E

Algorithm to Estimate the Rate of Duplicate Fare Inspections:

An Applied Example

The following computation yields an estimate of the number of passengers involved in duplicate fare inspections assuming a fixed-post check in zone 2 coupled with an on-board check in zone 4 during the a.m. peak (5 a.m. - 9 a.m.), as described in the following scenario:

> If, during the a.m. peak, a fixed-post fare inspection is being conducted at Artesia Station, trains travelling through this station are likely to pick up passengers who have already had their fares inspected once. If one of these same trains, travelling northbound, is later boarded at, say, the Pico station by an LASD Deputy who again inspects fares, some of the passengers on board will now be involved in their second fare inspection.

The final result of the calculation (shown below) suggests that, on average, approximately four people will be asked to show proof of fare twice during this train trip. It is extremely important to note that this result applies only to this specific situation. This trip is only one of many on which duplicate fare inspections may occur over the course of a single day. In order to arrive at an estimate of daily duplications, each separate occurrence would have to be calculated and the individual results summed. It is also important to note that the value of factor "P" is fluid, and depends upon the fare inspection techniques being used by the Deputy Sheriffs at any given time. The value of 0.67 used in the current calculations is an estimate based on a very limited sample of data. For any computations undertaken in the future, we strongly advise that this value be reassessed.

$$\sum_{m=P}^{I}\left(\frac{A_k \times B_m}{C_k} \times \frac{F_m}{D_m} \times L_m \times \frac{H_m}{E_m} \times P\right) \times \left(\sum_{n=J}^{Z} \frac{E_n - H_n}{E_n} \times G_{mn}\right) \times (\textit{Av. Daily Ridership})$$

$$\left(\frac{(.18)(.255)}{31} \times \frac{1}{4} \times 2 \times \frac{1}{2} \times 0.67\right)\left(\frac{2-1}{2} \times (.87)\right)(33{,}000) = 4 \textit{ people}$$

k = Northbound, a.m. peak

A_k = .18 — See page E-IV for a table of these values.

I = 2 — Artesia Station, the location of the first inspection, is in zone 2 -- see the Metro Blue Line map in Appendix A.

J = 4 — Grand Avenue Station, the location of the second inspection, is in zone 4 -- see the Metro Blue Line map in Appendix A.

Z = 4 — There are four LASD zones along the Metro Blue Line route -- see the map in Appendix A.

P = 2 — The first inspection occurred at a fixed-post, therefore P=I.

m = 2 — We are only concerned with those passengers who board in zone 2, the location of the first inspection. Because the inspection occurred at a fixed-post, only these riders can be involved in duplicate inspections on this trip. If the inspection in zone 2 had occurred on board the train, a portion of the passengers who boarded in zone 1 would also be involved in duplicate inspections and, in that case, "m" would be equal to 1.

n = 4 — We are only concerned with those passengers who alight in zone 4, the location of the second inspection. Only these passengers can be involved in duplicate inspections on this trip.

B_m = .255 — See page E-IV for a table of these values.

C_k = 31 — This value is dependent on the SCRTD Metro Blue Line schedule. There are currently 31 northbound train trips during the a.m. peak.

D_m = 4 — There are 4 stations in zone 2 -- see the Metro Blue Line map in Appendix A.

$F_m = 1$	Set to 1 because m=I and the inspection occurred at a fixed-post.
$H_m = 1$	No inspections occurred in zone 2 during this train trip prior to the current one. 0 + 1 = 1.
$E_m = 2$	One inspection occurred in zone 2 during this train trip. 1 + 1 = 2.
$L_m = 2$	Set equal to E_m/H_m because the inspection did not occur on board a train.
$P = .67$	This value is a constant applied to fixed-post inspections. In the current data, LASD Deputies at fixed-posts inspected approximately two-thirds of boarding passengers.
$H_n = 1$	No inspections occurred in zone 4 during this train trip prior to the current one. 0 + 1 = 1.
$E_n = 2$	One inspection occurred in zone 4 during this train trip. 1 + 1 = 2.
$G_{mn} = .87$	See page E-IV for a table of these values.

Definitions and proportions for use in computation

Values of Factor "A":
Proportion of Metro Blue Line Daily Ridership
by Direction and Time Period*

Time Period	Time of Day	Direction	
		Northbound	Southbound
A.M. Peak	5 a.m. - 9 a.m.	.18	.09
Base	9 a.m. - 3 p.m.	.16	.16
P.M. Peak	3 p.m. - 7 p.m.	.13	.22

*The values in this table will not sum to 1.0 because late night and early morning Metro Blue Line passengers have not been included

Values of Factor "B": Northbound

Time Period	Zone			
	1	2	3	4
A.M. Peak	.621	.255	.105	.019
Base	.552	.308	.109	.031
P.M. Peak	.568	.286	.110	.036

Values of Factor "G":
Northbound -- A.M. Peak

Alighting Zone	Boarding Zone			
	1	2	3	4
1	.03			
2	.22	.04		
3	.12	.09	.02	
4	.63	.87	.98	1.0