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Abstract

In an earlier paper [Sen and Thakuriah, 1995] a method for computing static profiles was given. In this paper, the centrality of such profiles for ATIS is examined and the methods given in the earlier paper are applied to actual data. Except for a minor, easily correctable problem, the methods are shown to work very well under real-life conditions.
Keywords: Static Estimates, Advanced Traveler Information Systems, Dynamic Route Guidance and Link Travel Times.

1 Introduction

In an earlier paper (Sen and Thakuriah, 1995), we described ATIS systems and the potential role for static profiles. We also described a procedure to obtain static profiles. In this article, which is a follow-up to that one, we discuss static profiles further. In particular, using data collected as a part of the targeted deployment of ADVANCE, a large scale ATIS, we assess the quality of the static-profile updating procedure discussed in Sen and Thakuriah (1995).

In the following section, we briefly review ADVANCE and the role of static profiles in it. For further details, the reader is referred to Sen and Thakuriah (1995). After a description of the data and other preliminaries, the performance of the algorithms in an actual implementation is described in Section 5. A final section presents some concluding remarks.

2 Background

In the ADVANCE system, the Mobile Navigation Assistant (MNA) in equipped vehicles [called probes] computes desirable routes based on predicted travel times. Some of these estimated travel times are obtained via radio from a central computer, called the Traffic Information Center (TIC).

The TIC computes these predicted travel times from:

- link travel times obtained by the MNA in each vehicle as it traverses the link and then broadcasts the times to the TIC and

- from volumes and occupancies obtained from loop detectors at some intersections.

The MNA receives broadcasts only when the car ignition is turned on. Few drivers would be willing to wait very long to get route guidance after they have entered the car; on the other hand, there are over 10,000 links in the study area and the radio frequencies (RF) available have modest capacities. Thus, it is impossible to broadcast information on all links and have it available for the initial guidance given to the driver. Consequently, default travel-time predictions need to be available to the MNA. These defaults would be overwritten by real-time estimates of travel time (available via RF communication) when these real-time or *dynamic* estimates differ significantly from the default estimates. Moreover, the default estimates would also be available in case transmissions are interrupted.

These default travel times, based on historical and other information, reside on a compact disk in the MNA and are called Static Profiles (SP). They are also contained in the TIC within a corpus termed the Static Profile Database (SPD). Of course, when ADVANCE vehicles were first deployed no probe based travel-time data were available. Therefore, initial Static Profiles, which we call Base Data (BD) estimates, were constructed using a network equilibrium-based model called the Network Flow Model (NFM).

After enough data had been collected from probes, the NFM estimates were revised using a procedure called Static-Profile Updating (SPU). As more data were collected further revisions occurred using a slightly different version of the SPU procedure.

The SPU procedure is discussed in detail in Sen and Thakuriah (1995) and further details of how these procedures were implemented in the field is given below.

2.1 The Importance of Static Estimation

The initial purpose for introducing static profiles was as a default. However, the experience the authors have gained from the demonstration of ADVANCE has convinced them that static profiles are not only necessary but should be taken extremely seriously. There are several reasons for this, which we discuss below.

First note that even under uncongested situations, link travel times have very large variances. This is due to traffic signals. Some cars go through without stopping during a green phase, while others have to stop for various durations during a red phase. Figure 1 illustrates it rather dramatically. The vertical axis shows travel times obtained from probes for one day on Link 11. The horizontal axis gives link exit times starting at 1:00 pm. Two bands of travel-time observations are noticeable: the upper band represents vehicles that had to stop during red; the lower band represents probes that went through during green. It should be pointed out that this two-band phenomenon appears only on certain links and depends on traffic signal progression. This phenomenon would also be less obvious on a link in which the vehicle makes a right turn on red (a link does not necessarily require a through movement on green only).

During any short time interval [ADVANCE used 5-minute time intervals] there would typically be very few probes on a link. Even during the peak period, assuming a deployment of 5000 vehicles over the entire ADVANCE study area, the average was estimated by Boyce, Hicks and Sen (1991a, b) to be slightly over one vehicle. Thus any estimate of travel time based on probe observations would also have a large variance under ideal conditions.

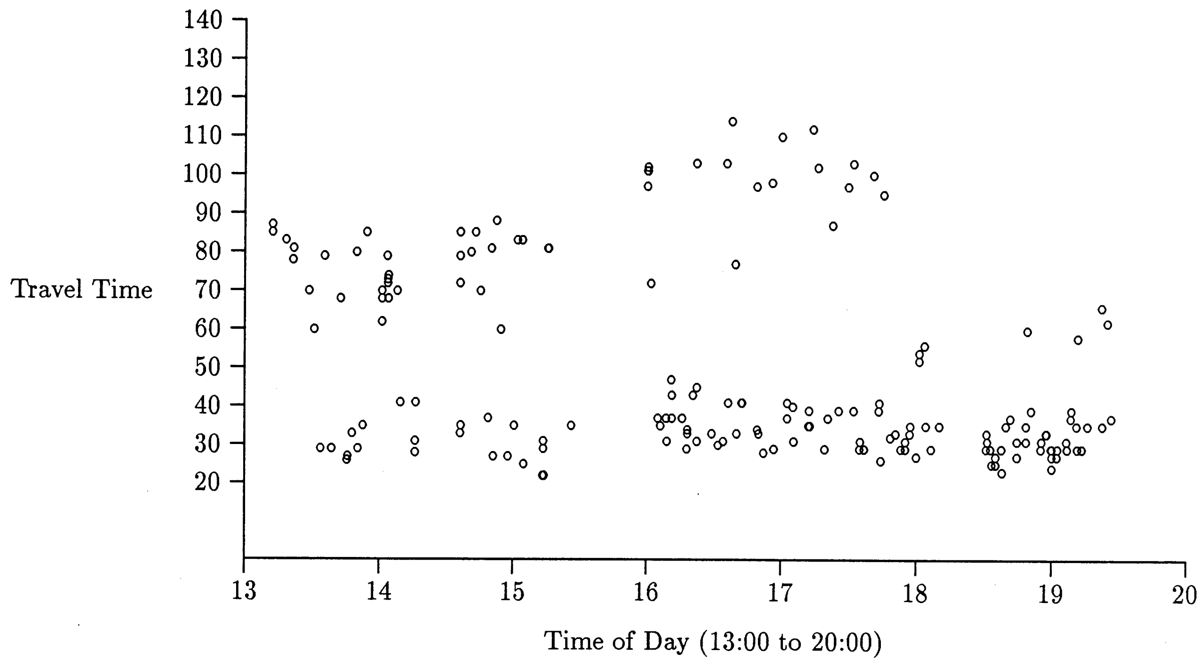

Figure 1: Probe-Reported Travel Time vs. Time of Day: Link 11, July 17

However, conditions prevailing on most signalized arterials are not ideal. Probe-reported travel times are far from being statistically independent. This is shown in Sen (1996) and Sen et al. (forthcoming) where it is also shown that variances of estimated link travel times do not go to zero with increasing number of probes per time interval. Indeed, the variances always remain large. This relationship is shown in Figures 2 and 3.

While dynamic estimates obtained from probe reports over short time intervals have large variances, static estimates or profiles, which are computed using data for several days have much smaller variances and hence are more reliable. Therefore, under 'normal' conditions it is preferable to use static estimates.

This is precisely what is done in the ADVANCE system. Dynamic estimates are broadcast only when they vary significantly from corresponding static estimates. That this is an excellent strategy is shown through a simulation exercise in Thakuriah and Sen (1995, see also Thakuriah, 1994). They show, not only that of all the information giving strategies this is the best, but also that with high enough deployment levels, route travel times obtained in this way are frequently very close to the travel times actually encountered by the vehicle.

Typically, when we use this strategy of providing dynamic estimates when they differ significantly from static estimates, for most links static estimates are used. This makes the computation of static estimates vital to ATIS.

Static estimates play other roles within ATIS systems, e.g., in incident detection. Most commercially available ATIS systems in the market today are autonomous in the sense that they do not receive travel-time estimates dynamically. That is, they rely solely on static estimates. For these systems, needless to say, static estimation is critical.

Since static profiles are critical, it is important to assess the quality of such estimates as we do in this paper.

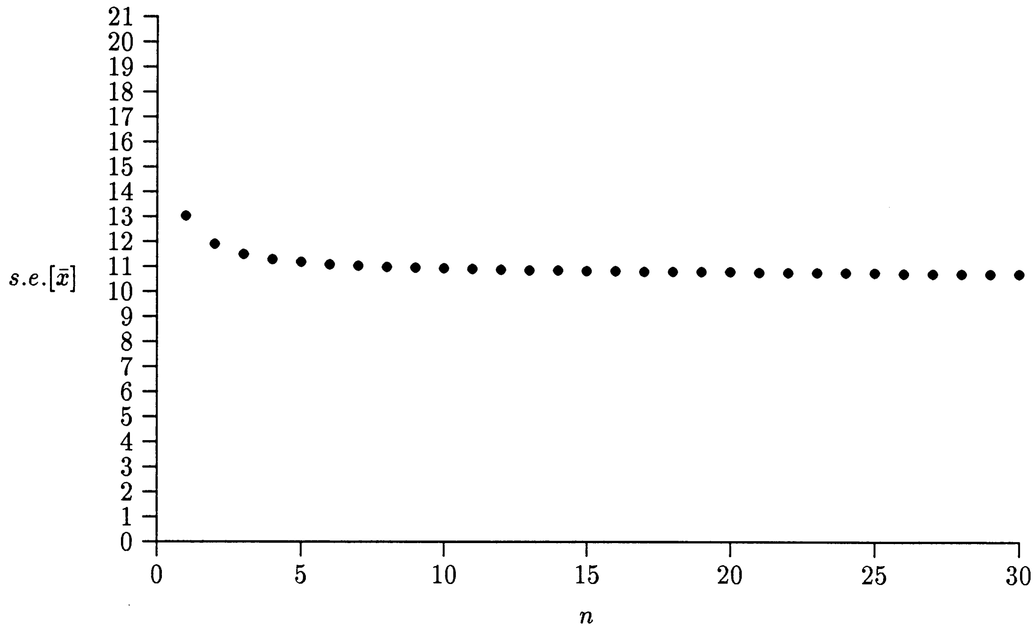

Figure 2: Relationship between Standard Error $s.e.[\bar{x}]$ and Frequency n of Probes on Link 32 during the Peak Period (x is the link travel time)

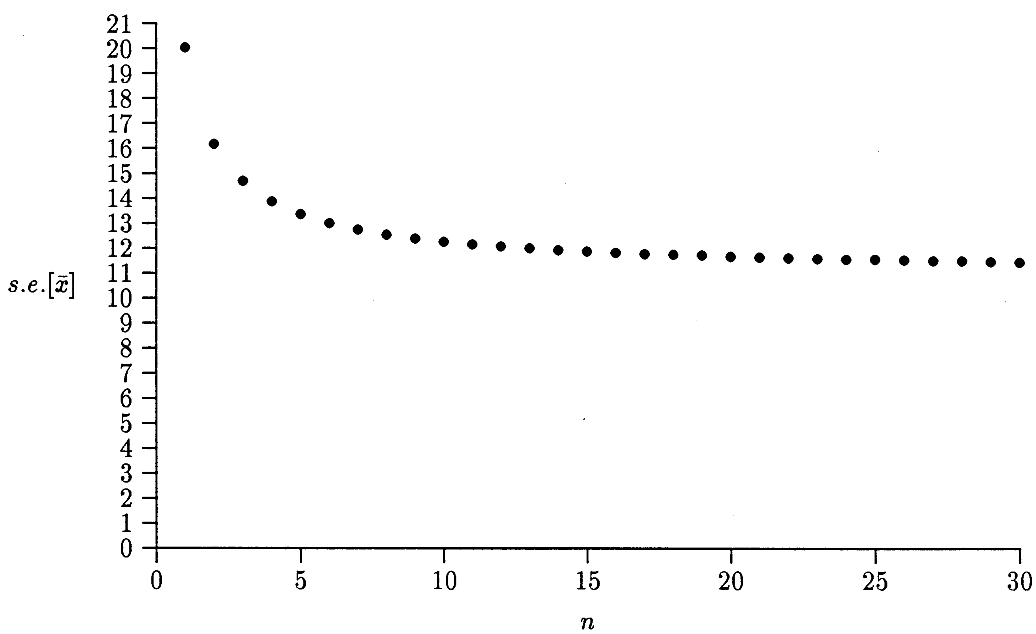

Figure 3: Relationship between Standard Error $s.e.[\bar{x}]$ and Frequency n of Probes on Link 11 during the Peak Period (x is the link travel time)

3 The Data

In order to assess the performance of the SPU procedure in a 'real-life' environment, during the summer of 1995, an average of twelve vehicles were driven four days a week over an eleven-week period. During this time almost 60,000 miles were driven to produce over 50,000 link reports within a confined study area. Data were gathered from 1:00 pm to shortly after 7:00 pm, Monday through Thursday (Table 1). While these reports have been and will be used for several purposes, they also provide the travel-time data required to perform static-profile updating.

Table 1: Probe Reports for each Hour of Data Collection

Hour Beginning	No. of Reports	Percent of Total
1pm	8464	16.7
2pm	7980	15.8
3pm	5187	10.2
4pm	8488	16.8
5pm	8433	16.7
6pm	7871	15.5
7pm	4197	8.3
Total	50620	100.0

A field manager ensured that vehicles were driving the study route at satisfactory headways and instructed drivers when to take breaks. An effort was made to release the probe vehicles at random intervals but variations in probe travel times caused some deviation from the schemes developed to achieve random release. The drivers were given ten-minute breaks at about 2:00 pm and at about 6:00 pm. A longer break occurred from 3:30 pm to 4:00 pm. Each driver took his or her break at a slightly different time, since each was dispatched by the field manager to the break area as they arrived at the staging area.

Two route configurations centered on Dundee Road in Wheeling, Illinois were used for most of the field data collection; these are depicted in Figure 4. The longer 12-link route, which extends to Milwaukee Avenue in the east, was designed to be completed within a fifteen-minute period. During the off-peak time period most drivers completed the route in ten to fourteen minutes. During the peak period this route proved to be too long to complete in fifteen minutes and a shorter alternative was used. This route includes the left turn on Link 31 onto Northgate where drivers were able to turn around and proceed to Link 10.

The section of the route on Schoenbeck Road and Palm Drive (near the west end) was used as a staging and turnaround area; since it was too short to complete a recognized link data were not collected for this section of the route.

Using two different data-collection routes resulted in variation in the numbers of probe reports from each link (i.e., the links solely on the long route are traversed less frequently). This is actually of some value in the present context since it gives us an understanding of the efficacy of the SPU procedure under different probe deployment levels. Since Links 4 through 9 are on the long route only, they have fewer link reports (Table 2).

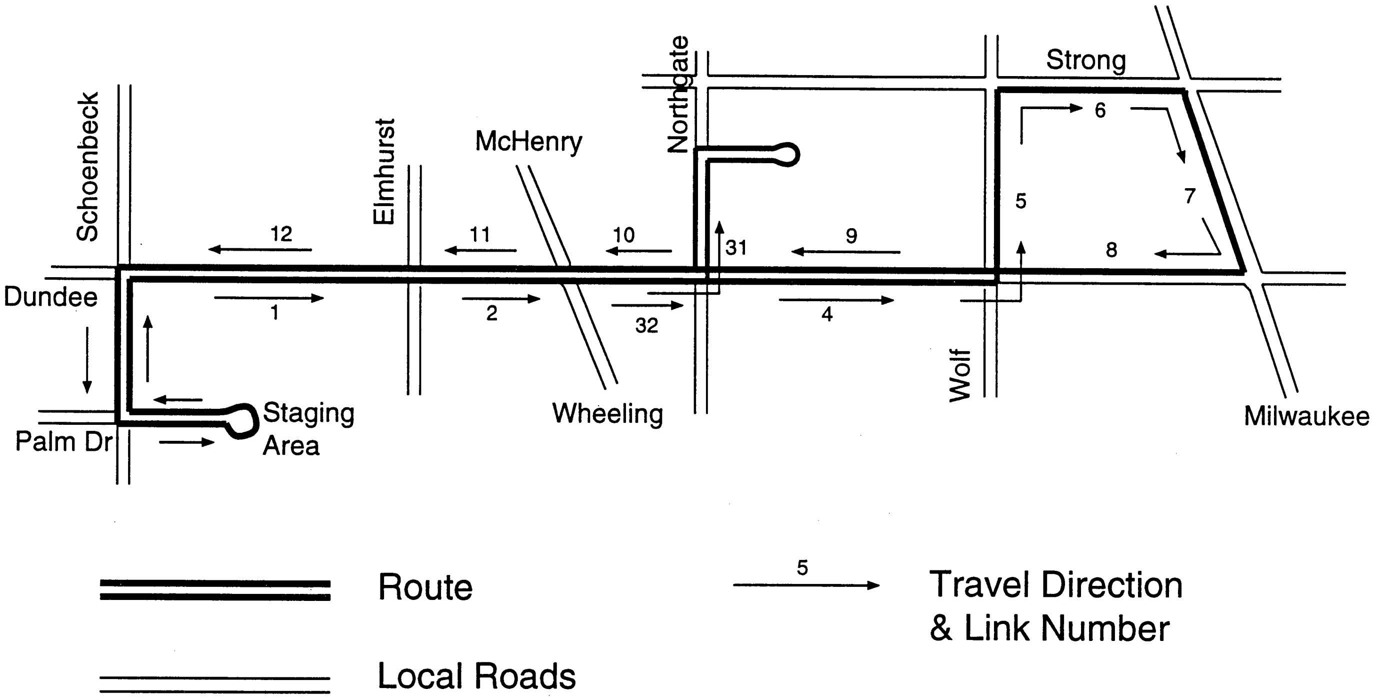

Figure 4: Probe-Data Collection: Dundee Road Routes

Table 2: MNA Reports by Link

Link	Frequency	Percent	Link	Frequency	Percent
1	5481	10.8	7	2323	4.6
2	6298	12.4	8	2172	4.3
3*	5886	11.6 *	9	2462	4.9
4	2313	4.6	10	6066	12.0
5	2294	4.5	11	7826	15.5
6	2293	4.5	12	5206	10.3
31*	3555	7.0 *			
32*	2331	4.6 *			
			Total	50,620	100.0

* Link 3 consists of two links, 31 and 32. Link 31 is on the short route and includes a left turn at the end of the link. Link 32 is on the long route and has a through movement at the end of the link (no turn)

Since the whole purpose of the BD and SP estimates is to reflect average travel times, most comparisons made below are with such averages computed from travel times reported by probes.

4 Other Preliminaries

In the NFM, used to construct the BD estimates, each weekday was divided into 5 intervals: 0000 - 0600; 0600 - 0900; 0900 - 1600; 1600 - 1800; and, 1800 - 2400. Only two of the BD intervals substantially intersect the time period over which data were collected (1:00 pm - 7:00 pm) and our evaluation is based on these. That is, our evaluation of BD is for the period 1:00 pm – 4:00 pm (the off-peak period), and for 4:00 pm – 6:00 pm (the peak period).

When probe data became available, SPU algorithms updated BD estimates. The basic method of updating is a straightforward Bayes' procedure augmented by some additional safeguards described in Thakuriah and Sen (1995). No decision had been taken as to how frequently SP updating was to occur. Since data gathering for the TRF evaluation was for an eleven-week period and we wished to carry out several updates for the purpose of this study we used much shorter updating time periods: June 6–June 18, June 19–July 9, and July 10–August 4. We call these intervals *updating intervals.* Updates were made corresponding to the last day of each collection period (i.e., June 18, July 9 and August 4).

As designed, each weekday was to consist of 2 day types (Monday to Thursday AM and Monday to Thursday PM). Each day type would have had 24 SP intervals. There were also 2 day types for Friday and one each for Saturday and Sunday and other holidays. However, since we only gathered data for Monday through Thursday, these other day types are not relevant for the rest of this paper.

The original plan was to update the original five NFM intervals once. From the next interval, the plan called for shifting to the larger number ($2 \times 24 = 48$) intervals. For purposes of this paper we carried out the SPU updating for *both* the 2 NFM intervals which significantly overlapped the time period over which the data were gathered *and* after the first SPU to move to a larger number of intervals. We call the former 2-interval SPU and the latter 10-interval SPU. Whether we use 2 or 10 intervals, we call the intervals themselves, which could be several minutes (or several hours) long, *SP intervals* to distinguish them from the *updating intervals* (which would be several days or weeks long) mentioned above.

The lengths of the intervals had not been defined in the SP design, the idea being that the most suitable intervals would only become apparent after some link travel-time data were available. Therefore, we needed to obtain suitable intervals. The intervals that were used in the evaluation were constructed using an ANOVA-based procedure. We are indebted to Todd Graves of the National Institute of Statistical Sciences for his assistance in constructing suitable intervals. These SP intervals were those over which travel times on links under study were relatively constant (see Table 3).

All analyses were performed off-line after data collection was complete. Table 4 identifies each SPU by number. SPUx refers to specific runs of the SPU procedure, and the results of these updates are referred to as SPx or Static Profile x.

Static Profile Updates 2 and 4 are both derived using probe data collected during the time period June 19–July 09; Static Profile Updates 3 and 5 are both derived using probe data collected during the time period July 10–August 04. Static Profile Updates 1, 2 and

Table 3: 10-Interval Schedule

Interval Number	Time Period	Interval Number	Time Period
1	1:00-2:30 pm	6	5:10-5:30 pm
2	2:30-3:10 pm	7	5:30-5:40 pm
3	3:10-4:00 pm	8	5:40-6:00 pm
4	4:00-4:40 pm	9	6:00-6:45 pm
5	4:40-5:10 pm	10	6:45-7:00 pm

Table 4: Static Profile Updating Intervals

Dates	2-Interval	10-Interval
June 6–June 18	SPU 1	
June 19–July 9	SPU 2	SPU 4
July 10–August 4	SPU 3	SPU 5

3 use a 2-interval schedule; Static Profile Updates 4 and 5 use the 10-interval schedule.

5 Results

In this section we proceed as follows. We use the NFM estimates and the results of the various SPU's and compare them with means of probe reported travel times. Our interest in the NFM estimates is only because they are the quantities that are updated by the SPU.

We use means for some comparisons because the static profiles were designed to estimate means, the reason being that the ultimate interest for route guidance is not so much with link travel times but with their sum — route travel times — and means of sums are the same as sums of means. This property is not shared by other measures of location [or central tendency] like the mode or median.

While such comparisons are interesting, the efficacy of travel-time estimates used for forecasting must be judged on how well they function as forecasts. We do this in the final subsection of this section. To conserve space, not all possible results are presented. More comparisons are available in Sen *et al.* (1996).

5.1 SPU Estimates — 2-Interval Schedule

The estimates of link travel times from the NFM model and from various SPU's for the 2-interval case are shown in Tables 5 and 6, for the peak period and the off-peak period respectively. Next to the NFM estimates are the means, the standard deviations and the estimates of the standard error of the mean for all observations for the appropriate SP interval for all days. It should be pointed out that the standard errors are the result of formal arithmetic using formulæ derived under an assumption of independence. Probe reports are *not independent*; consequently, these are underestimates. They are given here as a means of reference. Significance tests were not carried out because, apart from the fact that the standard errors are underestimates, it is difficult to compare two different estimates of the same parameter constructed using some of the same data.

Next to each of the SPU's are the means of probe report for the appropriate SP interval *and* update interval. These means were used in constructing the SPU's.

Given that the NFM estimates were synthesized without the benefit of probe data, the results (BDs) cannot be considered too poor. They are, however, not likely to yield good route guidance. In fact, Links 5 and 6 where the correspondence is close are lightly traveled links with no socialization. Indeed, for a variety of reasons, we do not believe that network equilibrium-based models would yield excellent travel-time estimates. However, we postpone this discussion for a later paper.

Table 5: Link Travel-Time Data and Static Profile Travel-Time Estimates (in seconds), 2-Interval Schedule: Peak Period

	Probe (June 6 - July 23)					SPU 1		SPU 2		SPU 3	
Link	# Reports	Mean	S.D.	S.E.	BD	est	probe	est	probe	est	probe
1	2032	75.6	22.5	0.50	54	64.1	71.1	66.9	68.9	69.1	72.3
2	2085	43.8	28.7	0.63	34	57.3	62.3	58.5	59.5	58.1	56.6
31	940	62.8	31.3	1.02	—	61.7	65.3	63.9	65.7	65.3	67.8
32	1185	30.3	16.2	0.47	79	35.1	40.0	39.8	40.7	41.2	42.2
4	1189	95.4	33.1	0.96	65	94.6	104.0	112.8	117.9	116.5	120.5
5	1163	36.5	4.1	0.12	33	36.1	37.2	36.8	37.5	37.7	38.2
6	1164	45.3	9.7	0.29	53	52.7	52.4	54.6	54.5	56.2	58.3
7	1171	107.4	52.0	1.52	56	204.4	244.8	200.2	200.0	219.4	238.8
8	1025	55.6	21.2	0.66	44	113.4	134.0	76.6	75.6	82.1	118.3
9	1125	64.0	30.5	0.90	175	231.7	255.3	177.8	155.3	196.4	218.7
10	2023	60.3	30.4	0.68	34	82.0	91.8	80.5	79.8	80.4	80.4
11	1833	56.6	28.4	0.64	57	65.4	60.7	49.2	44.5	51.4	56.7
12	1822	74.7	22.5	0.53	46	75.3	83.7	81.5	94.2	80.5	79.3

Note: For Tables 5 and 6, "est" refers to the SPU estimate of mean travel time and "probe" refers to the average travel time for that link as determined from actual probe data gathered in that updating interval (see Table 4).

It is apparent that the static estimates are quite good in that they are quite close to the means of probe-reported travel times, a point which is particularly true for the third update. Even when the BD estimates are relatively poor, the corresponding SP estimate moves rapidly towards a better value. This is particularly evident if we compare the overall means of probe travel times with the SPU3 travel-time estimates. It may be seen that there is a fair amount of variation from updating interval to updating interval for the same link. Therefore, it would be unreasonable to anticipate smaller differences between the means from one SP to the next. For example, consider Link 8 during the peak period. The means

Table 6: Link Travel-Time Data and Static Profile Travel-Time Estimates (in seconds), 2-Interval Schedule: Off-Peak Period

	Probe (June 6 - July 23)					SPU 1		SPU 2		SPU 3	
Link	# Reports	Mean	S.D.	S.E.	BD	est	probe	est	probe	est	probe
1	1793	70.8	24.2	0.57	56	64.4	70.7	69.6	72.5	74.4	79.8
2	1771	58.8	33.1	0.79	36	47.5	52.7	45.2	44.0	42.3	40.8
31	1307	66.5	32.2	0.89	—	56.9	67.9	60.4	63.9	60.0	61.0
32	551	41.6	19.6	0.84	76	27.1	29.6	30.1	31.6	29.7	29.2
4	558	119.1	47.1	1.99	64	84.8	95.6	92.8	96.6	93.4	94.3
5	555	38.0	7.5	0.32	33	34.8	36.1	36.0	36.5	36.3	36.8
6	548	56.8	26.6	1.13	44	44.2	44.4	45.0	45.4	45.2	45.5
7	500	225.4	120.8	5.40	47	91.2	97.0	98.1	103.2	102.6	114.8
8	580	104.6	73.4	3.05	55	55.9	54.4	55.5	55.4	55.7	56.2
9	613	198.8	106.9	4.32	105	58.2	61.2	63.7	68.1	62.1	61.2
10	1949	82.2	23.6	0.53	32	57.1	57.6	61.1	65.3	59.3	57.7
11	1830	52.7	27.8	0.65	35	51.4	59.7	55.2	57.7	55.0	54.7
12	1801	85.9	33.7	0.79	61	67.3	71.9	72.0	80.4	71.9	71.7

of probe reports for the three update intervals, which are 134.0, 75.6 and 118.3 seconds, offer too much of a moving target, especially because not only is the mean in the middle updating interval small, its estimated variance is also small, 'fooling' the updating procedure into 'thinking' it is more 'reliable' than it actually is. However, this link does get flagged [see, Sen and Thakuriah, 1995] as suspicious and if the data after the third update yielded a mean similar to that in update interval 3, the procedure would ignore update intervals 1 and 2. Link 7 during the off-peak illustrates another moving target. But here, the reason that the third mean is high is that there are two observations of over 800 seconds. This fact illustrates the robustness of SPU's.

5.2 SPU Estimates — 10-Interval Schedule

Tables 7 through 10 show the results from SPU4 and SPU5 for four of the time intervals in the 10-interval schedule. Recall that SPU4 uses data gathered after the application of SPU1 and updates the results of SPU1. SPU5 updates the results of SPU4. Also, while only two intervals were used for SPU1, 10 intervals are used for SPU4 and SPU5. Consequently, the sample sizes used for each SP interval in SPU4 and SPU5 are relatively small in comparison to those for SPU1. The sample sizes are also shown in Tables 7 through 10. Note that the sample sizes given for each link in these tables do not match those in Table 2 which includes links reports for the entire data-collection period.

Table 7: Link Travel-Time Data and Static Profile Travel-Time Estimates (in seconds), 10-Interval Schedule: 1:00-2:30 pm

	Probe (June 6 - July 23)				SPU4		SPU5	
Link	# Reports	Mean	S.D.	S.E.	est	probe	est	probe
1	1194	74.4	21.2	0.61	68.9	72.8	73.5	79.3
2	1230	42.6	28.7	0.78	46.1	44.8	42.2	40.2
31	538	61.3	32.6	1.38	57.7	59.3	57.0	57.3
32	705	30.5	16.6	0.63	29.7	31.8	29.8	29.9
4	699	92.0	31	1.17	89.4	92.7	90.4	92.0
5	699	36.5	3.7	0.14	36.0	36.6	36.2	36.5
6	698	45.3	10.3	0.39	44.9	45.6	45.0	45.2
7	705	98.4	40.0	1.55	95.5	99.8	97.4	100.7
8	612	53.6	16.8	0.92	54.6	53.7	54.7	54.9
9	625	58.3	17.4	0.70	59.9	60.9	57.2	56.7
10	1080	54.8	31.0	0.88	57.7	58.9	55.2	51.5
11	974	60.0	28.0	0.89	54.8	58.6	55.8	56.8
12	974	75.9	20.1	0.63	70.9	78.2	71.3	71.8

Note: For Tables 7 to 10, the heading "Probe (June 6 - July 23)" refers to measures derived from data collected by probes over the period June 6-July 23, the heading "est" refers to the SPU estimate of mean travel time (in seconds), the heading "probe" refers to the average travel time (in seconds) for that link as determined from actual probe data gathered in the updating interval (see Table 4).

Table 8: Link Travel-Time Data and Static Profile Travel-Time Estimates (in seconds), 10-Interval Schedule: 2:30-3:10 pm

	Probe (June 6 - July 23)				SPU4		SPU5	
Link	# Reports	Mean	S.D.	S.E.	est	probe	est	probe
1	521	72.3	21.6	0.97	65.9	68.9	69.8	79.2
2	510	42.3	28.7	1.23	45.0	41.2	43.8	41.9
31	243	70.9	31.9	1.95	59.1	68.5	59.1	62.8
32	284	28.9	14.2	0.84	27.9	29.9	28.0	28.1
4	288	100.0	35.6	2.10	90.4	104.1	92.0	96.2
5	293	36.4	3.4	0.20	35.4	36.0	35.9	36.8
6	274	45.5	8.2	0.50	44.6	45.3	45.0	45.9
7	274	109.4	58.1	3.51	91.7	93.2	96.5	125.6
8	251	55.4	16.8	1.10	55.7	55.3	55.9	56.1
9	343	62.6	24.6	1.33	61.4	67.5	59.6	59.1
10	623	62.0	31.7	1.17	59.0	66.3	59.3	60.0
11	570	52.4	26.8	1.12	51.8	52.6	51.7	51.7
12	551	76.2	26.4	1.10	68.8	83.9	69.3	70.2

Table 9: Link Travel-Time Data and Static Profile Travel-Time Estimates (in seconds), 10-Interval Schedule: 4:40-5:10 pm

	Probe (June 6 - July 23)				SPU4		SPU5	
Link	# Reports	Mean	S.D.	S.E.	est	probe	est	probe
1	494	70.5	23.5	1.10	65.8	69.8	67.4	71.6
2	475	61.9	45.2	1.95	58.0	60.1	58.0	58.8
31	354	63.9	30.5	1.66	62.7	65.1	63.5	69.6
32	141	40.9	18.4	1.55	36.8	37.5	39.6	43.1
4	148	112.1	43.5	3.58	105.5	114.8	107.6	110.8
5	153	37.1	4.4	0.35	36.3	36.5	36.8	37.4
6	146	49.8	14.5	1.20	51.6	50.7	51.1	49.5
7	133	187.3	75.9	6.58	167.1	163.4	183.4	201.7
8	143	99.9	70.9	5.90	75.6	74.1	77.34	112.3
9	148	187.5	118.1	9.67	187.5	124.9	194.7	216.3
10	518	83.0	25.3	1.05	81.5	81.2	81.2	80.8
11	487	48.5	27.7	1.26	53.3	42.1	53.9	57.4
12	482	90.8	52.8	2.23	76.6	99.4	78.2	81.1

Table 10: Link Travel-Time Data and Static Profile Travel-Time Estimates (in seconds), 10-Interval Schedule: 5:30-5:40 pm

	Probe (June 6 - July 23)				SPU4		SPU5	
Link	# Reports	Mean	S.D.	S.E.	est	probe	est	probe
1	154	66.9	21.6	1.73	64.5	67.3	64.8	65.9
2	147	61.9	28.3	2.30	57.4	58.6	57.5	60.4
31	121	69.8	37.0	3.10	61.8	62.1	63.6	78.7
32	42	37.4	18.3	2.97	37.0	42.4	37.1	36.9
4	40	137.4	53.6	8.48	98.8	120.5	107.9	148.8
5	39	40.4	16.0	2.56	36.4	36.7	36.7	42.5
6	47	86.9	50.7	7.39	64.5	72.9	72.3	94.6
7	25	350.9	166.3	33.27	227.3	285.5	267.4	402.2
8	45	105.5	55.1	8.26	76.1	72.1	79.7	116.8
9	39	245.4	78.0	12.50	243.8	257.7	243.0	235.8
10	150	84.9	27.3	2.03	82.8	88.5	82.6	81.7
11	142	50.6	25.6	2.16	61.6	49.1	61.0	55.4
12	142	93.4	29.1	2.36	76.7	95.6	78.3	88.7

The larger sample sizes for SPU1 lead to smaller standard errors for SPU1 estimates than for means of data in the various 10-interval SP intervals. This leads to a relatively small changes in SPU4 and SPU5 estimates. We had not anticipated this. Instead we had expected that the larger estimated variances of observations taken over longer intervals would more than compensate for the larger sample sizes so that standard errors of SPU1 estimates would be about the same as those of the means over the various 10-interval SP intervals. However, we were wrong. But the problem is easily corrected and would have been if a full deployment had occurred.

A simple method of solving this problem is not to use SPU1 at all, but simply do the updating from the original NFM estimates. Clearly there are other possibilities. Another one is to construct a set of 10-interval updates at the same time as SPU1 was run, not use them but store them for use for SPU4. The only difficulty with these alternatives is that we need some data before we can choose the intervals to use. However, SPUs are carried out off-line anyway, this contributes to the need for more data storage. Given the data storage capacities in ADVANCE, there would be no need for additional storage even under full deployment over 10,000 links.

5.3 Static Profiles as Forecasts

As mentioned earlier, static forecasts are used as default forecasts which are overwritten by dynamic forecasts when they differ sufficiently from the corresponding static forecasts. Therefore, it is important to compare static forecasts with average travel time during the period they would be used as forecasts. That is, we need to compare SPU1 estimates with 5-minute means during the time period between SPU1 and SPU2, and SPU2 needs to be compared with 5-minute means during the time period between SPU2 and SPU3. Similarly, SPU4 needs to be compared with means taken during the updating interval between SPU4 and SPU5. After SPU5 and SPU3 no data were collected. The reason for using 5-minute means is that ADVANCE works on the basis of 5-minute intervals. The histograms in Figures 5 and 6 show the results of this analysis.

Each histogram was constructed in the following way:

- probe travel-time means for 5-minute intervals contained in the appropriate update and SP interval were computed,
- the corresponding SP estimate was subtracted from these probe means, and
- the numbers obtained in this way were displayed as histograms.

Clearly, values close to zero reflect cases where the probe 5-minute means were very similar to the corresponding estimates. Figure 5 shows that for most of the links the SPU2 estimates are a good predictor of travel times in the next updating interval. A visual inspection confirms that for most links the zero-difference point is near the center of the distribution of differences.

Figure 6 illustrates the differences between SPU4 and the average 5-minute travel times for four SP intervals. Two of the intervals are during the off-peak and two are for the peak period. To make the figure manageable we have selected three links (Links 2, 10 and 11).

It can be seen that the dispersion around the zero difference is similar for the two SPUs (Figures 5 and 6; note that Figure 5 covers the peak period only and Figure 6 covers both the peak and off-peak periods). Link 10, for example, has a range from approximately -40 to 60 seconds on both figures, only the 5:30 pm to 5:40 pm interval shows a smaller range.

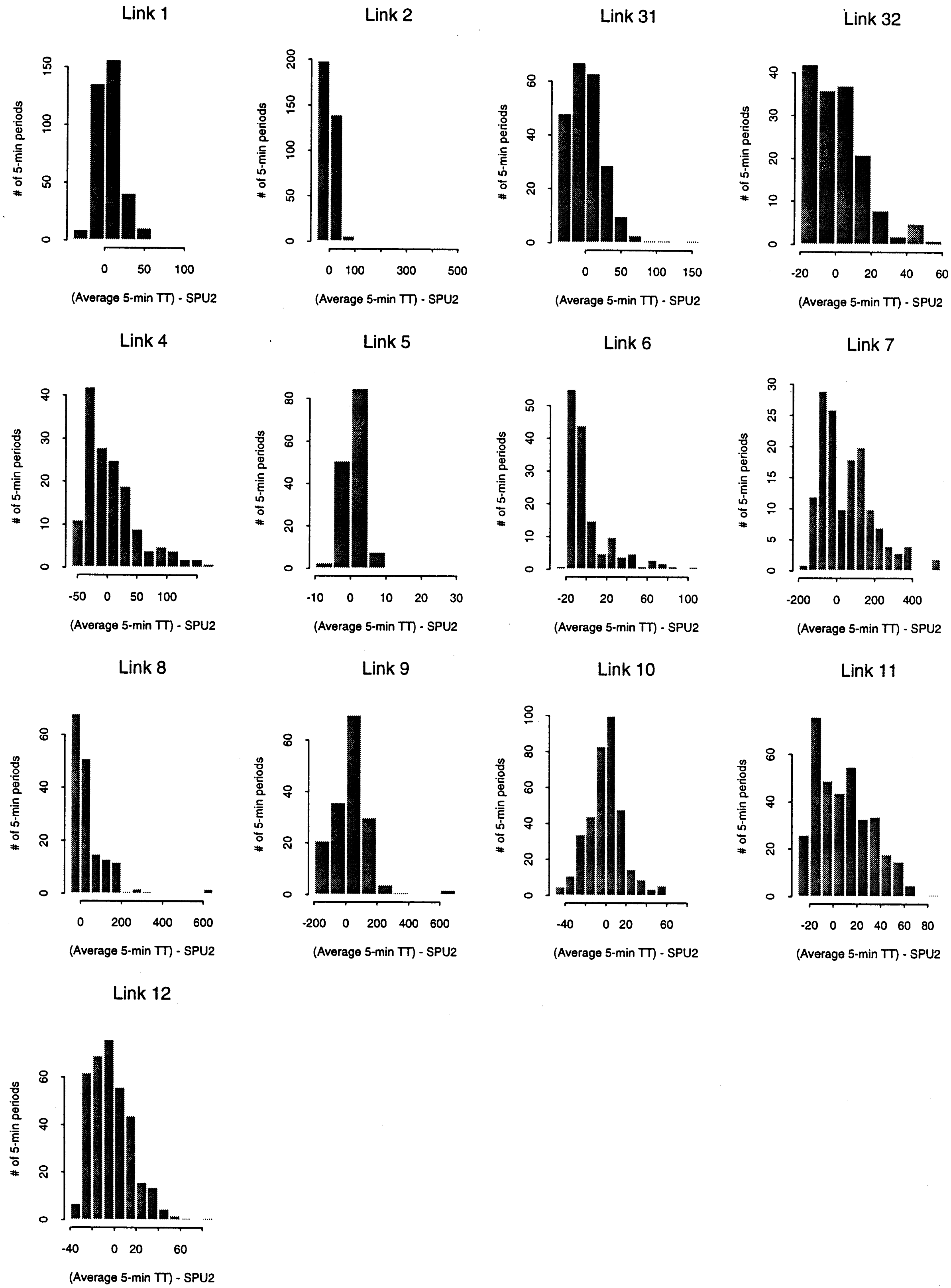

Figure 5: Histograms of Number of 5-minute Periods by the Difference between Average 5-minute Travel Time and SPU2 Estimate (in seconds): Peak

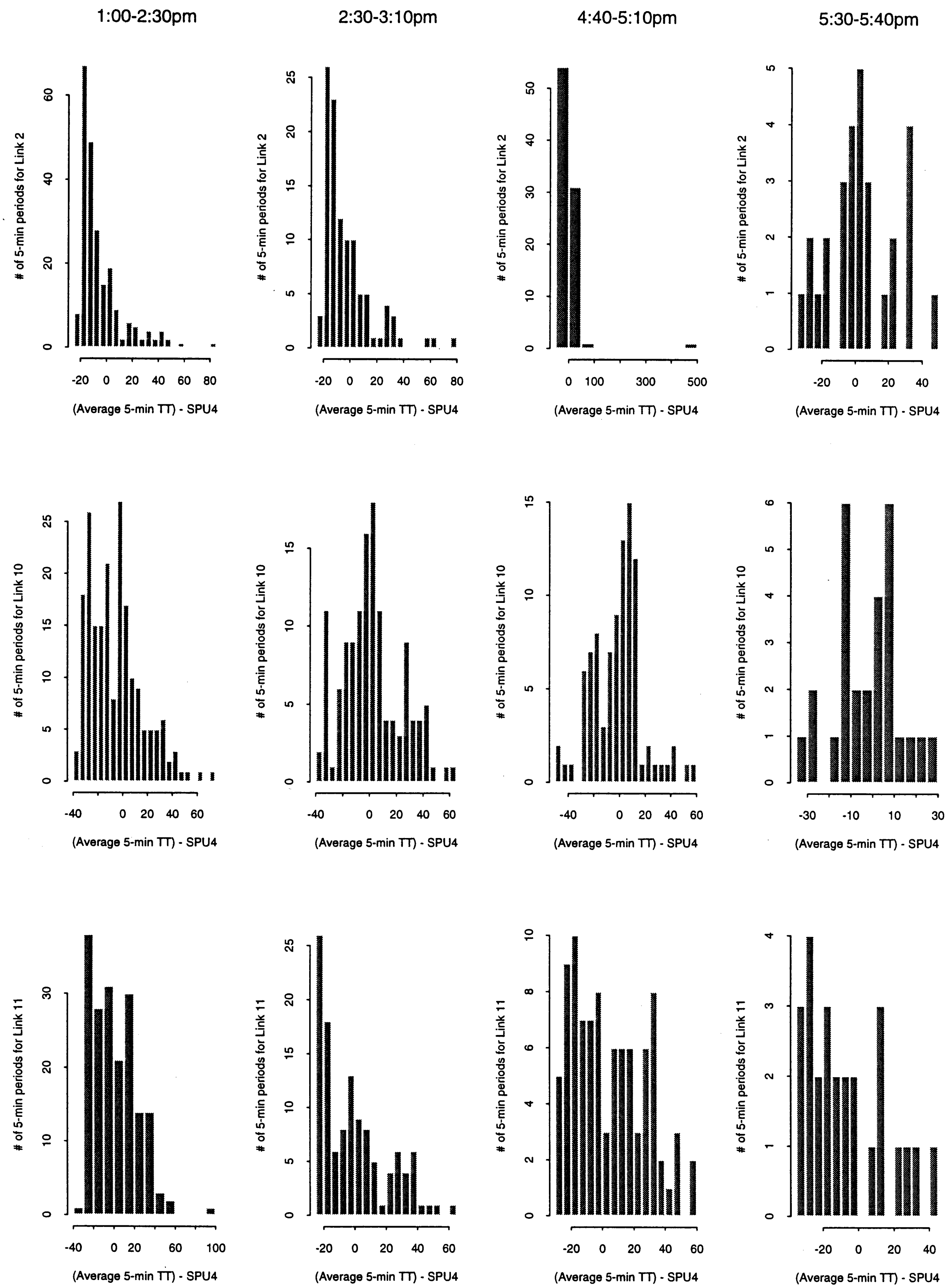

Figure 6: Histograms of Number of 5-minute Periods by the Difference between Average 5-minute Travel Time and SPU4 Estimate (in seconds): Links 2, 10 and 11

6 Conclusion

Static Profiles are critical to ATIS and the results given in this paper demonstrate that the method reported in Sen and Thakuriah (1995) is very effective in providing accurate profiles. One minor mistake was identified above, but that is easily corrected and would have been in an actual real life deployment.

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