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Arterial Performance Evaluation on an Adaptive Traffic Signal Control System

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Abstract

This paper documents the evaluation of Sydney Coordinated Adaptive Traffic System (SCATS) at a major signalized arterial in Las Vegas. The evaluation was based on various performance measures, including primarily travel times and stops at selected routes along the arterial. Extensive travel time runs were conducted during the weekday and weekend peak periods. Arterial performance was compared between SCATS and conventional time-of-day (TOD) coordination plans. Based on the data and analysis results, a general conclusion was reached that no significant improvement on arterial progression was achieved with SCATS under normal traffic conditions. However, this conclusion was made based on a major limitation of using video detection in the field, which may have significantly limited SCATS from achieving its best performance.

Keywords: SCATS, Arterial Performance, Adaptive Traffic Signal Control, Coordination, Travel Time

1. Introduction

The performance of signalized arterials is generally assessed under coordinated signal control and operations. Conventional coordination is generally achieved by implementing a set of time-of-day (TOD) coordination plans. A TOD plan is characterized as a fixed-cycle plan often obtained through minimizing total delay or maximizing arterial bandwidth based on given traffic volume and other variables. Several predetermined timing parameters (cycle lengths, offsets, and splits) are imbedded in the signal controllers and the plans run according to a time base regardless of traffic demand variance. In recent years, adaptive traffic signal control systems have emerged as an alternative to signal coordination. Unlike TOD coordination, adaptive traffic signal control systems can rapidly

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respond to traffic flow changes through active vehicle detection and communication (Gordon and Tighe, 2005; Abdel-Rahim, 1998).

Aimed at identifying advanced signal control systems to reduce urban traffic congestion, the Regional Transportation Commission of Southern Nevada (RTCSN) initiated a pilot program to implement and evaluate Sydney Coordinated Adaptive Traffic System (SCATS) in Las Vegas, NV, U.S.A. This study documents a before-after study regarding the system's performance. The study site was a section of Boulder Highway, which is one of the major arterials in the area. SCATS was implemented at ten signalized intersections as shown in Figure 1. Two intersections (E. Flamingo Rd./S. Nellis Blvd., and E. Flamingo Rd./ Perry St.) were not on the main arterial, but were included in SCATS because of the critical triangle area formed by these two intersections. The arterial segment was approximately 3.5 miles (5.6 kilometers) involving eight signalized intersections. The speed limit was 45 mph (72.4 km/hr) in both directions. Protected left-turn controls are used at all the intersection approaches on Boulder Highway. Two intersections have geometric constraints (Boulder Highway/Flamingo and Boulder Highway/Desert Inn) where simultaneous dual left-turn movements are prohibited and a lead/lag phasing sequence must be used. The vehicle detection system was the Vantage video detection system by Iteris Inc.

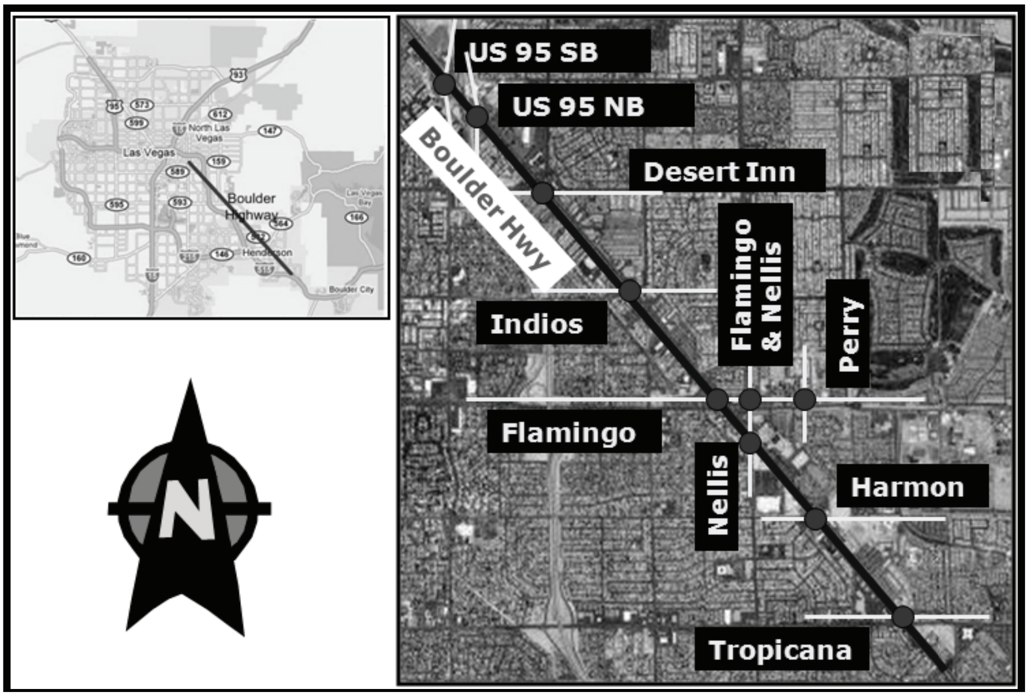

Figure 1 Site Location Map

2. Before-after study evaluation

Time-of-Day coordination plans

A new set of optimal TOD plans were developed prior to SCATS implementation and these timing plans were later compared with SCATS. TOD plans were developed according to the following rules:

- A 140-sec cycle length was used for the new plans. This was consistent with the cycle length used at nearby and crossing arterials. Therefore, disruption to the crossing arterials would be minimal.
- The new plans aimed at maximizing arterial bandwidth for the through movements along Boulder Highway and between the triangle area intersections. This was mainly done by adjusting the offsets and phasing sequences at each intersection.
- The TTI-4 phasing scheme (Abdel-Dayem and Tian, 2009a) was applied at the US 95 diamond interchange. Using this phasing sequence would eliminate all vehicle stops between the two signals.

Four peak periods were studied, which had the same 140-sec cycles although the offsets and phasing sequences were different among the four timing plans:

- AM Peak Period: 06:45 AM - 08:45 AM
- Midday Peak Period: 12:00 PM - 02:00 PM
- PM Peak Period: 03:45 PM - 05:45 PM
- Weekends (Saturday) Peak Period: 12:00 PM - 04:00 PM

Since the fundamental conclusions are similar among AM peak, Midday peak, PM peak, and Weekends peak periods, only the AM peak period results are presented. The time-space diagram and other related signal timing are shown in Figure 2. The marker and numbers shown in the figure indicate the offsets at each intersection, referencing to the end of the main street phase.

As part of this study, the characteristics of platoon dispersion were investigated. The primary objective of the platoon study was to identify whether vehicles would maintain a good platoon structure as they travel along the arterial. Because of the large signal spacing in the study network, it is important that the vehicles maintain good platoons in order to achieve the best benefit from coordination (Manar and Baass, 1996). Based on field observations (Abdel-Dayem and Tian, 2009b), it was found that, for most of the time, the vehicles were able to maintain good platoons while traveling along the arterial. Such platoons were the premises for coordinating the signals in the arterial.

Data collection

While travel times, stops, and delays are the typical performance measures, collecting system-wide vehicle delays in the field is generally impractical due to the significant amount of effort involved. In reality, drivers tend to be more sensitive to their route travel time and number of stops. Due to the above reasons, travel time and number of stops for every route were selected as the measures for evaluating the performance of TOD coordination plans and SCATS.

Figure 3 shows the 17 selected major routes for data collection and analyses. These routes cover all the major routes within the study network, including both arterial through routes and routes involving major turning movements entering or exiting the arterial. The sequence of the routes was carefully designed so that driving the routes would provide data collection continuously and the maximum number of travel run samples from each time period could be obtained. This would also guarantee consistency for the before-after study. One important aspect was to have the probe vehicle to be in a random position at each route. A random vehicle position means the vehicle can be in any part of a platoon, not always at the front of a platoon. Completing all 17 routes took about 1.5 to 2 hrs. Each route was driven at least once during each peak period. The entire data collection period lasted one week for both the before and after cases, covering all the weekday and weekend peak periods. Although this data collection effort was considered as one of the most comprehensive studies of similar nature, the number of samples was still limited from statistical point of view. The travel time data were collected using a GPS unit and PC-Travel software. The GPS data was also complemented with a video camera. The recorded videos were found to be valuable when later verification was needed for any unusual data and traffic circumstances. The videos also provided data backup in case the GPS unit did not function properly.

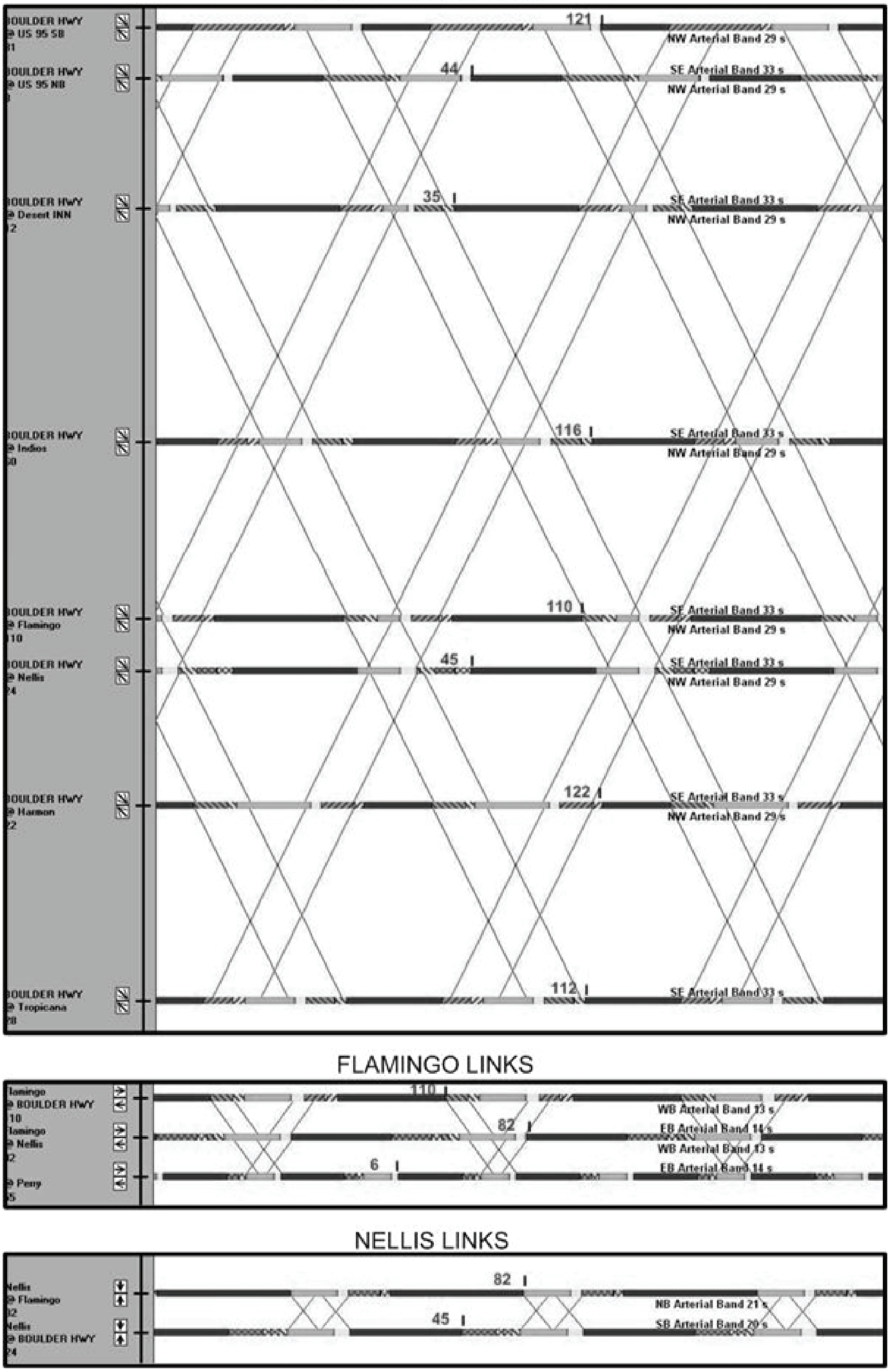

Figure 2 Time-Space Diagram of AM Peak Coordinated Plan

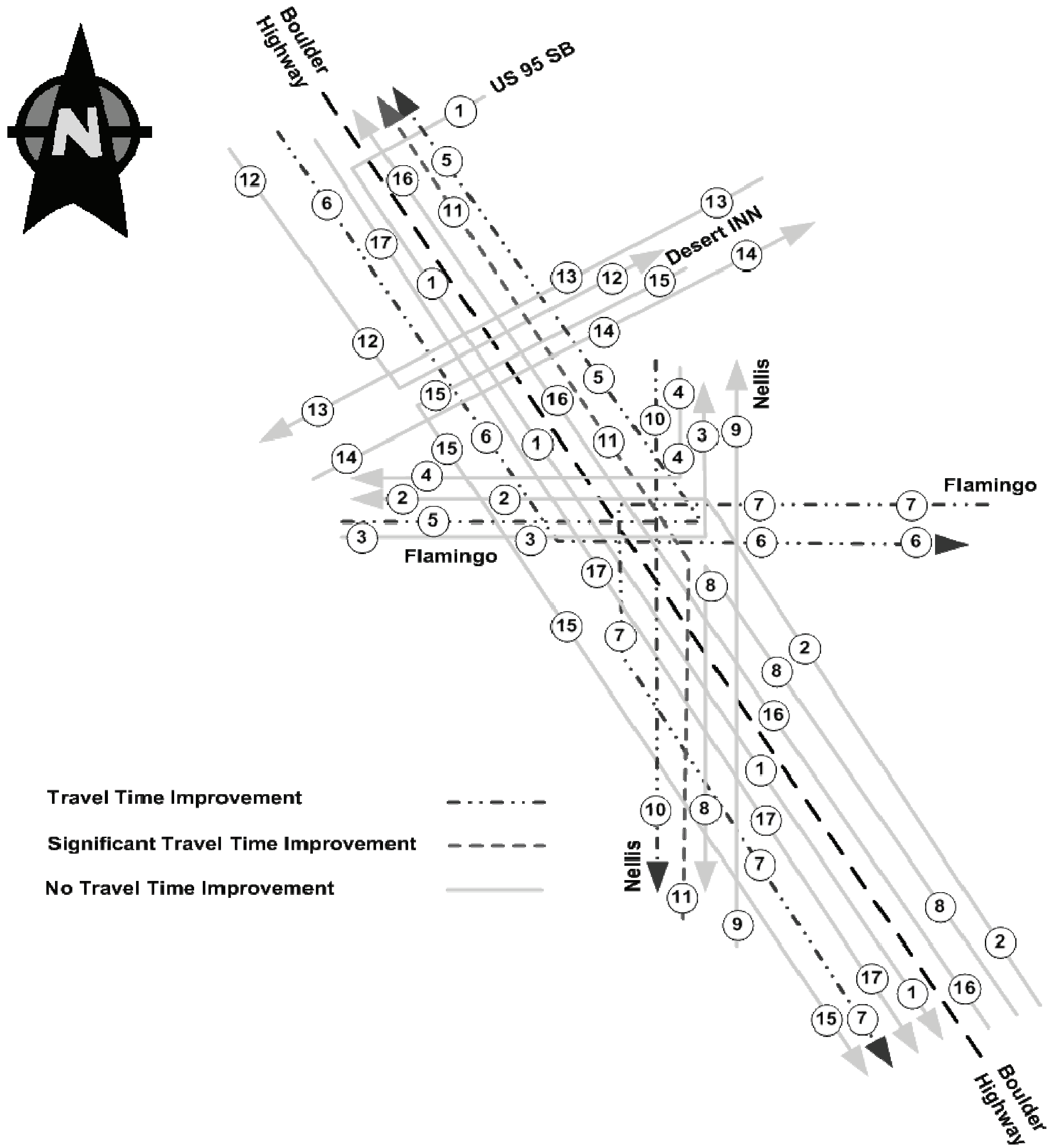

Figure 3 Routes of Travel Time Improvement - AM Peak

Results and analysis

The results of the travel time runs in the AM peak period are presented in Table 1. The mean and standard deviation of travel time and number of stops are also included in the table. A stop is defined when a vehicle's speed is less than or equal to 5 mph. A vehicle can therefore experience multiple stops at one intersection. Statistical t-tests were conducted to draw conclusions based on the 95% confidence levels. The t-tests were not done for the number of stops due to the small values which may not provide statistically valid results. Figure 4 highlights the routes showing various levels of improvement by SCATS over the TOD coordination.

Table 1 Travel time and stop - AM peak

Route	Case	Travel Time, sec		Travel Time Improvement	Travel Time T-test Significance	Number of Stops		No. of Stops Improvement	Number of Travel Time Runs Per Route
		Mean	STDEV			Mean	STDEV		
1	Before	375.0	8.7	N		1.0	0.0	N	4
	After	412.4	52.3		N	2.2	1.1		5
2	Before	135.0	11.0	N		0.5	0.6	N	4
	After	196.8	52.3		Y	1.4	0.6		5
3	Before	17.0	3.9	N		0.0	0.0	N	4
	After	101.4	51.4		Y	1.0	0.0		5
4	Before	19.5	3.9	N		0.0	0.0	N	4
	After	88.8	13.9		Y	1.0	0.0		5
5	***Before***	***282.8***	***10.3***	***Y***		1.8	0.5	N	4
	After	***265.0***	***6.2***		Y	2.4	0.6		5
6	***Before***	***383.5***	***63.7***	***Y***		1.5	0.6	N	4
	After	***301.8***	***45.8***		Y	2.6	0.6		5
7	***Before***	***349.0***	***59.7***	***Y***		2.3	0.5	N	4
	After	***261.6***	***52.0***		Y	3.4	0.6		5
8	Before	137.8	6.9	N		1.0	0.0	N	4
	After	137.8	11.7		N	1.0	0.0		5
9	Before	50.3	8.2	N		***1.0***	***0.0***	***Y***	4
	After	79.4	33.5		Y	***0.8***	***0.5***		5
10	***Before***	***53.8***	***28.9***	***Y***		***0.5***	***0.6***	***Y***	4
	After	***19.2***	***9.2***		Y	***0.2***	***0.5***		5
11	***Before***	***268.8***	***5.9***	***Y***		***2.0***	***0.0***	***Y***	4
	After	***266.2***	***12.9***		N	***1.6***	***0.6***		5
12	Before	53.0	7.7	N		0.0	0.0	N	4
	After	95.8	47.5		Y	1.4	0.9		5
13	Before	129.0	10.6	N		1.0	0.0	N	4
	After	215.0	29.5		Y	1.8	0.5		5
14	Before	114.3	58.7	N		0.5	0.6	N	4
	After	155.4	38.1		N	1.40	0.89		5
15	Before	275.5	4.2	N		1.75	0.50	N	4
	After	283.6	9.5		Y	1.80	0.45		5
16	Before	275.5	4.9	N		1.00	1.15	N	4
	After	374.0	42.6		Y	2.00	0.71		5
17	Before	308.5	68.5	N		0.75	0.96	N	4
	After	375.8	68.8		Y	2.00	1.00		5

For the AM peak period results shown in Table 1, several conclusions can be made. The travel times were reduced for five routes, four of which were statistically significant. The remaining 12 routes showed increases in travel times, nine of which were statistically significant. The number of stops was reduced for three, while the remaining 14 routes showed either increases or no change.

For evaluating signalized arterial performances, travel time and number of stops along the main street routes are commonly used performance measures. Figure 4 and Figure 5 illustrate the detailed travel time runs with SCATS and conventional TOD coordination plans. The total travel time and number of stops can be clearly seen from the figures.

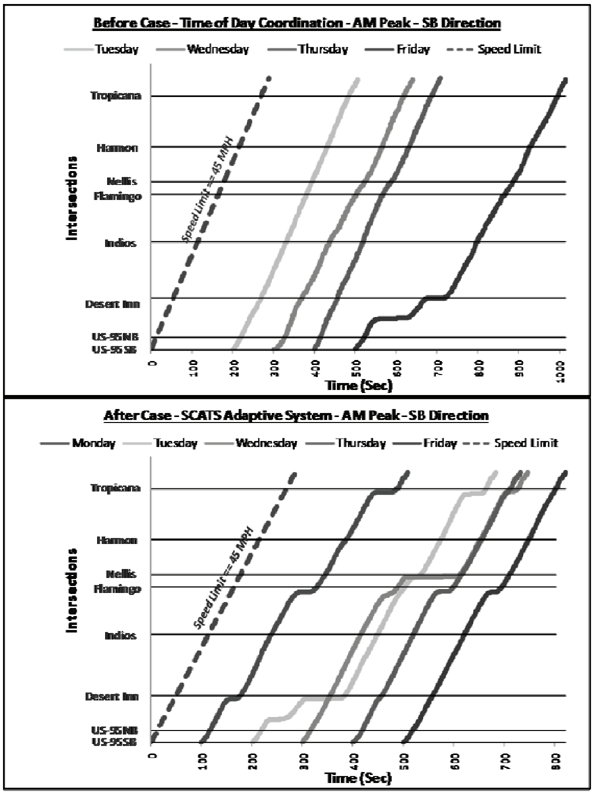

Figure 4 – Travel time runs for the SB arterial route – AM peak

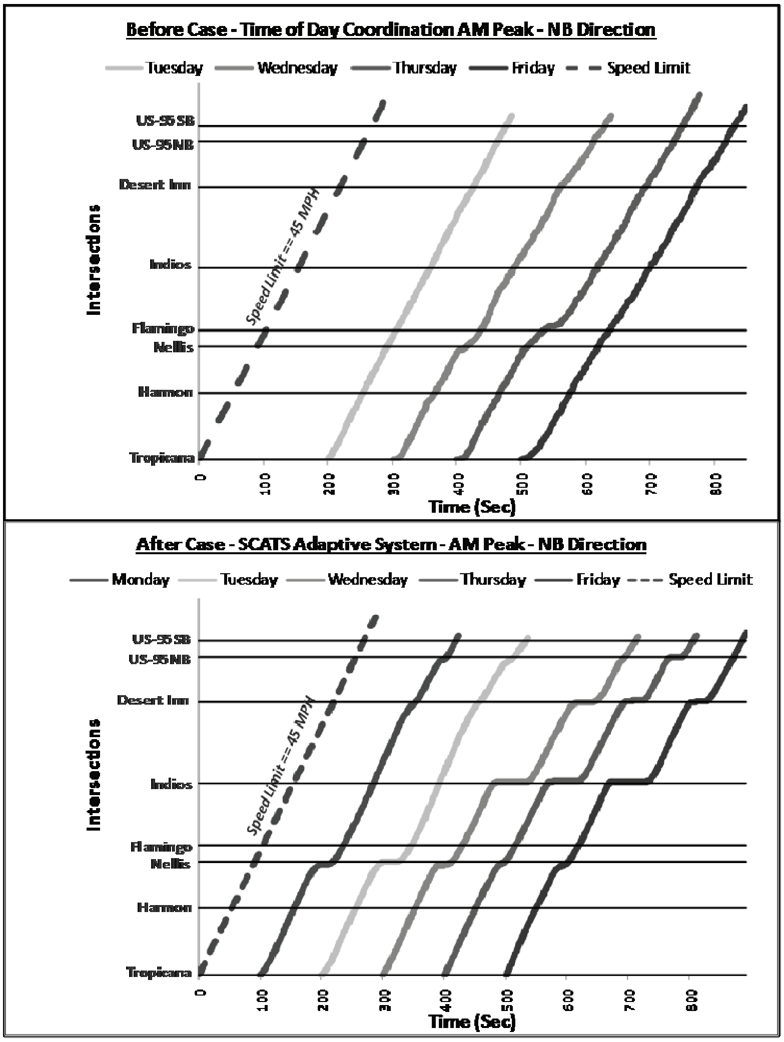

Figure 5 – Travel Time Runs for the NB Arterial Route – AM Peak

Based on the results shown in Figures 4 and 5, the following observations were made. For the AM peak period, each travel time run experienced at least one stop under SCATS control. The majority of travel time runs under the TOD plan experienced no stops or short stops, except for the southbound direction run on Friday. It is noticed that long stops occurred in the middle between US 95 NB off-ramp and Dessert Inn. A further examination from the recorded video revealed that a school bus was on the site, causing blockage of the moving traffic. After another stop at Dessert Inn, the vehicle was able to progress through the rest of the intersections. Overall, the TOD plan performed better than SCATS in both travel times and number of stops. The results for other time periods were similar. However, the following constraints must be pointed out, which may have significantly affected SCATS from achieving its best operational potentials.

- Similar to other signal control systems, SCATS heavily relies on accurate vehicle detection. The existing video detection system configuration resulted in non-optimal views at many intersection approaches, which may have significantly limited SCATS's potentials. The video detection system along the arterial was an older version of the Vantage Video Detection System by Iteris Inc.
- There was about a one-year time span for the before and after cases, therefore, the traffic demands and patterns were not the same. Particularly, the before case involved a major sewer construction project at the intersection of Flamingo and Nellis.

- The study only compared the performance during normal weekday and weekend peak periods. The before case time-of-day plans were developed according to newly collected traffic flow data. The study did not compare the performance during off-peak periods and special events. The long-term benefits of SCATS under evolving traffic conditions could not be assessed in this study.
- Even though the travel time runs were considered as one of the most extensive field studies so far, the number of samples for each individual route may still be too low to conduct reliable statistical tests and draw decisive conclusions.

3. Summary and conclusions

This study documented the arterial performance evaluation on the SCATS adaptive signal control system. Field data and analysis were based on a major arterial section in Las Vegas, Nevada, U.S.A. The evaluation was conducted based on extensive before and after travel time runs at selected routes within the study network. A particular focus was on the arterial travel times and stops, which are typical performance measures used for evaluating signalized arterials. The major findings and conclusions from this study are provided below:

- When compared with the optimized TOD coordinated plan operations, SCATS plans showed insignificant improvements on a small portion of the travel routes. The majority of the routes showed either no improvement or worse performance (increased travel times and number of stops). No improvements were found with SCATS plans for the arterial through routes during all study periods. This finding is inconsistent with some previous studies involving field evaluations (Martin and Stevanovic, 2008; Peters et al. 2008).
- The use of an older video detection system for SCATS may have limited its performance, because problems might arise due to detector reliability and accuracy.
- This study supports a conclusion drawn from a study by Petrella and Lappin (2006) that a well-designed coordinated plan should always provide equal or better performance than adaptive signal control systems under predicable traffic conditions. Adaptive signal control systems are likely to be better when traffic flow is highly variable and can sustain for a longer period without involving major re-timing efforts.

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