

# **AN ANALYSIS OF THE TEMPORAL AND SPATIAL VARIABILITY OF FREE-SPEED ALONG A FREEWAY SEGMENT**

J.A. Stewart<sup>1</sup>, H. Rakha<sup>2</sup>, and M. Van Aerde<sup>2</sup>

1 Royal Military College, Kingston, Ontario, Canada K7K 5L0.

2 Queen's University, Kingston, Ontario, Canada K7L 3N6.

## **ABSTRACT**

In order to determine the speed-flow relationship for a highway section, a number of parameters must be estimated. These include the free-speed, speed-at-capacity, the capacity, as well as the jam density. Due to fluctuations in demand, variations in driver behaviour, as well as geometric and environmental conditions, these parameter values may vary both spatially for different stations and temporally for different days. If these speed-flow relationships are to be utilized to estimate link travel times, diversion capacities, or if they are to be used in incident detection algorithms, it is important that these spatial and temporal variations in the speed-flow relationship be quantified so that accurate estimates of the relevant traffic parameters can be made.

This paper presents a statistical analysis of the variability of free-speed estimates for 24 stations along a section of I-4 in Orlando, Florida during a four month time period. This analysis is a first step in performing similar analyses of capacity, speed-at-capacity, and jam density. In the analysis presented in this paper, it was found that free-speed estimates along I-4 had a standard deviation of 4.7 km/hr and were most dependent on the location at which they were observed. This location factor explained 60% of the sum of squared errors. Minor variations in free-speed from one day to another were overshadowed by these spatial differences and only accounted for approximately 6% of the sum of squared errors. These two findings suggest that on this freeway section there is little loss in accuracy, if many days of data are aggregated for a specific location, but a great loss in accuracy if many locations are averaged for the same day. There is also little to be gained by estimating day-of-the-week specific free-speeds.

## **1.0 INTRODUCTION**

The objective of the research reported in this paper was two-fold. The primary purpose was to ascertain if there were statistically significant differences in free-speed estimates from one location to the next, or from one day to the next. In the absence of such variations it would be sufficient to calibrate a speed-flow relationship for an entire highway section based on either one day's worth of data at a single station or a composite single data set of all stations and days combined. The second objective was to determine, if significant temporal or spatial differences existed in the estimated free-speeds. For example, it is often perceived, that mid-week (Tuesday through Thursday) traffic behaviour is different from driver behaviour on Friday or Monday. If

this perception is substantiated, then it would be necessary to establish different free-speeds for the same section of highway in order to model these different types of days.

Initially, the characteristics of the study network together with the data collection time frame are presented in Section 2 of the paper. This is followed by an overview of the study procedure in Section 3. In Section 4 the details of the Analysis of Variance (ANOVA) tests are described. These tests are followed by the conclusions of the paper in Section 5.

## **2.0 STUDY DESCRIPTION**

### **2.1 Network Configuration**

A 16 kilometer (10 miles) portion of the I-4 freeway in Orlando, Florida was considered in this study as it was modeled as part of an IVHS/ITS benefit assessment. I-4 serves as a major route that travels across the center of Florida from the south-west (Tampa) to the north-east (Daytona) passing by the Disney World complex to the west of the study area. The detectorized portion of the I-4 freeway is located in the vicinity of the downtown of Orlando, extending from 33<sup>rd</sup> street to the south-west and ending downstream of Maitland Boulevard to the north-east, as illustrated in Figure 1.

There was a total of 24 loop detector stations located along I-4 numbered from 1 to 25, with no data being provided for station 10. The spacing of the detector stations ranged from approximately 0.40 to 0.90 kilometers (0.25-0.54 miles). There were no major terrain variations along the detectorized section of the I-4 freeway, as Orlando is rather flat. However, at many interchanges with arterials the freeway was elevated. The entire detectorized section of I-4 was composed of three lanes in each direction.

### **2.2 Data Collection Time Frame**

The analysis period included traffic data for portions of a four month time period during the winter of 1992-93. The data included 11 days in November 1992, 29 days in January 1993, 26 days in February 1993, and 11 days in March 1993. This data set amounted to a total of 75 days of 30 second data with approximately 10 different days of data being available for each day of the week.

The Freeway Management Center (FMC) dual loop detectors measured and logged the flow, occupancy and space mean speed for each of the three lanes at 30 second intervals. These data were aggregated for this analysis into five minute data summaries in order to reduce the amount of data to be handled, while still capturing most of the variability in the traffic conditions. An average lane flow, occupancy and mean speed estimate for each station were generated from the individual loop detector measurements. In estimating the average speed at a specific station, the loop speeds were weighted by the volume on each set of loops.

### 3.0 OVERVIEW OF STUDY PROCEDURE

#### 3.1 Typical Traffic Conditions Along the I-4

Based on the FMC data for all the available days within the above four month period it was possible to generate surfaces which represent the average speed, average flow, or average occupancy at a particular station and at a particular time of day. Figure 2a, represents the resulting average flow surface in the eastbound direction along the I-4 section. The x-axis represents the time-of-day that ranges from 0, at midnight at the start of the day, to 24 at midnight at the conclusion of the day, while the y-axis represents the station numbers that are traversed. The eastbound flow proceeds in the upward direction from station 1 to station 25. For each cell combination of time-of-day and station the z-axis represents the average hourly lane flow rate measured.

It can be noted from Figure 2a that the flow gradually increased at 6:00 a.m. along all eastbound stations until it reached a flow of approximately 2000 vph/lane at 8:00 a.m. along detector stations 5 through 18. The flow increased again during the p.m. peak at approximately 3:00 p.m. until 6:30 p.m. at stations 12 through 22. It appears from Figure 2a that the flow from 5:00 to 7:00 p.m. at stations 7 through 12 was lower than 2000 vph/lane. However, after examining Figure 2b it appears that during this period the speeds were also low (20 to 40 km/hr). Thus, the lower flow measurements were likely due to the presence of congestion, rather than a reduction in demand.

Figure 2b illustrates that only stations 5 through 20 experienced speeds near and/or in the congested portion of the speed/flow relationship (speeds < 60 km/hr) during the p.m. peak in the eastbound direction. As subsequent analyses of the variability of speed-at-capacity, capacity, and jam density required congested data to be present, only stations with congested data were subsequently considered for the fitting of a complete speed-flow relationship, as will be discussed next.

#### 3.2 Structure of Speed/Flow Relationships

The selection of a particular shape for a speed-flow relationship has been a topic for more than 50 years. May (1990) provides an excellent discussion and comparison of the various single and multi-regime models, and describes their respective strengths and limitations in the context of producing "reasonable" free-speed, speed-at-capacity, capacity and jam density estimates. In response to these limitations a new single regime speed-flow relationship was developed, which is illustrated in Figures 3a and 3b. This relationship is described in detail in Van Aerde (1995). The main features to be noted here are the highly linear and almost horizontal behaviour in the uncongested region, the speed-at-capacity in excess of half the free-speed and the jam density value which is higher than two times the density at capacity, yet still finite. Of particular interest to this paper is the fact that the free-speed, which theoretically occurs when the volume is 0, can reliably be extrapolated from the near linear uncongested portion of the curve. An average of the speeds observed when flows are below a given maximum flow threshold, say  $V/C < 0.5$ , would always represent an underestimate of the free-speed in view of the small negative slope of the curve in this region.

### 3.3 Estimation of Speed/Flow Parameters

Figures 3a and 3b illustrate sample fits of Equation 1 and its density counter part to data collected over an entire day at detector station 13. The discrete points represent the five-minute loop detector measurements, while the continuous curve represents the fit estimated by the curve fitting model.

In order to generate the free-speed estimates at each station a heuristic curve fitting program was developed that selects the speed-flow relationship parameters that produce the minimum normalized squared error in a three dimensional flow-speed-density data space (Van Aerde and Rakha, 1995). This curve fitting model estimates four parameters namely: the free-speed ( $u_f$ ), the speed-at-capacity ( $u_c$ ), the capacity ( $q_c$ ), and the jam density ( $d_j$ ). The structure of the speed-flow relationship is represented in Equation 1, where Equations 2 through 5 are utilized to calculate the three model parameters  $c_1$ ,  $c_2$ , and  $c_3$  in addition to the intermediate parameter  $k$ .

It appears, from Figure 3a, that the macroscopic relationship captures most of the deterministic variation in speed-flow while achieving a reasonable compromise estimate when stochastic variability exists. The four parameters for station 13 selected by the model were:  $u_f=87.2$  km/hr,  $u_c=70.6$  km/hr,  $q_c=1925$  vph,  $d_j=92.2$  veh/km. In Figure 3a the free-speed is identified as the higher y-axis intercept, the speed-at-capacity is the y-axis value that corresponds to the maximum flow point (nose of curve) while the capacity is the maximum x-value. The jam density is the inverse of the slope of the fitted curve as it emerges at the origin to the axes in Figure 3a, but is more easily identified as the x-value at 0 speed in Figure 3b.

$$q = \frac{u}{c_1 + \frac{c_2}{u_f - u} + c_3 u} \quad (1)$$

$$k = \frac{c_1}{c_2} = \frac{(2u_c - u_f)}{(u_f - u_c)^2} \quad (2)$$

$$c_2 = \frac{1}{d_j(k + \frac{1}{u_f})} \quad (3)$$

$$c_1 = k c_2 \quad (4)$$

$$c_3 = \frac{-c_1 + \frac{u_c}{q_c} - \frac{c_2}{(u_f - u_c)}}{u_c} \quad (5)$$

Where:

- $c_1$  = fixed distance headway constant (km)
- $c_2$  = first variable distance headway constant (km<sup>2</sup>/hr)
- $u_f$  = free-speed (km/hr)
- $u_c$  = speed at capacity (km/hr)
- $u$  = prevailing speed associated with headway  $h$  (km/hr)
- $q$  = flow rate of traffic traveling at speed  $u$  km/hr (vph)
- $q_c$  = flow at capacity (vph)
- $d_j$  = jam density (veh/km)
- $k$  = dimensionless constant to set the speed at capacity relative to the free-speed

It should be noted in Figures 3a and 3b that in order to generate a satisfactory fit of a typical speed-flow relationship's jam density and speed-at-capacity at a specific location, sufficient data points in both the uncongested and the congested portion of the curve are required. This is the

basis for the fact that the curve fitting model was set to not estimate the desired four parameters if no points existed in the congested region (speeds < 60 km/hr.) of the curve.

### **3.4 Typical Spatial and Temporal Variation in Free-Speed**

Figure 4 demonstrates the temporal and spatial variation in the free-speed estimates at stations 9 to 22 over a sample ten day analysis period. As a result of a lack of points in the congested portion of the speed-flow relationship, at stations 1 to 8 and 23 to 25, the curve fits and therefore the free-speed estimation was only performed for the stations located in the downtown area (stations 4 to 22). One can observe from the surface plot that the free-speed ranged from 80 to 110 km/hr. It appears that the free-speeds were relatively constant during the ten day period as indicated by the minor variations in the y-axis direction. However, the speeds varied to a greater extent for the different locations along the x-axis. The variation in free-speed was in the range of approximately  $\pm 15\%$  of the average free-speed and had a standard deviation of 4.7 km/hr. A more detailed analysis of the free-speed variation will be presented in Section 4.

## **4.0 INTRODUCTION TO ANALYSIS OF VARIANCE**

An examination of the speed contours in Figure 4 suggested that the free-speed is much more spatially dependent than temporally dependent. This qualitative assessment motivated a statistical ANOVA of the free-speed data, in an attempt to ascertain if different days of the week or different station locations, or both, affected the value of the free-speed in a statistically significant fashion. In order to accomplish this analysis, a data set of free-speeds as a function of the day of the measurement (75 different days) and the location (24 station locations) was produced for subsequent analysis using SYSTAT (1992).

### **4.1 Screening of Data**

For this data set data for the east bound direction at stations 1, 2, 3, 10, 23, 24, and for the west bound direction at stations 1, 2, 3, 4, 5, 10, 13, and 21 were removed due to lack of congested data. Data from most Saturdays and Sundays were also removed. After the removal of several other days for the same reason, there remained approximately 31 days of acceptable data for the west bound direction and 33 days of acceptable data for the east bound direction.

### **4.2 Analysis Scenarios**

Once the data set had been conditioned in the above manner a series of Analyses of Variance (ANOVA) was carried out (Crow et al., 1960, Draper and Smith, 1981). A brief introduction to the actual procedure will be presented next in this Section.

The data set was split first into two main sets, one for the east bound and the other for the west bound direction. These data sets were treated separately for the remainder of the analyses. Three different ANOVA models were fit for the aggregated data set. First a one way ANOVA was performed on calendar date (Analysis 1a), while subsequently the location factor was analyzed (Analysis 1b). In the third analysis, a two-way ANOVA was conducted considering the date factor and location factor could be significant (Analysis 1c). As the data set contained free-speeds for each location for several weeks, it was also possible to group the data by the day-of-

the-week as opposed to the calendar date. This grouping permitted a one-way ANOVA with replication of measurement (Analysis 2).

In order, to explore the impact of location and date within a single week of data, for the east bound direction Monday, 25 January, to Friday, 29 January 1993, were analyzed in detail. For the west bound direction the above screening of the data set made it impossible to find a continuous Monday to Friday period. Hence, the period from Friday 22 January, to Thursday 28 January, (excluding the weekend) was analyzed. As with the entire data set, three ANOVA's were fit, two one-way ANOVA's (grouped either by day or location) and one two-way ANOVA were fit (Analyses 3a, 3b and 3c, respectively).

A further set of ANOVA's was fit in order to explore the premise that traffic behaviour is different during the core midweek period (Tuesday, Wednesday, and Thursday) from Monday or Friday. For this reason, a two-way ANOVA with replication, similar to Analysis 2, was performed on a date set of Tuesdays, Wednesdays and Thursdays data (Analysis 4).

A total of 13 different analyses of variance models were fit for each direction. Typical data sets used in these analyses are shown in Tables 1 and 2. In addition, Tables 3 and 4 summarize the results of the most important ANOVA's that were performed. The following sections discuss in detail each series of ANOVA's.

It is readily apparent from Table 2 that the mean free-speed changed significantly along the route in the east bound direction. The west bound direction experienced a similar change in free-speed, however, due to the limited space in this paper the results are not presented here. The large drop in free-speed at Station 9 in the east bound direction and a corresponding increase in free-speed in the west bound direction is most probably caused by the fact that there is an uphill grade at station 9 in the east bound direction. The large increase in free-flow speed at station 20, however, in the east and west bound directions is most likely attributable to a change in free-speed limit from 88 km/hr (55 mph) to 104 km/hr (65 mph).

#### **4.3 Analysis 1: ANOVA of Entire Data Set (Monday - Friday)**

The data were first grouped by calendar date in order to test for the significance of the calendar date factor on the free-flow speed for both the east and west bound directions (Analysis 1a). The one-way ANOVA results showed that the free-flow speed was not significantly different, at the 95% confidence level, from one day to the next. When these data were grouped by the location (Analysis 1b), the one-way ANOVA revealed that the free-speed varied significantly from one location to the next. Finally, when both variables were included in a two-way ANOVA without replication (Analysis 1c), the results indicated that both the calendar date factor and location factor were statistically significant.

The summary results of the latter two-way ANOVA analyses are shown in line one of Tables 3 and 4. As can be seen from Tables 3 and 4, the largest amount of variation (as indicated by Mean Sum of Squares that is explained) is accounted for by the station factor. Specifically, in the east bound direction 96% and in the west bound direction 92% of the variation in the data was explained by the location factor. Four and six percent of the error in the respective directions was explained by the factor which accounts for the calendar day on which the data were collected. These percentages are based on the mean square ratios. However, in terms of the total sum of squared errors the error explained by the station factor was approximately 60%. Consequently,

when specifying speed-flow relationships for this highway it would therefore appear that it is more important that a different relationship be developed for each location along the route than for each separate day. The observed minor differences from day-to-day motivated the analyses that attempted to determine if the differences were systematic or random.

#### **4.4 Analysis 2: Two-Way with Replication (Monday - Friday)**

As Analysis 1c showed that the free-speed at a specific location did vary to some extent with the day on which the data were measured, an ANOVA was carried out to determine if a day-of-the-week factor was a systematic source of these differences. In other words, is it possible that a traffic behaviour varies in a consistent fashion from Monday to Tuesday or Thursday to Friday? The results of these type of analyses are referred to as Analysis 2 and are shown in lines two of Tables 3 and 4. It can be seen from the mean sum of squares that for the east bound direction there appeared to be very little, if any, differences between the different days-of-the-week, as the  $F$  statistic indicated that the day-of-the-week factor is not significant at the 95% level of confidence ( $1.90 < 2.40$ ). On the other hand, though, in the westbound direction, the location factor is still the most important source of variation ( $48.87 > 1.70$ ), there is a statistically significant difference between each day-of-the-week ( $5.87 > 2.40$ ). At this stage of the research, the reason as to why the east and west bound directions produce different results remains unclear.

#### **4.5 Analysis 3: One Week of Data**

The next of the series of analyses, referred to as Analysis 3, was to examine in detail a continuous period of five week days. The purpose of this analysis was to determine if a week of data would be sufficient to determine an average free-flow speed at a specific location. The results of this analysis are illustrated on line 3 of Tables 3 and 4. As with the entire data set for Analysis 1, three different ANOVA's were performed for each direction, two one-way analysis of the calendar date (Analysis 3a) and location (Analysis 3b), and one two-way analysis without replication (Analysis 3c) using both factors. In both directions it was found that, even though the location factor was still the most significant factor, the day-of-the-week factor was also statistically significant. In the east bound direction 25%, and in the west bound direction 24%, of the variation in free-speed was found to be due to the presence of day-of-the-week factor. This would suggest, based on these data, that it is not possible to obtain a representative estimate of the free-speed at a specific location by only gathering data on one day of the week.

#### **4.6 Analysis 4: Mid-Week Only**

Analysis 3 showed that there were differences between the free-speed obtained from one day to the next. It is often hypothesized that the mid-week period behaviour is different from Friday or Monday behaviour. As such, it might be possible to estimate two different estimates of free-speed, one for each portion of the week. An analysis of the mid-week data was performed to ascertain if the temporal differences seen above in Analyses 1 to 3 could be adequately explained by simply having mid-week and Monday/Friday data grouped together. The results of this analysis, referred to as Analysis 4, are shown on line 4 of Tables 3 and 4. An examination of the Mean Sum of Squares and the  $F$  statistic, show that in the east bound direction, there is no statistically significant difference in the free-speed from one day to the next during the mid-week period. Virtually, all the variation in the data is explained by the location factor. Therefore, it is

possible to obtain a location specific measure of free-speed for the mid-week period. However, in the west bound direction this is not the case. In fact, 24% of the variation is due to the day on which the data were measured. This finding is consistent with the results obtained during the analysis of the entire data set using replication (Analysis 2).

## 5.0 CONCLUSIONS AND RECOMMENDATIONS

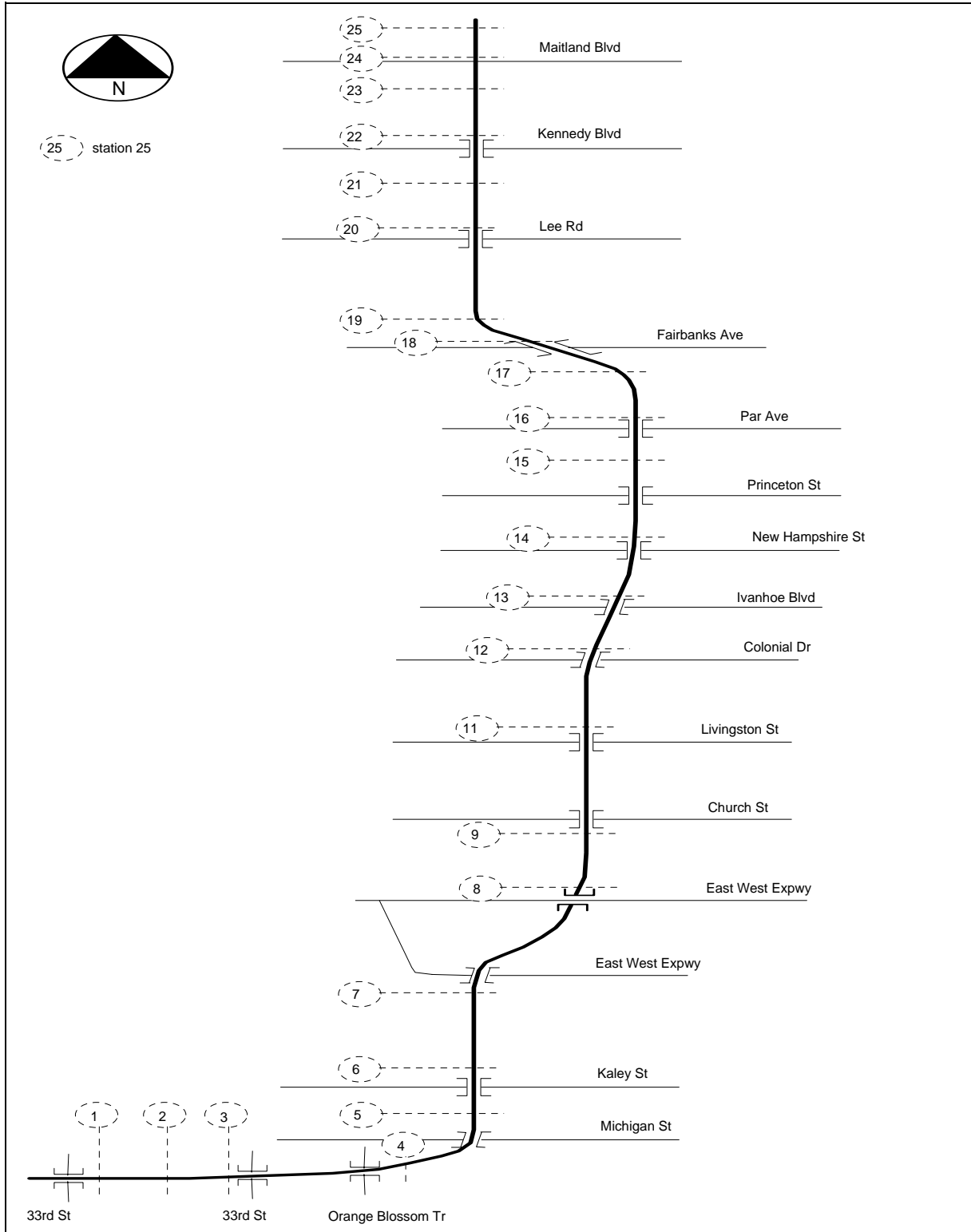
There are several conclusions that can be drawn from the analyses that were presented in this paper. Although these conclusions are based on the specific I-4 data, it is felt that the trends in the I-4 freeway behaviour may be representative of many typical freeways in North America and that the analysis approach is applicable elsewhere.

Firstly, it is concluded that free-speeds along I-4 are most strongly dependent on the location at which they are observed. Changes in geometry, ramp location/configuration and speed limit may all be responsible for the observed significant differences in free-speed as a function of the location factor. Secondly, clearly there are minor variations in free-speed from one day to another due to differences between mid-week versus weekend characteristics.

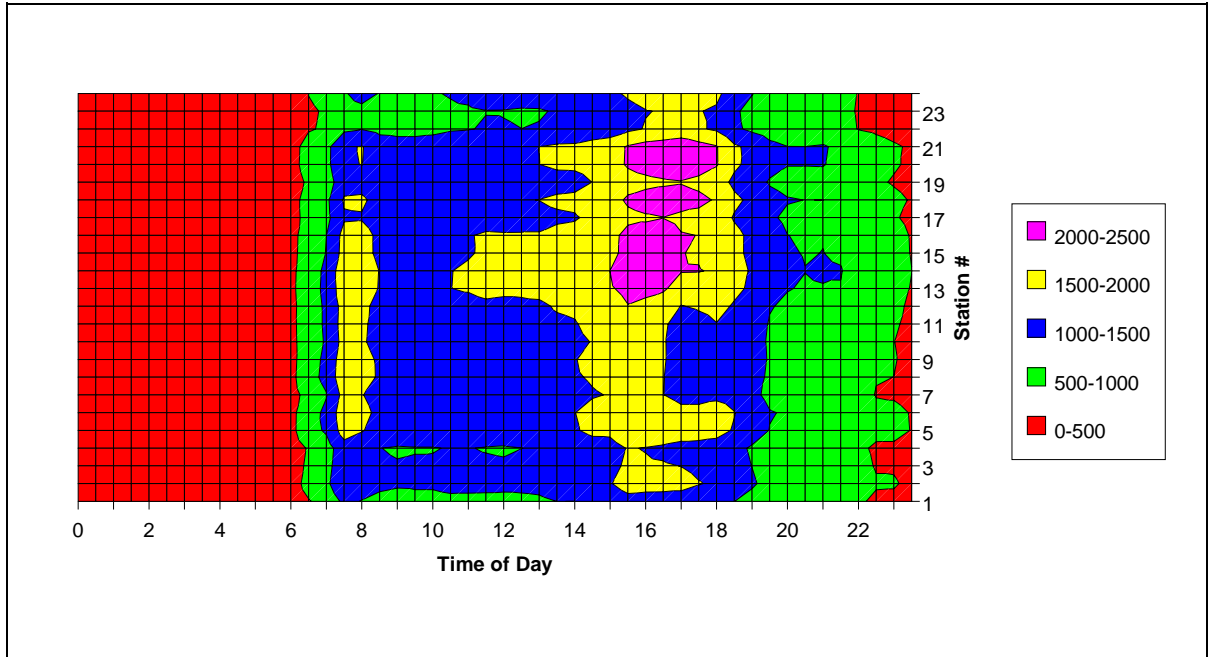
It is therefore recommended that in the analysis of freeways such as I-4, location specific free-speeds be estimated first. Subsequently, day-of-the-week specific adjustments may be made, but these will have a much smaller effect. However, even when the above factors have been accounted for, some residual day-to-day variations will still remain in effect.

## REFERENCES

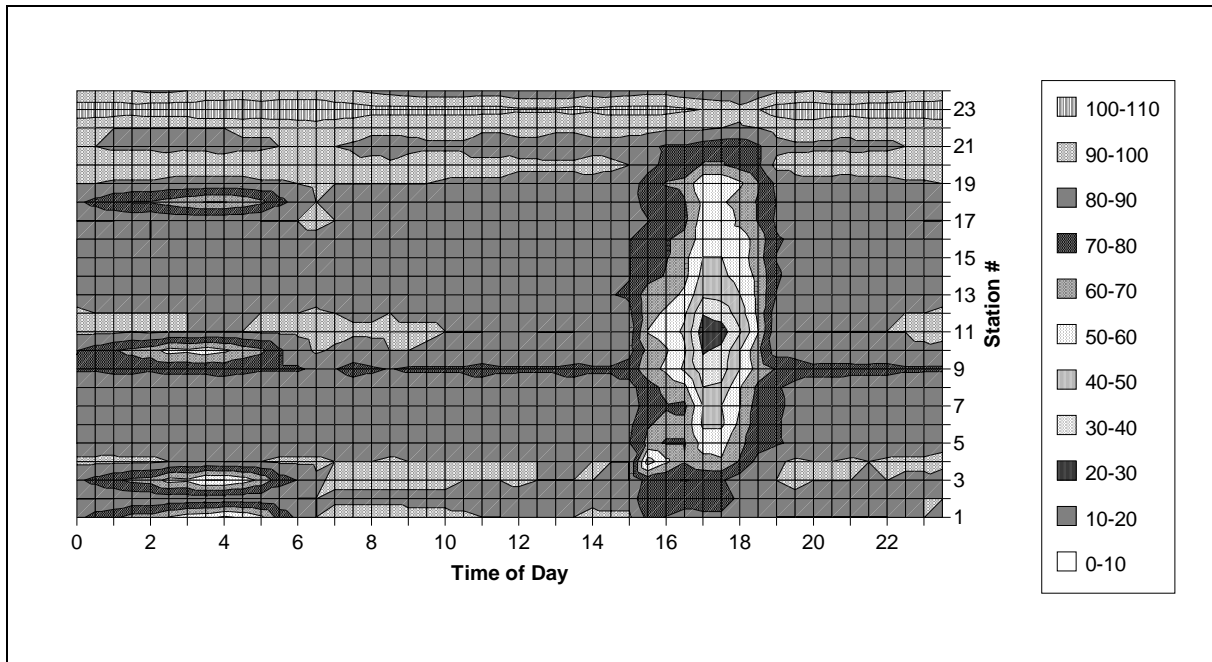
- Crow E.L., Davis F.A. and Maxfield M.W. (1960), "Statistics Manual," Dover Publications, Inc., Book No. 0-486-60599-X.
- Draper N. and Smith H. (1981), *Applied Regression Analysis, Second Edition*, John Wiley and Sons, Inc.
- May A.D. (1990), *Traffic Flow Fundamentals*, Prentice Hall, New Jersey 07632.
- SYSTAT (1992) *SYSTAT for Windows: Statistics, Version 5 Edition*, Evanston, IL: SYSTAT, Inc.
- Van Aerde M. (1995), "A Single Regime Speed-Flow Density Relationship for Congested and Uncongested Highways," Transportation Research Board (TRB), January.
- Van Aerde M. and Rakha H. (1995), "Multivariate Calibration of Single Regime Speed-Flow-Density Relationships," Working paper, Queen's University.



**Figure 1: Location of FMC detector stations along the I-4 freeway**



**Figure 2a: Temporal and spatial variation in 30 minute EB average lane flow (vph/lane)**



**Figure 2b: Temporal and spatial variation in 30 minute EB average lane speed (km/hr)**

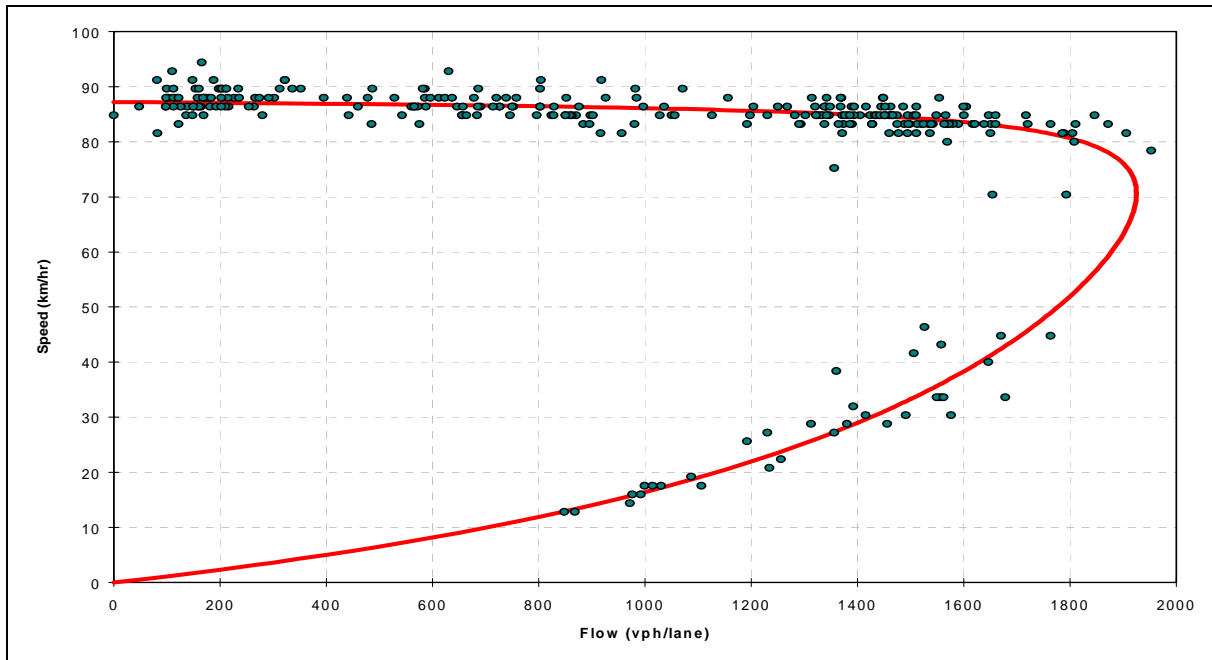


Figure 3a: A typical speed-flow fit to I-4 data ( $u_f=87.2$  km/hr,  $u_c=70.6$  km/hr,  $q_c=1925$  vph,  $d_j=92.2$  veh/km)

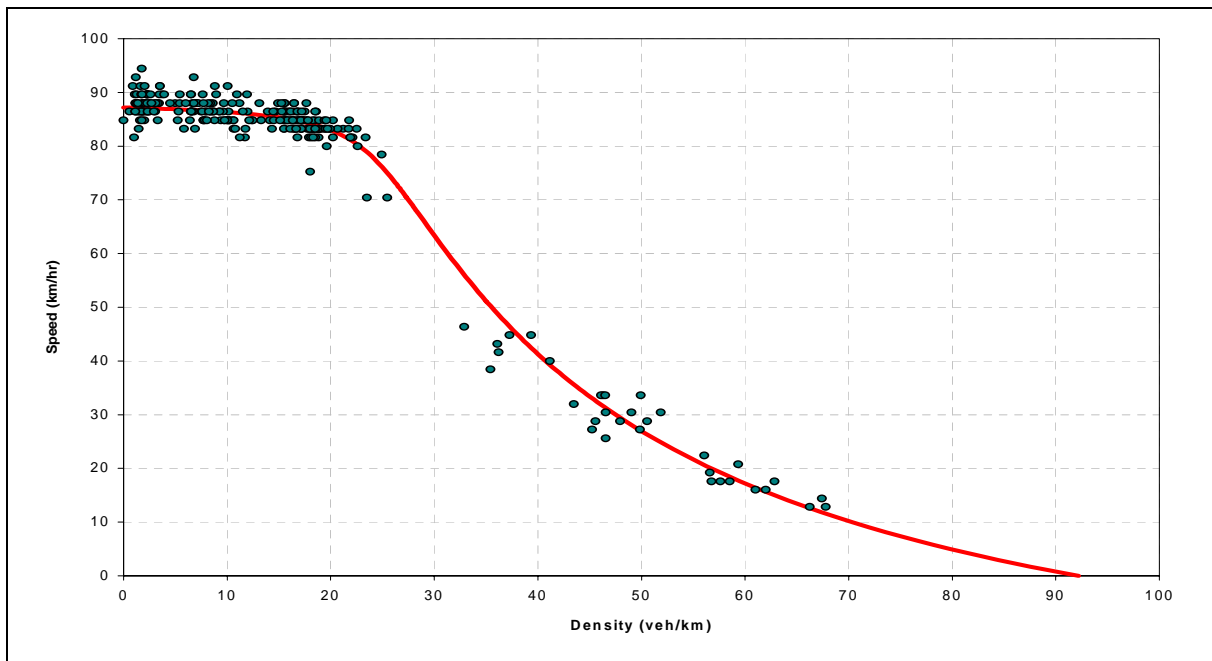
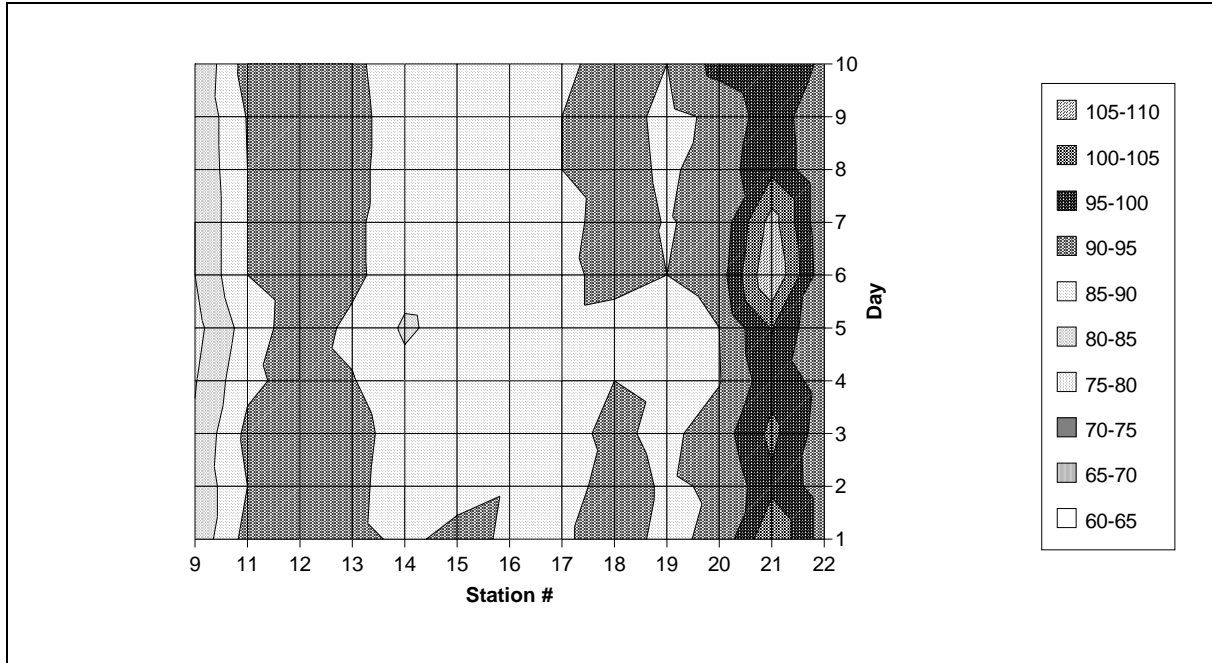


Figure 3b: A typical speed-density fit to I-4 data ( $u_f=87.2$  km/hr,  $u_c=70.6$  km/hr,  $q_c=1925$  vph,  $d_j=92.2$  veh/km)



**Figure 4: Temporal and spatial variation in free-speed along I-4 (km/hr)**

**Table 1: Data set for east bound (Mondays)**

Station	02-Nov-92 MON	09-Nov-92 MON	25-Jan-93 MON	01-Feb-93 MON	22-Feb-93 MON	29-Mar-93 MON		STD
4	92.2	90.9	90	93.1	97.5	92.5		2.38
5	87.5	85.3	82.5	87.2	89.1	86.9		2.07
6	87.5	89.4	84.7	88.1	84.4	84.1		2.05
7	87.5	90	85.3	86.3	89.4	86.9		1.66
8	90	90.9	83.1	87.5	86.9	87.2		2.50
9	85	82.5	78.1	80	79.7	77.8		2.52
11	91.3	91.3	88.8	90	89.4	88.8		1.05
12	95.6	95	92.5	92.5	90.6	91.3		1.82
13	91.3	92.5	88.8	91.3	96.6	90.3		2.42
14	88.4	87.5	83.8	86.6	89.4	86.6		1.76
15	90.6	89.4	85	86.9	88.4	90		1.92
16	88.8	95.6	87.2	88.4	92.5	87.5		3.05
17	86.6	91.6	89.1	88.8	86.3	88.8		1.76
18	89.4	93.8	90.3	91.6	90	90.6		1.44
19	88.8	90.9	88.1	90	93.8	89.4		1.85
20	91.3	92.2	90.6	92.5	100.6	92.5		3.34
21	97.5	100	103.1	110	102.5	105.9		4.02
22	91.3	93.1	90	91.3	95.6	91.3		1.81
<b>MEAN</b>	<b>90.03</b>	<b>91.22</b>	<b>87.83</b>	<b>90.12</b>	<b>91.26</b>	<b>89.36</b>	<b>89.97</b>	<b>4.41</b>
<b>STD</b>	<b>2.99</b>	<b>3.78</b>	<b>5.10</b>	<b>5.70</b>	<b>5.56</b>	<b>5.24</b>	<b>1.17</b>	

**Table 2: Data set for east bound (25-29 January 1993)**

Station	25-Jan-93 MON	26-Jan-93 TUE	27-Jan-93 WED	28-Jan-93 THUR	29-Jan-93 FRI		STD
4	90	91.9	92.2	95	91.3		1.64
5	82.5	82.5	85.3	86.9	88.1		2.27
6	84.7	86.3	90	88.8	89.1		1.97
7	85.3	84.4	86.9	87.5	86.9		1.16
8	83.1	83.1	85.6	85.9	85		1.21
9	78.1	77.5	80	79.4	80		1.02
11	88.8	85.3	90	91.3	90.3		2.08
12	92.5	89.4	91.6	93.8	93.8		1.64
13	88.8	87.5	89.7	90.9	90.6		1.24
14	83.8	82.5	85.3	85.3	85.6		1.18
15	85	83.8	86.3	89.4	90.3		2.50
16	87.2	85	87.5	88.8	88.8		1.39
17	89.1	87.5	88.1	88.1	87.5		0.59
18	90.3	87.5	91.9	92.5	90.6		1.73
19	88.1	86.3	89.4	88.8	89.4		1.15
20	90.6	90	90.6	91.9	90.6		0.62
21	103.1	93.8	100	99.4	97.5		3.07
22	90	88.8	91.3	91.3	91.3		1.01
<b>MEAN</b>	<b>87.83</b>	<b>86.28</b>	<b>88.98</b>	<b>89.72</b>	<b>89.26</b>	<b>88.42</b>	<b>4.01</b>
<b>STD</b>	<b>4.96</b>	<b>3.63</b>	<b>3.92</b>	<b>4.08</b>	<b>3.49</b>	<b>1.24</b>	

**Table 3: Summary of ANOVA for east bound free-flow speed along I-4 freeway in Orlando, Florida**

sample size	MEAN SUM OF SQUARES						F		F <sub>crit</sub>		
	Station	(%)	Date	(%)	Error	(%)	Station	Date	Station	Date	
Analysis 1 (without replication)	594	622.74	96%	23.43	4%	3.08	0%	202.36	7.61	1.64	1.47
Analysis 2 (with replication)	450	467.77	97%	9.45	2%	6.58	1%	94.04	1.90	1.65	2.40
Analysis 3 (25 Jan-29 Jan 93)	90	85.25	70%	34.34	28%	1.60	1%	53.31	21.47	1.78	2.51
Analysis 4 (midweek with repl.)	330	294.57	97%	3.46	1%	5.38	2%	65.00	0.47	1.67	3.04

**Table 4: Summary of ANOVA for west bound free-flow speed along I-4 freeway in Orlando, Florida**

sample size	MEAN SUM OF SQUARES						F		F <sub>crit</sub>		
	Station	(%)	Date	(%)	Error	(%)	Station	Date	Station	Date	
Analysis 1 (without replication)	496	310.09	92%	21.86	6%	6.04	2%	51.32	3.62	1.69	1.48
Analysis 2 (with replication)	400	244.03	86%	29.32	10%	9.51	3%	48.87	5.87	1.70	2.40
Analysis 3 (25 Jan-29 Jan 93)	80	48.98	72%	16.44	24%	2.16	3%	22.67	7.61	1.84	2.53
Analysis 4 (midweek with repl.)	240	128.93	70%	45.64	25%	10.85	6%	22.99	8.13	1.72	3.04