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To: Chih-Lin Chung
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An Approach to Assessing Freeway Lane Management Hot Spots

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Abstract

This research presents a procedure for capitalizing on the tradeoff relationship between managed lanes and general-purpose lanes on an urban freeway that compete for limited road space. The basic goal of the procedure is to provide policy guidance for sharing any excess lane capacity on a timely and efficient basis. Potential operating policy options between these two types of lanes are categorized as “do nothing,” “lane management,” and “more than lane management.” The “lane management” condition recognizes the extent and duration of a “hot spot” as defined by underutilized managed lanes with congested general-purpose lanes, or vice versa. Four major and three minor lane management hot spots are deterministically and stochastically captured along a 24-mile freeway stretch in California. The major ones account for 8.3 percent of the total time-space set. The approach can also be applied to predict upcoming hot spots and generates satisfying accuracy. Finally, strategies are proposed to prevent the hot spots and the effects of lane management are estimated. The application of this approach is especially useful for managed lanes with limited access points that prohibit arbitrary lane changing.

Keywords: Lane Management, Managed Lane, HOV/HOT Lane, Level of Service

INTRODUCTION

Lane management strategies attempt to maximize lane utilization by adjusting lane use permission. Typical strategies include truck lanes, high-occupancy vehicle (HOV) / high-occupancy and toll (HOT) lanes, contra-flow lanes, reversible lanes, mainline metering, speed controls, etc. Among these strategies, adoption of HOV lanes have long been regarded as an effective way to improve freeway efficiency in terms of passenger throughput. HOV lanes, however, are often criticized for insufficient utilization of existing vehicle capacity compared to the adjacent general-purpose (GP) lanes (*1*). Releasing a portion of any excess capacity of HOV lanes while maintaining HOV incentives of travel time savings and reliability beyond a specified threshold can potentially better utilize existing road resources. One particular option gaining increasing attention, the conversion of HOV lanes to HOT lanes, is considered to provide more flexible and efficient use of facilities than do HOV lanes because they fill the excess lane capacity with tolled non-HOV traffic.

A principal aspect in the consideration of such lane management strategies as HOV/HOT lane designations is identification of just “where” and “when” a hot spot occurs and “how critical” it is. Without knowing the extent, duration, and amount of the excess capacity, neither HOV nor HOT lanes could possibly operate well. The purpose of this study is to develop a simplified approach for identifying hot spots due to imbalanced use relationships between HOV/HOT and GP lanes in freeway systems that may respond effectively to potential lane management strategies. The next section introduces how hot spots are determined through a simple concept. We demonstrate hot spot assessment on a freeway in Orange County, California. The approach is also applied to predict hot spots, followed by discussions relating to their causes, effects, and preventive strategies. Finally, conclusions are presented, together with the application limitation of the study.

DETERMINATION OF LANE MANAGEMENT HOT SPOTS

Lane management hot spots are characterized by an imbalance in lane performance, or level of service (LOS). Among possible HOV/HOT performance indicators, flow is commonly the one used to characterize the condition of imbalance. Flow between 1,200 and 1,500 vphpl on concurrent HOV facilities and between 1,500 and 1,800 vphpl on separate right of way HOV facilities have been identified as threshold ranges for the onset of degradations (*2*). ASSHTO indicated the high end of the maximum flow ranges of most HOV facilities as 1,600 vphpl (*3*). In California, HOV facilities are gauged with the flow rates between 800 and 1,650 vphpl (*4*). San Diego I-15 and Orange County SR-91 HOT lanes use flow-based LOS as the sole criterion to adjust toll rates (*5*, *6*).

Some other common indicators include travel time, time savings, and speed. California DOT (*4*) suggests that HOV facilities save at least one minute per mile and facilitate a total trip savings of

from 5 to 10 minutes in comparison to GP lanes. The one-minute-saving criterion implies speed on HOV lanes would be 10 to 40 mph higher than that on GP lanes. Based on the trip travel time equalization, Chung (*7*) proposed equilibrium speed curves between the HOV and GP lanes; depending on the setting of travel time savings, vehicle occupancies, passenger or vehicle basis, the HOV speed should be about 5-20 mph higher than the GP lanes. SAFETEA-LU (*8*) considered HOV facilities to be degraded if the speed is less than 45 mph (with speed limit of 50 mph) in one or both of the peak hours for more than 18 out of 180 days.

Such indicators as flow and speed are absolute and consider the performance of HOV/HOT only, while time savings and relative speed are comparative and vary with the performance of GP lanes. HOV/HOT flow of about 1600 vphpl would be expected if the adjacent GP lanes are congested; HOV flow of 600 vphpl is practically adequate if the GP lanes are in a free-flow state. The concept implies that interrelationships between HOV/HOT and GP lanes are key to lane management hot spots. California DOT (*4*) suggests that the LOS of HOV facilities ideally be maintained at LOS C and not be allowed to reach unstable flow, or LOS E, on a regular basis; HCM (*9*) states that LOS C or D are typically used in design or planning tasks.

To ensure not only acceptable operations of both types of facilities but also that HOV/HOT incentives are maintained, in this study LOS C and LOS D are set as the service thresholds of HOV/HOT and GP lanes, respectively. Based on performance criteria, sections of freeway that have a combination of HOV/HOT and GP lanes are classified into three treatment categories, namely "**Do Nothing**" (DN), "**Lane Management**" (LM), and "**More Than Lane Management**" (MTLM). The details of these classifications are summarized below:

- **DN** if the HOV/HOT and GP lanes are operating at not worse than LOS C and D, respectively. This classification is preferable since traffic operates at acceptable conditions in both types of lane. The relationship between HOV/HOT and GP lanes is regarded as compatible.
- **LM** if either the HOV/HOT or GP lanes are congested. The relationship between HOV/HOT and GP lanes for sections of freeway in this classification is regarded as imbalanced, and the system could possibly be improved simply by lane management. The affected sections (or zones) can be further divided into two sub-zones as LM-1 and LM-2.
    a. **LM-1**: In this sub-zone, the HOV/HOT lane is greatly under utilized, defined by its LOS being at least three levels better than that of the GP lanes.
    b. **LM-2**: In this sub-zone. HOV/HOT LOS is in the D-F range and is worse than that in the GP lanes. Under such conditions, the travel time savings of the HOV/HOT would, of course, disappear. As a result, this condition rarely happens since, for HOV lanes, the HOV traffic will shift to the GP lanes, and for HOT lanes, the toll mechanism will keep the SOVs in the GP lanes. In the case of HOV lanes with limited access, HOV drivers'

misjudgment, or temporary failures of HOT toll mechanism, may possibly result in LM-2 conditions prevailing for a certain period of time.

- **MTLM** if the HOV/HOT and GP lanes are both congested, or one is congested but the other can not be manipulated enough to remove the congestion. This is the least preferable condition since the system cannot be improved simply by lane management. Sections of freeway in this classification can further be divided into three sub-zones as MTLM-1, MTLM-2, and MTLM-3.
  a. **MTLM-1**: In this sub-zone, the HOV/HOT and GP lanes need improvement.
  b. **MTLM-2**: In this sub-zone, the HOV/HOT lanes need improvement without taking resources from the GP lanes.
  c. **MTLM-3**: In this sub-zone, the GP lanes need improvement without taking resources from the HOV/HOT lanes.

These relationships are shown in TABLE 1.

Instead of using the indicators reviewed above, this paper identifies the lane interrelationships by occupancy-based level of service (LOS) for several reasons. First, occupancy is a surrogate of density that is sensitive to a broad range of flow conditions (*9*, *10*). Second, unlike flow and speed, density has an identical LOS lookup table for free flow speeds between 55 to 75 mph (*9*). Third, occupancy data can be obtained directly from loop detectors widely configured in many freeway systems around the world. Fourth, speed is neither sensitive to LOS nor directly output by single loop detectors. Finally, a flow rate could ambiguously represent either a stable and an unstable state unless accompanied by other parameters like density or speed. TABLE 2 shows the occupancy-based LOS lookup table converted from density by equation (1).

$$density = \frac{5280 \times occupancy}{100 \times (L_V + L_D)} \qquad (1)$$

where L_V is vehicle length(ft); L_D is vehicle detector length(ft).

In summary, lane management hot spots are discovered through the following steps.

- Collect occupancy data of the HOV/HOT and GP lanes.
- Look up the LOS of HOV/HOT and GP lanes with TABLE 2.
- Determine the lane relationship by TABLE 1.
- Determine the lane management and congestion hot spots as LM and MTLM, respectively.

STUDY SITE AND DATA COLLECTION

The study site is the I-405 southbound in Orange County, California, as shown in FIGURE 1. Orange County is the second densest county in California with a population of about 3 million. The typical configuration of I-405 is one 24-hour HOV and multiple GP lanes. Stripped buffers separate the HOV and GP lanes with 16 access (egress/ingress) points along the 24-mile study

stretch.

The study site contains 51 sets of vehicle detector stations (VDS) embedded in the GP lanes, and 54 sets in the HOV lane. The VDS record 30-second flow count and occupancy data that are later transformed to value-added information by the Freeway Performance Measurement System, or PeMS (*11*). Each VDS of the GP lanes basically corresponds to that of the HOV lane at an identical postmile. It enables use of VDS pairs to compare these two types of lanes.

The study covers the 7 to 9 AM period for 30 weeks starting from January to August 2007. The weeks with any holiday on Monday through Friday are discarded to keep the 150-weekday data clean. There were 401 reported incidents during the study period; specifically, occurring on 134 out of the 150 days and at 74 locations out of the 24-mile route. The incident database reproduced by PeMS from California Highway Patrol records the "nominal" durations and locations of most incidents. Actual numbers, however, are difficult to estimate (e.g., unknown durations for removal of the incidents to restore traffic back to normal, discrepancy between the incidents' reported and real starting time, and affected ranges of the incidents). We thus simply note the distribution of these incidents as a reference, as shown in TABLE 3.

The observation rate of each VDS is set to be greater than 50% to keep the data accurate beyond a certain degree; only 20 out of 51 VDS pairs satisfy the requirement, as shown in TABLE 4. The data type is a 5-minute mean occupancy. Both types of lanes (HOV and GP) have 72,000 observations, or $24(\text{time segments from 7:00 to 9:00}) \times 150(\text{weekdays}) \times 20(\text{VDS})$.

HOT SPOT ANALYSIS

Deterministic Hot Spots

Let a cell be a postmile at a 5-minute segment. We first use mode to clarify the lane relationship. FIGURE 2 shows an example of the scattered 150-day occupancy pairs of the cell at postmile 23.19 and 7:00 to 7:05 AM. The mode (134 out of 150 days) falls in the zone DN that represents the cell. Repeating the case above on the remaining 479 presents a complete picture as FIGURE 3. Most cells fall in the DN (354 out of 480 cells, or 73.8%), followed by the MTLM-1 (17.9%) and LM-1 (8.3%). Problems occur continuously from postmile 13.16 to 17.98, about a 5-mile long section, and occasionally at postmile 5.50 and 10.28.

Another way to capture the relationship is to use of the 150-day mean occupancy; each cell is represented by its mean occupancy pair that corresponds to a single relationship, as shown in FIGURE 4. Much like FIGURE 3, most cells fall in the DN (73.1%), MTLM-1 (17.5%), and LM-1 (8.3%). Several LM-1 and MTLM-1 cells in FIGURE 3 become MTLM-3 in FIGURE 4, and some DN become LM-1. The differences likely resulted from the extreme values that affect the mean, rather the mode.

Both FIGURE 3 and FIGURE 4 result in deterministic hot spots, and disclose the same spots of

lane management at postmile 17.98, 14.72, 10.28, and 5.5, and those of congestion at postmile 17.98, 16.60, 15.16, 14.72, and 13.16.

Stochastic Hot Spots

The probabilities of the relationships within the major hot spot section (postmile 13.16-17.98) can be further computed by equation (2).

$$P_{ij}(X) = \frac{\#\text{ of } X}{150} \qquad (2)$$

where *i* for postmile, *j* for time segment, and *X* is LM-1, LM-2, MTLM-1, MTLM-2, MTLM-3, or DN. Three color types characterize the probabilities and show the various degrees of hot spots; the darker one has a probability greater than 0.6, the lighter is between 0.3 and 0.6, and the white is below 0.3. As shown in FIGURE 5, MTLM-1 dominates postmile 13.16, 15.16, and 16.6 during 7:00 to 9:00 AM, while postmile 14.72 and 17.98 varies between LM, MTLM-1 and DN. During 7:30 to 7:50 AM, the HOV and GP lanes are mainly congested along the 5-mile section. As time approaches 9:00, the probabilities of LM and MTLM drop and those of DN increase. The figure also displays that the HOV lane has excess vehicle capacity only at limited locations and durations.

The day-of-week probabilities of LM-1 and MTLM-1 are computed by equation (3) and shown in FIGURE 6 and FIGURE 7, respectively. The same as FIGURE 5, three color types are used. Although some relationship patterns are similar to some degree, such as LM-1 on Tuesday and Wednesday, and MTLM-1 on Monday and Wednesday, each pattern is significantly different from one another in a 99% confidence interval with paired-sample t test.

$$P_{ij}(X \mid D) = \frac{\#\text{ of } X}{30} \qquad (3)$$

where *i* is postmile, *j* is time segment, *X* is LM-1 or MTLM-1, and *D* is day of the week. In addition to the four lane management hot spots (LM-1) revealed in FIGURE 3 and FIGURE 4, another three spots were recognized in FIGURE 6 at postmile 11.2, 5.69, and 5.01. The spots basically appear discretely and lack of uniformity dimensionally and temporally. If the probabilities within each day of the week are added, the aggregated probability of lane management from the greatest to the least would accordingly be on Tuesday, Wednesday, Thursday, Monday, and Friday.

As for the congestion hot spots (MTLM-1) in FIGURE 7, they are relatively uniform from postmile 13.16 to 17.98 and match the results of FIGURE 3 and FIGURE 4. It demonstrates a consistent message that this section may soon need major engineering improvement. Back to TABLE 4, lane reduction may provide a clue to the congestion. The number of GP lanes in this section is four; one to two lanes less than its preceding and succeeding sections. No congestion occurs in another 4-lane section from postmile 5.69 to 1.93 since SR-73 shares some outflow from

I-405. The analysis is also consistent with the I-405 Major Investment Study (*12*) that suggested one additional GP lane and one auxiliary lane at the congestion hot spots mentioned earlier, and a second HOV lane from postmile 20 to 24. If the probabilities within each day of the week are added, the aggregated probability of congestion from the greatest to the least would accordingly be on Thursday, Wednesday, Tuesday, Friday, and Monday.

Some general findings are listed below.

- A location could be a hot spot of lane management for some times and that of congestion for other times (based on FIGURE 3 to FIGURE 5).
- Not "DN and MTLM" but "DN and LM" and "LM and MTLM" tend to appear alternately; LM serves as a transitional state between DN and MTLM (based on FIGURE 3 and FIGURE 4).
- Lane relationships vary with day of the week and lack of uniformity (based on FIGURE 6 and FIGURE 7).
- Traffic on Tuesday through Thursday is likely more imbalanced and congested than Monday and Friday (based on FIGURE 6 and FIGURE 7).

APPLICATION AND LIMITATION

Prediction of hot spots is important due to the dynamic lane relationships. Let the observed occupancies at t_i , t_{i-1} , and t_{i-2} be explanatory variables, noted as $Occ(t_i)$, $Occ(t_{i-1})$, and $Occ(t_{i-2})$. With the same observed dataset mentioned earlier, the linear regression method is applied to predict the occupancy at t_{i+1} , or $Occ(t_{i+1})$, so as to clarify the upcoming relationships between HOV and GP lanes.

As shown in TABLE 5, $Occ(t_{i+1})$ is well explained by the observed occupancies, and the HOV has greater R^2 than the GP lanes. Use of $Occ(t_i)$ alone to predict $Occ(t_{i+1})$ is recommended because of its simplicity and the satisfying R^2 .

To distinguish the differences between the predicted and observed lane relationships, equation (4) defines a rate of accuracy (ROA) as the ratio of the number of matched cells to the total cells. Full match of the deterministic lane relationships will result in a ROA of 1.

$$ROA = \frac{\sum x_{ij}}{T \times VDS} \qquad (4)$$

where T is number of time intervals (= 24); VDS is the number of VDS pairs (=20); $x_{ij} = 1$ if the predicted and observed conditions at the i^{th} time interval and the j^{th} VDS pair are the same, otherwise $x_{ij} = 0$. With the regression models in TABLE 5, the predicted mode-based relationships have a ROA of 0.973 in comparison with the observed ones in FIGURE 3, while the predicted mean-based relationships have a ROA of 0.971 in comparison with the observed ones in FIGURE 4. The predicted probabilities of LM-1, on the other hand, have an average deviation of 0.02 in

comparison with the observed ones. The lane relationships are well forecasted by the regression models not only deterministically but stochastically.

Balancing lane traffic follows recognition of lane management hot spots. If the spots are temporally and spatially continuous, strategies such as adjustment of eligibility (vehicle occupancy, exempt vehicles), access control (continuous, multiple access, access limited to the both ends), and pricing (free, static toll, dynamic toll) may be considered.

On the contrary, if the spots are discretely distributed, the strategies above would not work. Location of the VDS may be one of the reasons for the discrete spots. As shown back in TABLE 4, some VDS are between the upstream off-ramp and downstream on-ramp. Low HOV flow may be recorded because HOV heading off the freeway have left the HOV lane while those heading for the HOV lane are still on the way. The HOV lane will soon regain its flow at the next access point without intervention. In the case of HOV lanes of limited access points, another possible reason for the discrete spots is insufficient information. Changeable message signs would be useful to alert drivers about realtime traffic ahead.

The effect of lane management is positive, albeit limited. The excess capacity of one HOV lane hardly satisfies the needs of the congested multiple GP lanes. FIGURE 8 shows an ideal condition that the excess HOV capacities of the LM-1 hot spots in FIGURE 3 are completely utilized; the LOS of the HOV lane deteriorates to the boundary of C and D, while the LOS of the GP lanes remain in E or F with slight improvements.

CONCLUSION

Different indicators have been used to gauge the absolute and/or relative performance of HOV/HOT lanes. This study recommends occupancy-based LOS to define the interrelationships between HOV/HOT and GP lanes, and develops an approach to deterministically and stochastically identify lane management as well as congestion hot spots. Four major and three minor lane management hot spots are recognized along a 24-mile freeway stretch in Orange County, California. These spots vary by time of day and day of the week. Although lack of uniformity, the upcoming lane relationships are found to be well predicted by the observed occupancy data. Corresponding strategies can thus be sought to prevent the hot spots. The approach requires reliable data along the study site, and is recommended for freeways with automatic data collection equipment. If detailed incident information is available, the affected duration and extension should be discarded. The application of the approach is especially useful for HOV/HOT lanes of limited access points that prohibit arbitrary lane changing.

REFERENCES

1. Long, R. *HOV Lanes in California: Are They Achieving Their Goals?* Legislative Analyst Office, Sacramento, CA, 2000.
2. Turnbull, K. F. and D. G. Capelle. *HOV Systems Manual*. NCHRP Report 414. Transportation Research Board of the National Academies, Washington, D.C., 1998.
3. *Guide for High-Occupancy Vehicle Facilitie*s. American Association of State Highway and Transportation Officials, Washington, D.C., 2004.
4. *High-Occupancy Vehicle Guidelines*, California Department of Transportation, Sacramento, CA, 2003.
5. *Attachment D: I-15 Managed Lanes Dynamic Pricing Algorithm Documentation*. San Diego Association of Government, 2006, pp23. www.sandag.org/services/fastrak/pdfs/5000680/attachD.pdf. Accessed Oct. 20, 2008.
6. Kenan, J. S. 91 Express Lanes; Run Like a Business by The Public Sector. *International Bridge, Tunnel, and Turnpike Association 75th Annual Meeting*, Vienna, Austria, 2007, pp11. www.senate.ca.gov/ftp/SEN/COMMITTEE/STANDING/TRANSPORTATION/_home/SR91 Toll-lanes.pdf. Accessed Oct. 20, 2008.
7. Chung, C. L. Travel Time-Based Equilibrium of High-Occupancy-Vehicle and General-Purpose Lane Allocation. *Transportation Research Board 87th Annual Meeting*, Washington, D.C., 2008. www.its.uci.edu/~cchung/paper/TRB_08.pdf. Accessed Oct. 20, 2008.
8. Neudorff, L. G., J. E. Randall, R. Reiss, and R. Gordon. *Freeway Management and Operations Handbook*. Publication FHWA-OP-04-003. Federal Highway Administration, U.S. Department of Transportation, 2003.
9. *Highway Capacity Manual*. Transportation Research Board, Washington, D.C., 2000.
10. *Traffic Engineering Handbook*. Institute of Transportation Engineers, Washington, D.C., 1999.
11. Freeway **Pe**rformance **M**easurement **S**ystem (PeMS). //pems.eecs.berkeley.edu. Accessed Oct. 20, 2008.
12. *I-405 Major Investment Study.* Orange County Transportation Authority, CA. www.octa.net/major_investment_studies(3).aspx. Accessed Oct. 20, 2008.

List of tables and figures

TABLE 1 Relationships between HOV/HOT and GP Lanes

LOS		HOV/ HOT Lane					
		A	B	C	D	F	E
GP Lane	A	**DN**			**LM-2**		
	B						
	C						
	D				**MTLM-2**		
	E	**LM-1**		**MTLM-3**	**MTLM-1**		
	F						

TABLE 2 LOS Lookup Table

LOS	maximum density (pc/mi/ln) *	**Maximum occupancy (%) ****
A	11	**5.21**
B	18	**8.52**
C	26	**12.31**
D	35	**16.57**
E	45	**21.31**
F	>45	**>21.31**

Note: * from HCM (2000).

** converted from the equation (1) in which $L_V + L_D = 25$ ft is used.

TABLE 3 Reported Incidents in the Study Period and Site

CA postmile	# of incident	average duration (min/incident)	total incident duration / total study period
N 21-24	79	14.9	6.5%
18-21	48	10.2	2.7%
15-18	46	11.8	3.0%
12-15	20	23.0	2.6%
9-12	60	16.3	5.4%
6-9	55	18.1	5.5%
3-6	32	10.9	1.9%
S 0-3	22	7.4	0.9%
unknown	39	12.9	2.8%

TABLE 4 List of the Selected VDS Pairs

CA Postmile		GP Lane			HOV Lane			Location of the GP lanes' VDS
		Lane No.	Max. Rate	Min. Rate	Lane No.	Max. Rate	Min. Rate	
N	23.19	5	100.0	50.6	1	100.0	50.6	Before on-ramp
	21.56	6	100.0	51.6	1	100.0	52.1	At basic section
	17.98	4	86.4	70.4	1	86.4	70.4	Between off- and on-ramp
	16.60	4	94.7	61.4	1	94.7	61.4	Between off- and on-ramp
	15.16	4	94.7	73.3	1	94.7	73.3	Between off- and on-ramp
	14.72	4	92.6	79.5	1	92.6	79.5	Between off- and on-ramp
	13.16	5	94.7	83.4	1	94.7	83.8	After on-ramp
	12.50	5	96.4	90.1	1	96.4	90.1	Between off- and on-ramp
	11.50	5	98.3	94.9	1	98.3	94.9	Between off- and on-ramp
	11.20	6	98.1	91.2	1	98.3	94.9	Before on-ramp
	10.48	5	100.0	96.4	1	100.0	78.5	Before off-ramp
	10.28	5	100.0	96.4	1	100.0	96.4	After off-ramp
	9.54	5	98.5	88.0	1	98.5	88.0	Between off- and on-ramp
	7.01	6	98.5	56.5	1	98.5	56.5	Between off- and on-ramp
	5.69	4	98.3	57.9	1	98.3	57.9	Between off- and on-ramp
	5.50	4	98.3	62.0	1	98.3	62.0	Before on-ramp
	5.01	4	88.9	58.1	1	98.3	62.3	At basic section
	4.03	4	98.4	62.3	1	98.4	62.3	Between off- and on-ramp
	2.88	4	66.2	51.1	1	69.0	51.1	Between off- and on-ramp
S	1.93	4	70.5	57.5	1	70.5	57.5	Between off- and on-ramp

Note: Max. (Min.) Rate is the maximum (minimum) observation rate of the first three quarters of 2007.

TABLE 5 Regression Models for Occupancy Prediction

	sample size	explanatory variable	Mon. coef.	Mon. t	Mon. R^2	Tue. coef.	Tue. t	Tue. R^2	Wed. coef.	Wed. t	Wed. R^2	Thu. coef.	Thu. t	Thu. R^2	Fri. coef.	Fri. t	Fri. R^2
HOV lane	14400	OCCti	0.9345	314.10	0.87	0.9435	336.84	0.89	0.9524	362.33	0.90	0.9468	340.44	0.89	0.9326	308.79	0.87
		Intercept	0.0046	14.51		0.0044	13.57		0.0038	12.23		0.0046	13.18		0.0054	15.75	
	13800	OCCti	0.5844	74.84	0.89	0.0021	6.84	0.95	0.5615	71.85	0.92	0.5934	74.06	0.90	0.5508	70.31	0.89
		OCCti-1	0.3730	47.71		0.5528	71.73		0.4137	52.76		0.3757	46.72		0.4100	52.19	
		Intercept	0.0025	8.25		0.0021	6.84		0.0018	6.14		0.0024	7.38		0.0029	8.90	
	13200	OCCti	0.5248	61.79	0.90	0.0014	4.57	0.95	0.4871	56.42	0.92	0.0015	4.51	0.95	0.4673	54.47	0.89
		OCCti-1	0.2627	28.52		0.4828	56.11		0.3068	32.79		0.5221	60.74		0.2976	32.35	
		OCCti-2	0.1762	20.89		0.3163	34.73		0.1874	21.37		0.2449	25.76		0.2036	23.64	
		Intercept	0.0018	5.99		0.0014	4.57		0.0012	4.00		0.0015	4.51		0.0021	6.40	
GP lane	14400	OCCti	0.8912	233.86	0.79	0.9025	246.04	0.81	0.9226	274.84	0.84	0.9268	287.47	0.85	0.9135	264.19	0.83
		Intercept	0.0139	24.97		0.0145	23.96		0.0115	20.54		0.0109	20.32		0.0114	22.14	
	13800	OCCti	0.0101	17.89	0.90	0.6442	78.81	0.82	0.7094	85.20	0.85	0.6338	78.32	0.87	0.7252	86.42	0.84
		OCCti-1	0.6625	81.08		0.2867	34.93		0.2347	27.99		0.3185	39.15		0.2080	24.68	
		Intercept	0.0101	17.89		0.0104	17.01		0.0085	14.78		0.0073	13.65		0.0089	16.72	
	13200	OCCti	0.0091	15.61	0.90	0.6107	70.29	0.83	0.6788	78.45	0.85	0.5944	68.68	0.87	0.7202	82.11	0.84
		OCCti-1	0.6424	74.67		0.2022	20.24		0.1551	14.89		0.2406	24.30		0.1978	18.46	
		OCCti-2	0.2010	20.09		0.1289	14.75		0.1192	13.60		0.1244	14.24		0.0166	1.88	
		Intercept	0.0091	15.61		0.0087	13.81		0.0070	11.92		0.0062	11.30		0.0086	15.49	

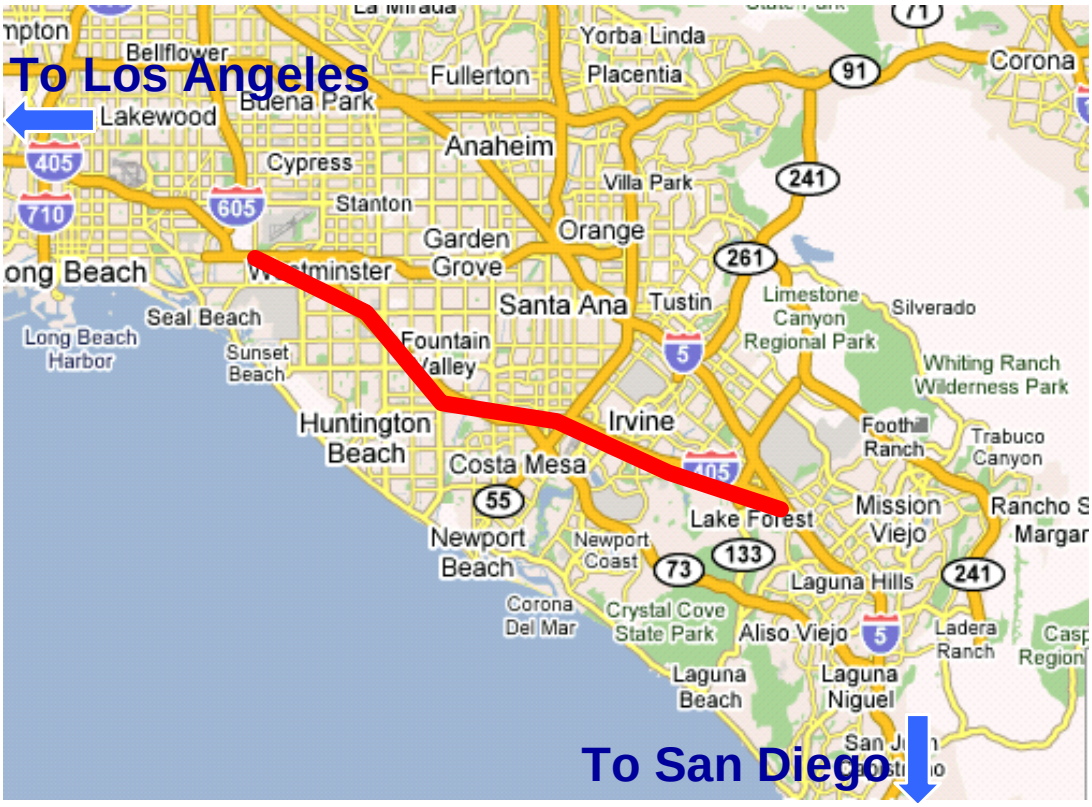


FIGURE 1 Study site

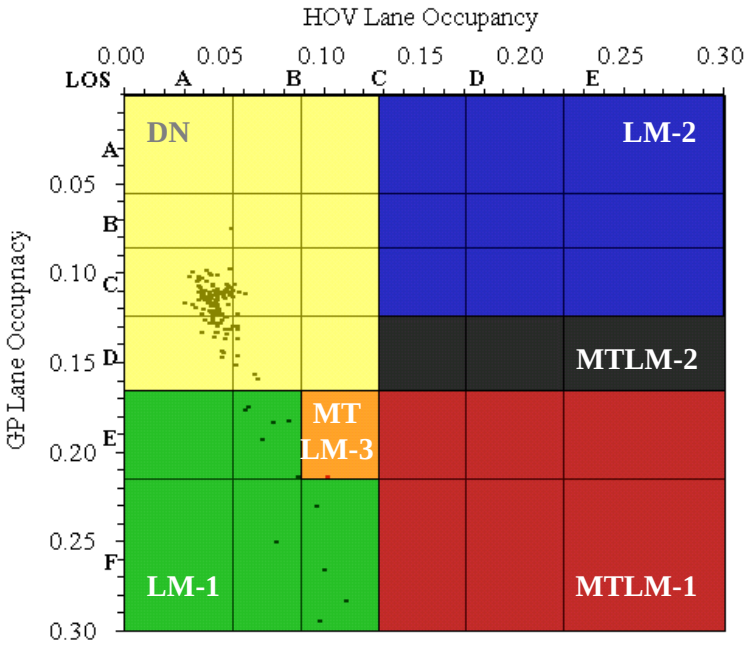


FIGURE 2 Data distribution of the cell at postmile 23.19 & 7:00-7:05

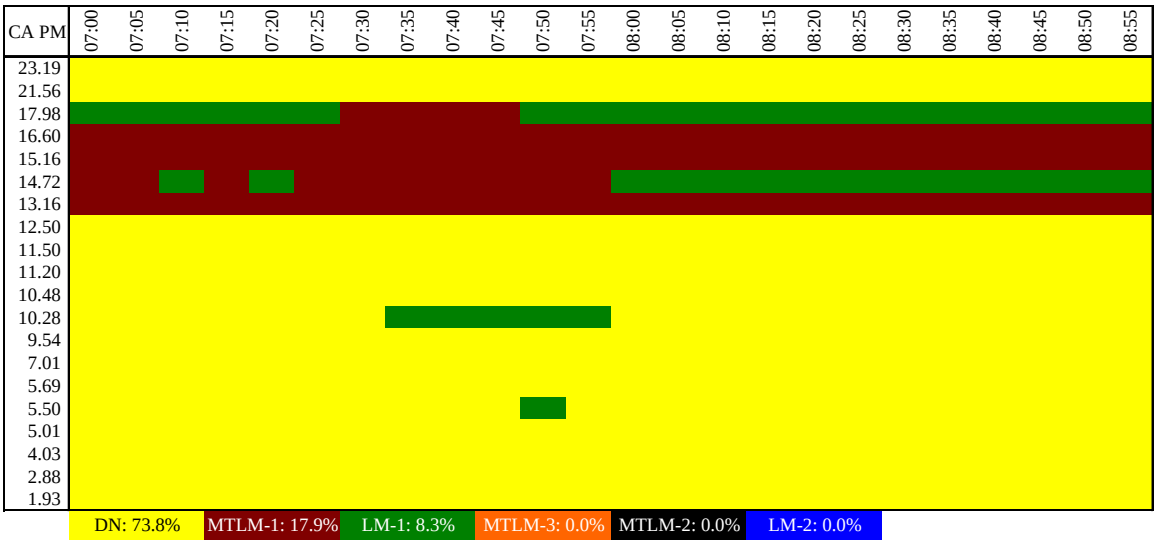


FIGURE 3 Mode of occupancy-based lane relationships

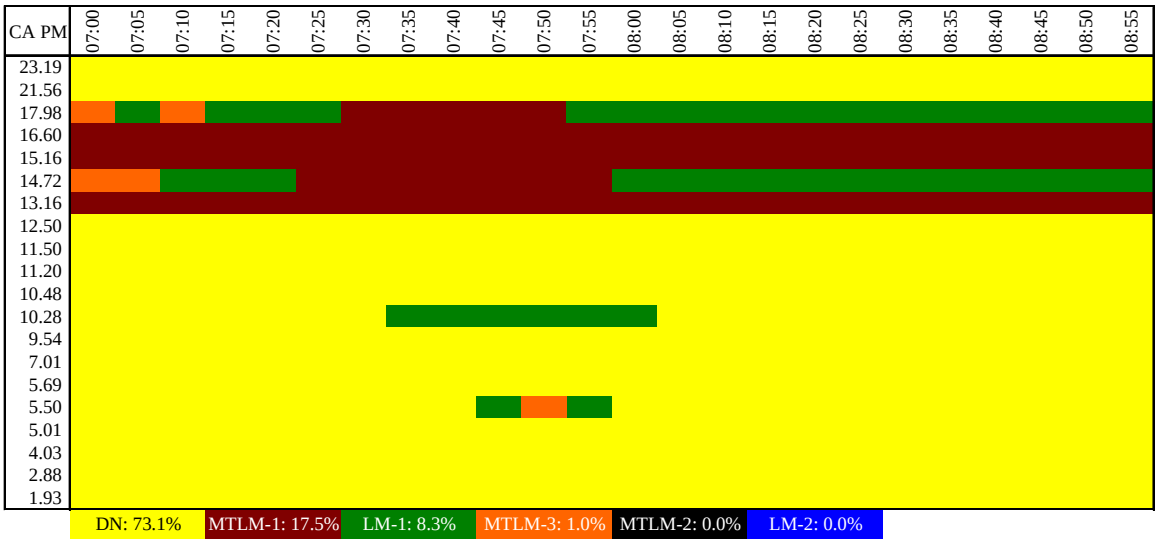


FIGURE 4 Mean occupancy-based lane relationships

CA PM	Condition	07:00	07:05	07:10	07:15	07:20	07:25	07:30	07:35	07:40	07:45	07:50	07:55	08:00	08:05	08:10	08:15	08:20	08:25	08:30	08:35	08:40	08:45	08:50	08:55
17.98	LM-1	0.43	0.37	0.33	0.36	0.41	0.37	0.31	0.27	0.32	0.37	0.48	0.56	0.61	0.64	0.64	0.62	0.65	0.60	0.61	0.67	0.58	0.59	0.59	0.53
	LM-2	0.00	0.00	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	MTLM-1	0.23	0.27	0.26	0.25	0.22	0.31	0.47	0.53	0.53	0.51	0.37	0.27	0.18	0.15	0.15	0.11	0.08	0.10	0.09	0.05	0.05	0.05	0.07	0.05
	MTLM-2	0.01	0.00	0.02	0.02	0.01	0.02	0.01	0.01	0.01	0.01	0.00	0.00	0.01	0.00	0.01	0.01	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.00
	MTLM-3	0.09	0.11	0.07	0.07	0.07	0.09	0.03	0.06	0.01	0.01	0.03	0.01	0.02	0.02	0.02	0.05	0.02	0.05	0.05	0.02	0.06	0.04	0.04	0.03
	DN	0.24	0.25	0.31	0.29	0.29	0.19	0.15	0.11	0.11	0.10	0.11	0.15	0.18	0.19	0.19	0.21	0.25	0.25	0.25	0.26	0.31	0.32	0.30	0.39
16.60	LM-1	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.01	0.01	0.00	0.01	0.01	0.01	0.00	0.01	0.00
	LM-2	0.09	0.07	0.05	0.05	0.04	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.03	0.03	0.01	0.02	0.03	0.03	0.03	0.03	0.04	0.04
	MTLM-1	0.68	0.59	0.63	0.74	0.80	0.88	0.90	0.93	0.93	0.93	0.94	0.93	0.94	0.91	0.86	0.87	0.90	0.86	0.84	0.82	0.85	0.79	0.74	0.71
	MTLM-2	0.13	0.22	0.20	0.10	0.08	0.03	0.04	0.02	0.02	0.02	0.02	0.03	0.03	0.04	0.09	0.05	0.05	0.09	0.07	0.09	0.05	0.10	0.10	0.13
	MTLM-3	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01
	DN	0.09	0.11	0.11	0.10	0.07	0.08	0.04	0.03	0.04	0.04	0.03	0.02	0.02	0.03	0.02	0.03	0.04	0.03	0.05	0.06	0.07	0.07	0.11	0.11
15.16	LM-1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	LM-2	0.03	0.02	0.03	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.01	0.02	0.01	0.03	0.01	0.03	0.01	0.03	0.03	0.01	0.03	0.05
	MTLM-1	0.73	0.76	0.75	0.85	0.89	0.93	0.93	0.98	0.97	0.98	0.97	0.99	0.96	0.93	0.89	0.91	0.88	0.93	0.89	0.86	0.86	0.89	0.89	0.76
	MTLM-2	0.24	0.22	0.22	0.12	0.09	0.07	0.07	0.01	0.02	0.02	0.03	0.01	0.02	0.05	0.09	0.06	0.11	0.05	0.10	0.11	0.11	0.10	0.09	0.19
	MTLM-3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	DN	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14.72	LM-1	0.27	0.23	0.39	0.29	0.43	0.32	0.36	0.17	0.21	0.17	0.25	0.35	0.48	0.57	0.55	0.61	0.57	0.67	0.67	0.57	0.60	0.64	0.60	0.58
	LM-2	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
	MTLM-1	0.27	0.35	0.31	0.47	0.39	0.55	0.55	0.76	0.73	0.77	0.69	0.61	0.41	0.32	0.30	0.26	0.25	0.20	0.18	0.19	0.17	0.21	0.21	0.18
	MTLM-2	0.01	0.00	0.01	0.02	0.01	0.01	0.01	0.00	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.01	0.01	0.01	0.00	0.02
	MTLM-3	0.26	0.23	0.13	0.11	0.07	0.05	0.04	0.03	0.01	0.03	0.01	0.02	0.07	0.06	0.09	0.07	0.09	0.07	0.10	0.13	0.17	0.06	0.11	0.13
	DN	0.19	0.19	0.15	0.11	0.09	0.06	0.04	0.03	0.03	0.02	0.03	0.03	0.03	0.05	0.06	0.06	0.08	0.04	0.05	0.10	0.05	0.08	0.08	0.09
13.16	LM-1	0.00	0.01	0.03	0.00	0.01	0.01	0.00	0.00	0.01	0.00	0.01	0.01	0.01	0.05	0.06	0.02	0.06	0.04	0.03	0.04	0.03	0.07	0.03	0.01
	LM-2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01
	MTLM-1	0.43	0.45	0.61	0.63	0.71	0.77	0.79	0.85	0.87	0.89	0.89	0.87	0.76	0.70	0.65	0.66	0.62	0.59	0.61	0.53	0.53	0.46	0.46	0.37
	MTLM-2	0.36	0.31	0.21	0.17	0.18	0.14	0.15	0.09	0.08	0.06	0.07	0.07	0.10	0.09	0.10	0.13	0.15	0.15	0.15	0.19	0.17	0.17	0.21	0.22
	MTLM-3	0.05	0.08	0.09	0.12	0.07	0.06	0.03	0.05	0.03	0.05	0.03	0.03	0.10	0.09	0.09	0.09	0.06	0.13	0.09	0.10	0.11	0.12	0.11	0.09
	DN	0.15	0.15	0.07	0.07	0.03	0.02	0.03	0.01	0.01	0.00	0.01	0.01	0.03	0.07	0.11	0.09	0.11	0.07	0.12	0.14	0.16	0.18	0.19	0.30

Note: color index

LM-1	prob>0.6	prob=0.3-0.6	prob < 0.3	MTLM-2	prob>0.6	prob=0.3-0.6	prob < 0.3
LM-2	prob>0.6	prob=0.3-0.6	prob < 0.3	MTLM-3	prob>0.6	prob=0.3-0.6	prob < 0.3
MTLM-1	prob>0.6	prob=0.3-0.6	prob < 0.3	DN	prob>0.6	prob=0.3-0.6	prob < 0.3

FIGURE 5 Probability of the lane relationships on the problematic locations

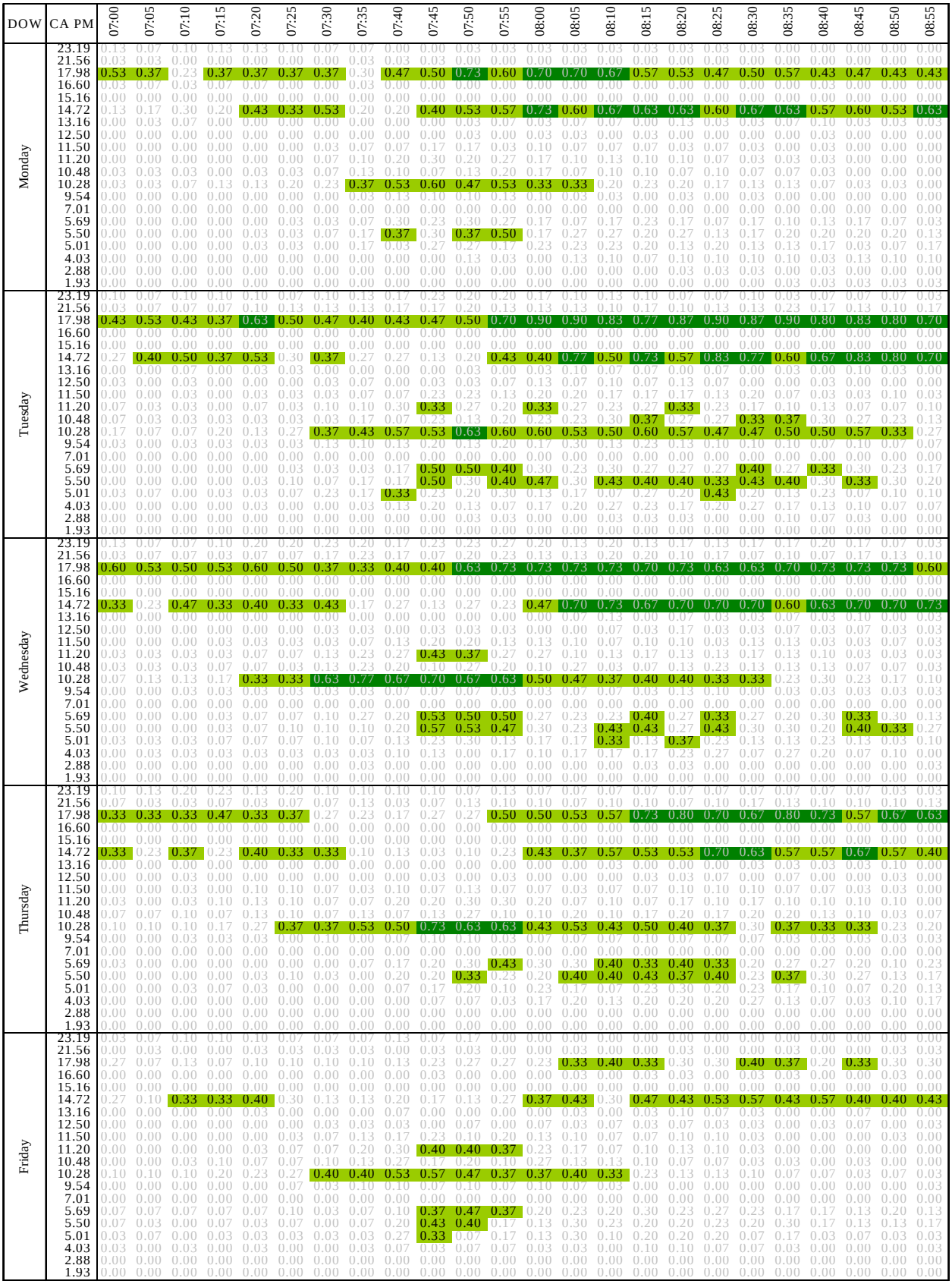
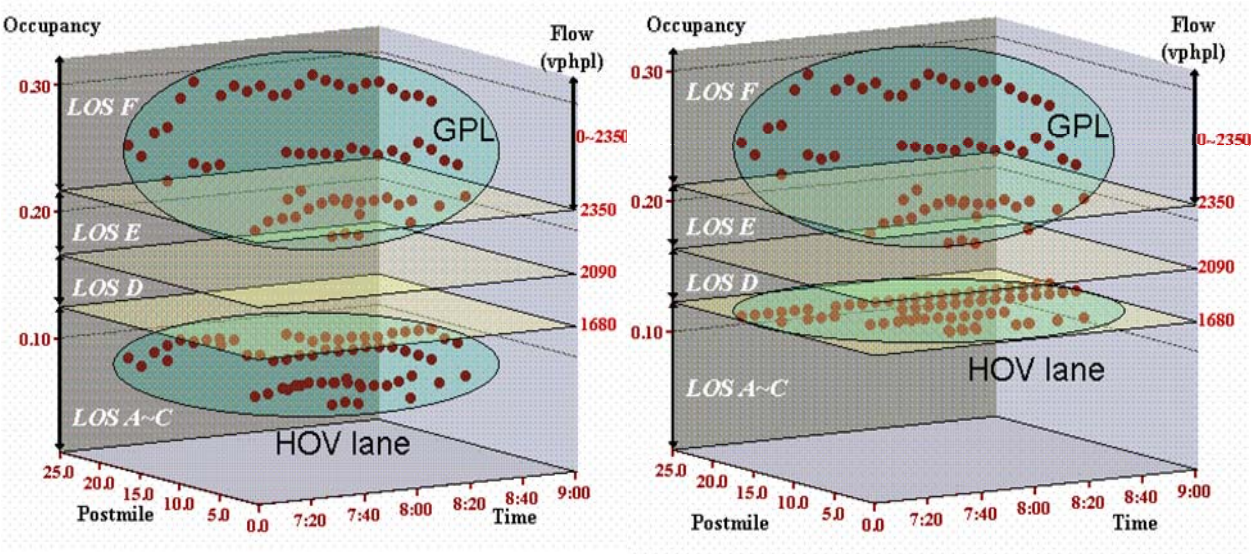


FIGURE 6 Probability of LM-1 by day of the week

DOW	CA PM	07:00	07:05	07:10	07:15	07:20	07:25	07:30	07:35	07:40	07:45	07:50	07:55	08:00	08:05	08:10	08:15	08:20	08:25	08:30	08:35	08:40	08:45	08:50	08:55
Monday	23.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	21.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	17.98	0.15	0.21	0.21	0.21	0.08	0.28	0.31	0.41	0.38	0.42	0.19	0.25	0.09	0.12	0.09	0.09	0.15	0.12	0.12	0.02	0.05	0.02	0.05	0.05
	16.60	0.43	0.30	0.40	0.64	0.74	0.77	0.87	0.93	0.93	1.00	0.97	0.90	0.90	0.87	0.80	0.83	0.87	0.70	0.67	0.57	0.57	0.53	0.43	0.43
	15.16	0.57	0.70	0.83	0.87	0.87	0.93	1.00	0.97	0.97	1.00	0.97	1.00	0.97	0.87	0.77	0.83	0.80	0.93	0.77	0.83	0.80	0.73	0.67	0.53
	14.72	0.17	0.24	0.38	0.44	0.48	0.51	0.35	0.77	0.67	0.55	0.45	0.39	0.16	0.29	0.19	0.15	0.19	0.15	0.12	0.15	0.12	0.12	0.12	0.05
	13.16	0.47	0.43	0.54	0.70	0.83	0.80	0.73	0.77	0.80	0.90	0.83	0.87	0.63	0.67	0.44	0.53	0.44	0.47	0.63	0.40	0.37	0.37	0.20	0.13
	12.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	11.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	11.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	10.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	10.28	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
	9.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	7.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5.69	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.00	0.01	0.00	0.00	0.01	0.00	0.00
	5.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.05	0.01	0.05	0.05	0.01	0.01	0.01	0.01	0.01	0.04	0.01	0.01	0.01	0.01	0.01	0.00
	5.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.01
	4.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	2.88	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	1.93	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tuesday	23.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.04	0.00	0.03
	21.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.01
	17.98	0.28	0.28	0.35	0.41	0.25	0.32	0.52	0.61	0.55	0.55	0.45	0.26	0.10	0.06	0.09	0.16	0.06	0.03	0.10	0.10	0.06	0.03	0.06	0.02
	16.60	0.83	0.63	0.83	0.87	0.87	0.97	0.97	0.97	0.97	0.93	0.97	0.97	0.93	1.00	0.93	0.90	1.00	0.97	0.93	0.93	0.97	0.90	0.87	0.77
	15.16	0.80	0.80	0.73	0.93	0.97	0.97	0.97	1.00	1.00	1.00	1.00	1.00	1.00	0.93	1.00	1.00	0.97	0.97	0.97	0.83	0.83	1.00	0.97	0.83
	14.72	0.21	0.28	0.28	0.55	0.32	0.64	0.65	0.64	0.71	0.77	0.71	0.51	0.48	0.19	0.42	0.22	0.22	0.09	0.16	0.12	0.16	0.13	0.13	0.22
	13.16	0.47	0.40	0.64	0.77	0.67	0.77	0.77	0.87	0.87	0.87	0.80	0.83	0.80	0.70	0.64	0.70	0.67	0.64	0.60	0.53	0.53	0.44	0.37	0.30
	12.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	11.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.04	0.04	0.01	0.01	0.01	0.01	0.04	0.00	0.01	0.00	0.00	0.00	0.00	0.00
	11.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00
	10.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00
	10.28	0.01	0.00	0.00	0.01	0.00	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01
	9.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	7.01	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.03	0.03	0.03	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5.69	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	5.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.05	0.08	0.08	0.02	0.04	0.05	0.01	0.01	0.04	0.01	0.01	0.01	0.01	0.01	0.07
	5.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.00	0.01	0.01	0.01	0.01	0.00	0.01	0.00	0.00	0.00
	4.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00
	2.88	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	1.93	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Wednesday	23.19	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.03
	21.56	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00
	17.98	0.25	0.22	0.25	0.22	0.22	0.25	0.61	0.64	0.55	0.55	0.29	0.22	0.16	0.09	0.09	0.09	0.02	0.15	0.15	0.06	0.02	0.06	0.09	0.12
	16.60	0.80	0.70	0.73	0.87	0.83	0.93	0.97	0.97	0.97	0.97	0.97	1.00	1.00	0.93	0.90	0.93	0.93	0.87	0.87	0.90	0.93	0.83	0.87	0.80
	15.16	0.80	0.80	0.83	0.87	0.93	0.97	0.97	1.00	1.00	1.00	1.00	1.00	0.97	0.93	0.93	0.97	0.90	0.90	0.93	0.87	0.93	1.00	0.97	0.77
	14.72	0.28	0.44	0.25	0.48	0.51	0.61	0.51	0.84	0.74	0.87	0.74	0.77	0.45	0.29	0.22	0.29	0.19	0.26	0.26	0.22	0.25	0.22	0.29	0.16
	13.16	0.43	0.60	0.60	0.63	0.73	0.77	0.77	0.83	0.93	0.80	0.87	0.87	0.83	0.64	0.60	0.77	0.77	0.60	0.63	0.57	0.53	0.50	0.57	0.37
	12.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	11.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.04	0.00	0.00	0.00	0.04	0.04	0.03	0.00	0.00	0.07	0.03	0.04	0.03
	11.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.03	0.03	0.03
	10.48	0.00	0.00	0.00	0.00	0.04	0.03	0.00	0.01	0.01	0.00	0.01	0.01	0.04	0.01	0.00	0.00	0.00	0.01	0.04	0.04	0.04	0.04	0.04	0.03
	10.28	0.00	0.00	0.00	0.01	0.01	0.01	0.02	0.03	0.02	0.02	0.02	0.02	0.05	0.02	0.01	0.01	0.01	0.01	0.01	0.04	0.04	0.04	0.04	0.04
	9.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.03	0.03	0.03	0.03	0.03
	7.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.03	0.03	0.03	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5.69	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00
	5.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.01	0.05	0.05	0.05	0.01	0.04	0.01	0.01	0.08	0.01	0.01	0.01	0.04	0.05	0.01	0.01
	5.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.01	0.01	0.01	0.00	0.01	0.01	0.00	0.00	0.01	0.00	0.00	0.00
	4.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.00	0.00	0.00
	2.88	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	1.93	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Thursday	23.19	0.00	0.00	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	21.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
	17.98	0.41	0.54	0.44	0.35	0.44	0.58	0.71	0.71	0.81	0.74	0.71	0.48	0.42	0.38	0.39	0.19	0.13	0.12	0.06	0.06	0.09	0.12	0.09	0.05
	16.60	0.80	0.80	0.70	0.83	0.90	0.93	0.90	1.00	1.00	1.00	1.00	1.00	1.00	0.97	0.97	1.00	0.97	1.00	1.00	0.97	0.97	0.87	0.90	0.90
	15.16	0.90	0.83	0.80	0.90	0.93	0.93	0.90	0.97	0.93	0.97	0.97	1.00	0.97	1.00	0.93	0.97	1.00	1.00	0.97	0.93	0.90	0.93	0.93	0.90
	14.72	0.48	0.37	0.41	0.61	0.41	0.54	0.64	0.84	0.80	0.93	0.84	0.77	0.51	0.55	0.32	0.42	0.38	0.26	0.19	0.22	0.22	0.29	0.25	0.28
	13.16	0.43	0.47	0.70	0.60	0.80	0.87	0.77	0.90	0.93	0.97	0.97	0.93	0.83	0.73	0.80	0.70	0.67	0.70	0.67	0.67	0.70	0.57	0.60	0.63
	12.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.03	0.00	0.03	0.00	0.00	0.00	0.00	0.00
	11.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	11.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.03
	10.48	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00
	10.28	0.00	0.00	0.00	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.02	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	9.54	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	7.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.03	0.03	0.03
	5.69	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01
	5.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.01	0.01	0.08	0.07	0.04	0.01	0.05	0.01	0.05	0.01	0.01	0.01	0.01	0.04	0.00	0.07
	5.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.01	0.00
	4.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.01
	2.88	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	1.93	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Friday	23.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	21.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	17.98	0.11	0.17	0.10	0.14	0.17	0.20	0.24	0.34	0.40	0.34	0.31	0.24	0.24	0.21	0.18	0.14	0.14	0.18	0.15	0.11	0.14	0.11	0.18	0.08
	16.60	0.53	0.50	0.50	0.50	0.67	0.80	0.80	0.77	0.77	0.73	0.80	0.80	0.87	0.77	0.70	0.70	0.73	0.77	0.73	0.73	0.83	0.83	0.63	0.67
	15.16	0.60	0.67	0.53	0.70	0.73	0.83	0.80	0.97	0.97	0.93	0.90	0.93	0.90	0.90	0.80	0.80	0.73	0.83	0.80	0.83	0.83	0.77	0.90	0.77
	14.72	0.28	0.44	0.31	0.34	0.31	0.51	0.67	0.74	0.74	0.77	0.77	0.64	0.55	0.38	0.44	0.32	0.38	0.35	0.29	0.35	0.19	0.41	0.35	0.28
	13.16	0.37	0.37	0.57	0.47	0.50	0.67	0.90	0.87	0.84	0.90	0.97	0.83	0.70	0.77	0.77	0.60	0.57	0.57	0.53	0.50	0.53	0.44	0.57	0.40
	12.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.04	0.10	0.00	0.03	0.00	0.03	0.00	0.00	0.00	0.03	0.03	0.00	0.00	0.00
	11.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.07	0.01	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	11.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	10.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.04	0.04	0.04	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	10.28	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.05	0.05	0.05	0.05	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	9.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	7.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.03	0.00	0.00
	5.69	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.01	0.01	0.01	0.01	0.04	0.01	0.01	0.01	0.04	0.00	0.01	0.00	0.00
	5.50	0.00	0.03	0.00	0.00	0.03	0.00	0.00	0.00	0.04	0.01	0.01	0.04	0.04	0.04	0.07	0.01	0.01	0.07	0.01	0.01	0.07	0.10	0.00	0.01
	5.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.01	0.00	0.01	0.00	0.01	0.01	0.04	0.00	0.01	0.00	0.00	0.00	0.00
	4.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	2.88	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	1.93	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

FIGURE 7 Probability of MTLM-1 by day of the week



(a) Before lane management **(b) After lane management**

FIGURE 8 Estimated effects of lane management