VALIDATING THE COST EFFECTIVENESS MODEL FOR CALIFORNIA'S FREEWAY INCIDENT MANAGEMENT PROGRAM

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ABSTRACT

Freeway service patrol (FSP) is a widely used incident management measure designed to assist disabled vehicles along congested freeway segments and reduce non-recurring congestion through quick response to accidents and other incidents on freeways. A FSP beat performance evaluation model has been developed and used to analyze the cost effectiveness of providing FSP service on selected freeway corridors, and to assess the overall cost effectiveness of California's FSP program. The FSP beat evaluation model estimates traffic delay savings, fuel savings and emissions reductions per assisted incident due to FSP using deterministic queuing techniques.

This paper presents a method of using real-world traffic and incident data to validate the FSP performance evaluation model, and presents the model validation results. The paper also presents key findings about the reliability freeway performance measures, like VMT, VHT and traffic delays, estimated using Caltrans PeMS stationary loop data and INRIX Analytics probe vehicle data.

Keywords:
Freeways, incidents, freeway service patrol (FSP), delay

1. INTRODUCTION & BACKGROUND

The Caltrans Freeway Service Patrol (FSP) is an incident management measure designed to assist disabled vehicles along congested freeway segments and reduce non-recurring congestion through quick detection, response, and removal of accidents and other incidents on freeways. In California, the program is jointly administered by the California Department of Transportation (Caltrans), the California Highway Patrol (CHP) and regional transportation planning agencies. Currently, FSP operates on 193 freeway sites ("beats") across the State with 364 tow trucks over 1,800 centerline miles. California, having a large scale FSP program and performance driven decision making policies, developed an analysis tool to evaluate the performance of FSP service on selected freeway corridors (i.e., FSP beats).

The benefits of providing FSP service depend on the beat's geometric and traffic characteristics, and the frequency and type of assisted incidents. Incidents that occur in-lane tend to be more congestion causing than shoulder incidents. Likewise, incidents occurring on freeways with high traffic demand (relatively little excess capacity) tend to cause more congestion than incidents on freeways with lower volumes. Earlier studies performed by the University of California at Berkeley validated the FSP beat evaluation model by analyzing the effectiveness of FSP on a section of the I-880 freeway in San Francisco Bay Area (1) and a section of I-10 freeway in Los Angeles (2). Extensive data on incidents and traffic characteristics were collected "before" and "after" the FSP deployment using specially instrumented probe vehicles and data from loop detectors. The data were processed, verified and integrated into databases. Then analytical procedures were developed to estimate incident specific delays. The resulting FSP performance evaluation model (FSPE model) estimated benefits based on delay and fuel savings, fuel consumption, and air pollution reduction; and it showed that FSP was a cost-effective measure at the specific test sites.

These previous FSP model validation efforts focused on a very limited set of test sites and previous model validation methodologies were only applicable to those FSP beats with relatively closely spaced PeMS vehicle detector stations. Methods that could be applied to a broader range of FSP beats (including FSP beats serving less congested corridors and/or where PeMS detection stations are sparsely spaced or not available) would be better suited for statewide FSP model validation and performance monitoring purposes.

To address these needs, a method was developed to validate FSP delay savings for freeway corridors which was not dependent on tightly spaced (and fully functional) PeMS detector stations. The FSP's performance measures are directly derived from its vehicular delay savings; So any validation method would need to quantify vehicular delays and delay savings attributable to FSP.

The next section of the paper (Section 2) introduces the concepts for the FSP performance evaluation model. Section 3 discusses the methods used to validate the FSP performance evaluation model. Section 4 introduces the data sources used to develop the validation targets, and discusses data quality and highlights some observations about the data. The results of the FSP model validation efforts and an interpretation of the results follow in Section 5. Section 6, the last section, concludes with lessons learned and possible future work.

2. OVERVIEW OF THE FSP PERFORMANCE EVALUATION MODEL

The FSP performance evaluation model (FSPE model) employs deterministic queuing techniques to estimate incident induced traffic delays and the associated delay savings attributable to the provided FSP service, graphically depicted in Figure 1. Deterministic queuing and queueing diagrams originally discussed in the freeway operations context by Moskowitz (3) has been applied in numerous studies to analyze the incident impacts (4).

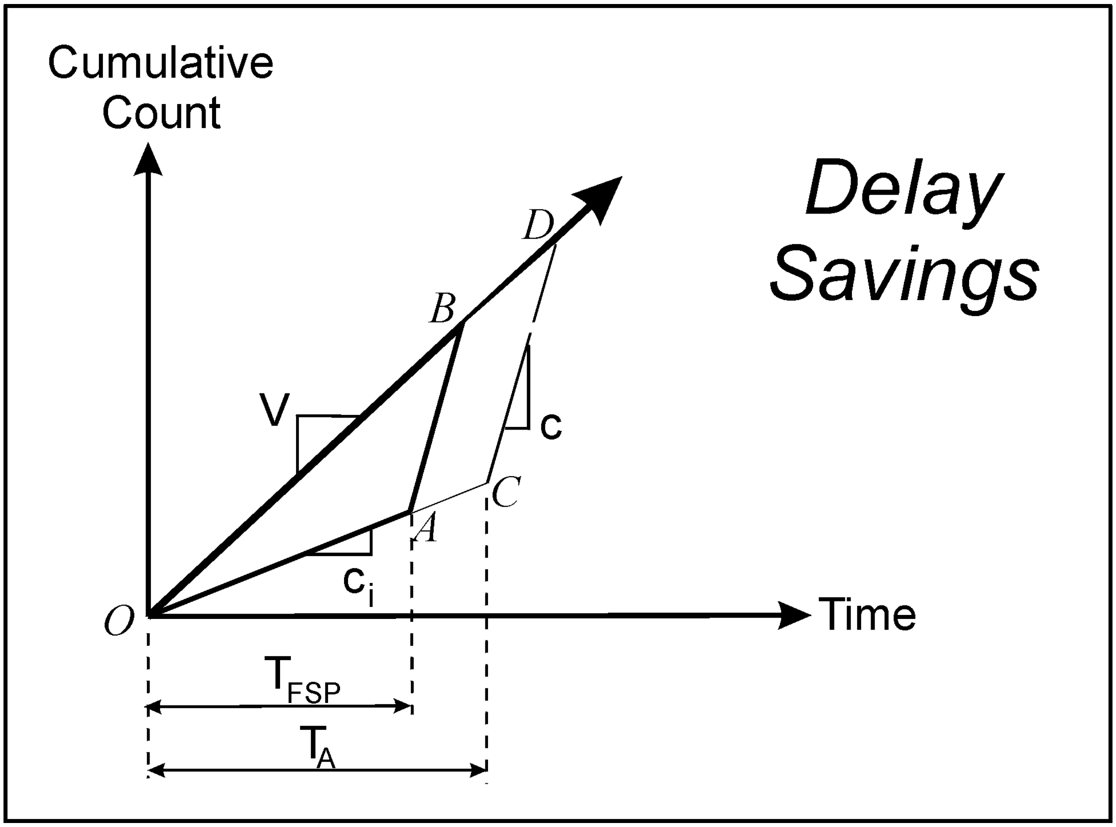

FIGURE 1 Estimation of Incident Delays and FSP Delay Savings.

When an incident occurs, the normal freeway capacity c is reduced to a lesser capacity, c_i, for the duration of the incident, T_A. If the traffic demand on the freeway, v, is greater than the remaining capacity c_i then a queue is formed upstream of the incident. Once the incident has cleared, after T_A minutes, the built-up queue will discharge at the capacity of the freeway, c, until the queue is dissipated. The total delay (in vehicle-hours) caused by the incident is the area of the triangle OCD in Figure 1:

$$delay = \frac{(v - c_i)(c - c_i)T_A^2}{2(c - v)}$$

The deployment of FSP results in shorter response times that reduce the incident duration (T_{FSP}) and the associated incident delay (area of triangle OAB in Figure 1). The delay savings due to FSP is the difference in delays without and with FSP service (area ABDC in Figure 1). The delay savings is attributable to FSP's faster response time. The FSP response time reduction is the difference between the time that the FSP tow-truck arrived at the incident and the time that a tow-truck would have arrived had there been no FSP service on the beat. It is assumed that without the FSP service, stranded motorists would wait for service by a member tow company or a rotational tow arranged by CHP.

The method predicts no delays when the traffic demand v is less than the remaining capacity under incident conditions, c_i. However, in reality, there is a small amount of delay to the traffic stream because of vehicle slow-downs and rubbernecking. These small delays are ignored. The delay savings (and the benefit-to-cost ratio) depend on incident frequency and characteristics (remaining capacity and duration) and the FSP beat's operating characteristics (traffic demand and freeway capacity). The benefits are greater on heavily traveled FSP beats with a high frequency of lane-blocking incidents than on free-flowing beats with mostly shoulder breakdowns.

The methodology used to validate the FSP performance evaluation model is discussed next, followed by data sources in Section 4.

3. METHODOLOGY FOR VALIDATING THE FSP EVALUATION MODEL

In a previous research effort, a method was developed a method to divide the total congestion along a freeway corridor into six components: the delay caused by 1) incidents, 2) special events, 3) lane closures, and 4) adverse weather, 5) the potential reduction in delays at bottlenecks that ideal ramp metering could achieve, and 6) the remaining delays due mainly to excess demand (5). The Caltrans PeMS system currently hosts a fully automated two-step version of this method. The first of the two steps estimates the components of non-recurrent congestion using statistical regression. The second method locates all bottlenecks and estimates the potential reduction in traffic delays that ideal ramp metering could achieve. The method requires input data on traffic volumes and speeds; the time and location of incidents; special events; lane closures; and adverse weather. It can readily be applied to any freeway corridor with minimal calibration.

This components of congestion model assumes that each incident, special event, lane-closure, and adverse weather condition contributes linearly to the overall delays observed in the corridor. More complicated causality between explanatory variables, such as between the bad weather and the number of accidents, was not considered to keep the number of parameters in the model reasonable. For the components of congestion research efforts, the traffic volume and speed data were obtained from the Caltrans PeMS website. Using these methods, traffic delays caused by incidents can be quantified for any freeway corridor given that adequate traffic and incident data are available for the corridor. These components of congestion techniques were used to provide empirical based estimates of incident induced delays that could be compared to the FSPE model's delay savings estimates.

One of the main outputs of the FSPE model is the annual delay savings, in vehicle-hours, that is attributable to the provided FSP service for a freeway corridor. The expected delay savings per FSP assist can be easily calculated using the FSPE model inputs and outputs. Likewise, the expected delay savings per minute of incident reduction can be easily estimated. For example, if the FSPE model estimated 1,600 VHT of delay savings on a beat, and the FSP tow trucks were involved with 80 assists annually, with an average incident reduction of 5 minutes per assist, then the delay savings per incident-minute would be 1,600/(80*5) = 4.00 vehicle-hours per incident-minute. Traditionally, the crucial challenge for the FSPE model validation efforts was to find comparable and reliable empirical delay estimates to compare to the FSPE model output.

Fortunately, a comparable measure (traffic delays per incident-minute) for a freeway corridor can be estimated using the components of congestion techniques and a combination of Caltrans PeMS and INRIX Analytics data for selected freeway corridors where FSP service is provided.

4. DATA SOURCES FOR FSP MODEL VALIDATION

The two primary data sources for the FSPE model validation dataset were INRIX and PeMS.

The INRIX website provides historical and real-time traffic information, travel times and travel time information to public agencies, businesses and individuals. To do this, INRIX collects trillions of bytes of information about roadway speeds from nearly 100 million anonymous mobile phones, trucks, delivery vans, and other fleet vehicles equipped with GPS locator devices. The data is processed in real-time, creating traffic speed information for major freeways, highways and arterials across North America, as well as much of Europe, South America, and Africa. INRIX "Analytics" and INRIX "User Delay Cost Analysis" modules were used to provide traffic delay (congestion) and corridor travel time measures for preselected freeway corridors (i.e., FSP beats).

The Caltrans Performance Measurement System (PeMS) collects data in real-time from over 39,000 individual detectors spanning the freeway system across all major metropolitan areas of the state of California. PeMS is also an Archived Data User Service (ADUS) that provides over ten years of data for historical analysis. It integrates a wide variety of information from Caltrans and other local agency systems including:

- Traffic Detectors
- Incidents
- Lane Closures
- Toll Tags
- Census Traffic Counts
- Vehicle Classification
- Weight-In-Motion
- Roadway Inventory

The Caltrans PeMS website was used to provide stationary point traffic volume, and delay data (mainly from freeway loops) for the set of preselected FSP beats. The Caltrans PeMS website also collects and reports CHP reported freeway incident data.

The minimum data required to produce an estimate of expected (average) traffic delays per incident are: 1) traffic incident data and 2) traffic delay data. PeMS was used to provide the incident data. Both INRIX and PeMS calculate and report traffic delays. This led to questions about how INRIX and PeMS estimate their traffic delays, how well the two delay estimates compare, and which estimate was the most reliable.

During the data preparation and analysis, the PeMS reported delays and the INRIX reported delays were compared to see how closely they agreed – for a common corridor, time period and level of aggregation. Figure 2 shows a scatter plot comparing the PeMS Corridor reported daily traffic delays with the INRIX Analytics reported daily traffic delays for State Route 24 in California's

East Bay area for the July 1, 2012 through June 30, 2013 time period. Both sets of daily traffic delays were estimated using a threshold free flow speed of 60 mph.

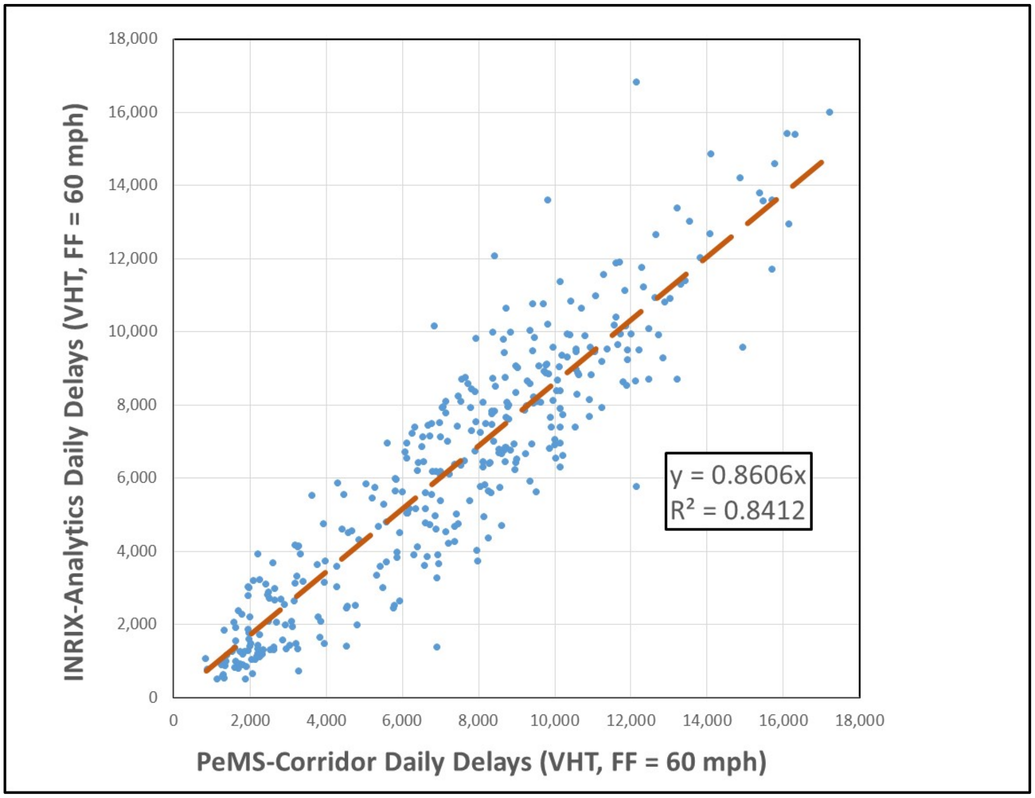

FIGURE 2 Daily Traffic Delays: PeMS-Corridor and INRIX-Analytics (State Route 24; July 1 2012 through June 30 2013)

The strength of the correlations between the traffic delays and the freeway incidents was used to help determine whether the INRIX or PeMS estimated delays were better suited for the components of congestion analysis techniques. It is well known that positive correlations exist between traffic delays and incident rates, and that errors (e.g., measurement, estimation errors) in the traffic delay estimates and incident data only serve to deteriorate the strength of these correlations.

Table 1 shows the correlation coefficients between daily freeway traffic delays (PeMS and INRIX) and daily freeway incidents for along State Route 24 in California's East Bay area. Freeway collisions are one category of incidents in the CHP incidents database. As a sensitivity test, the correlation analysis was repeated using daily collisions (also shown in Table 1).

TABLE 1 Correlations between Traffic Delay Data and Incident Data
FSP Beat #1: State Route 24; Fiscal Year 2012-13

Variable Sets	Incident Correlation Coefficient	Collision Correlation Coefficient
INRIX Delays ←→ CHP Incidents	0.4018	0.2503
PeMS Delays ←→ CHP Incidents	0.3454	0.2180

Using the SR-24 dataset, the INRIX correlations were slightly stronger than the PeMS correlations. This finding held for incidents and collisions. The average functional detector spacing was about 1.7 miles per detector station along the SR-24 corridor.

Table 2 shows the correlation coefficients between daily freeway traffic delays and daily freeway incidents for FSP Beat #12– an 8.4 mile stretch of I-80 in the East Bay. The average functional detector spacing was about 0.5 miles for the FSP Beat #12 corridor.

TABLE 2 Correlations between Traffic Delay Data and Incident Data
FSP Beat #12: Interstate 80; Fiscal Year 2012-13

Variable Sets	Incident Correlation Coefficient	Collision Correlation Coefficient
INRIX Delays ←→ CHP Incidents	0.3649	0.3101
PeMS Delays ←→ CHP Incidents	0.3573	0.3220

The PeMS (stationary detector) data correlates about as closely to the CHP incident data as did the INRIX (probe vehicle) data along the FSP Beat #12 corridor with its closely spaced PeMS detector stations.

Previous work has cited that the reliability of PeMS reported traffic data is dependent upon, among other factors, corridor's detector station spacing. For example, in an "Evaluation of PeMS to Improve the Congestion Monitoring Program" report, researchers found "*Accuracy in PeMS-based congestion estimates requires a detector spacing of less than 0.5 miles.*" (6) Another UC Berkeley study concluded "*Spacing loop detectors less than an average of 0.83 miles apart (i.e., using data from more than eight inductive loop detector stations along the stretch of roadway under study) did not provide extra benefit in the travel time estimation. The error remains constant between 6–13% depending on the time of day, regardless of the added loop detector stations.*" (7)

The reliability of the results from regression analysis, like that in the components of congestion techniques, depends heavily on the reliability on the dataset used to feed the regression analysis. As such, components of congestion analysis have typically been employed on corridors with relatively closely spaced detector stations. However, FSP service is provided on several freeway corridors with sparse or no PeMS coverage. So a validation method and data sources were sought that could be applied to FSP beats regardless of the level of PeMS coverage throughout the corridors where FSP service is provided.

Previous work has shown that PeMS detector station spacing has a direct impact on the accuracy of reported travel times and delays. What was not shown was whether PeMS detector station spacing affects the accuracy of some performance measures more than others. For example, widely spaced loops might do a better job of reliably reporting VMT than delays or vice versa.

Sensitivity testing was done on corridors with a high density of functional PeMS detector stations to gain insights into how the PeMS spacing affected key performance measures for FSP monitoring and FSPE model validation. Figure 3 shows the correlation coefficients for PeMS reported traffic volumes as a function of distance between detector stations along a corridor. It is a measure of how well traffic volumes can be approximated from measured volumes as distance from the point of measurement increases. Figure 3 also shows the same for approximating traffic delays from upstream measured delays.

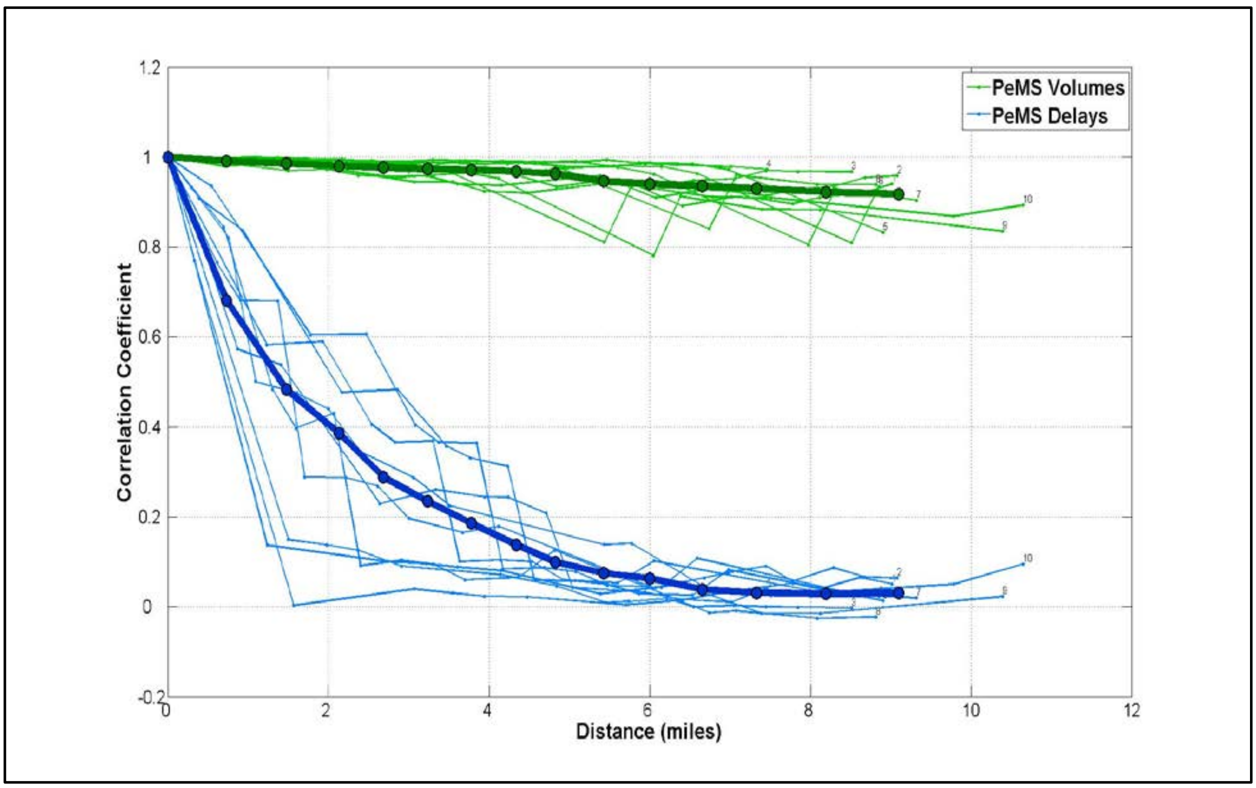

FIGURE 3 Correlations for Traffic Delays at PeMS Stations, I-15 NB San Diego CA

As PeMS detector spacing increases, the ability to approximate traffic volumes deteriorates slowly as compared to the ability to approximate traffic delays. This implied that for corridors with widely spaced PeMS Stations, INRIX delay data might provide better delay estimates than PeMS. This is consistent with findings presented previously in Table 1 and Table 2.

5. STUDY FINDINGS – FSP EVALUATION MODEL VALIDATION RESULTS

Linear regression techniques were used to estimate the expected (average) traffic delays attributable to freeway collisions. For this FSPE model validation effort, one year's worth of CHP, PeMS and INRIX data were compiled – July 1, 2012 through June 30, 2013 for FSP beats (corridors) listed in Table 3.

TABLE 3 Beats Selected for FSPE Model Validation

FSP Beat	County	Freeway	Beat Limits	One-way Beat Length (miles)	Weekday FSP Trucks
1	ALA	24	I-580 to Contra Costa County Line	4.39	2
	CC		Contra Costa Co. Line to Oak Hill Road	6.25	
	ALA	980	Interstate 580 to Interstate 880	2.03	
		880	7th Street to Jackson Street	2.04	
12	CC	80	San Pablo Dam Rd to Cummings Skyway	8.39	2
16	SCL	17	Junction SR-9 to Summit Road	7.07	1
18	SCL	880	Junction SR-237 to Alameda County Line	2.08	2
	ALA		SCL County Line to Mowry Avenue	7.18	
22	ALA	580	Santa Rita to Grant Line Road	16.48	3
29	SOL	80	Magazine Street to Abernathy Road	14.04	2
34	SOL	80	Abernathy Road to Vaca Valley Road	12.54	2
37	SOL	80	Junction I-505 to Richards Boulevard	16.40	2

On weekdays in the Bay Area, FSP provides service from 6:00 to 10:00 am and from 3:00 to 7:00pm. Although some beats operate from 5:30 am to 9:30am in the mornings, and Friday afternoon shifts might vary on some beats. Sunday (weekend) FSP service is generally provided with one truck operating from 12:30 pm to 7:00 pm.

Since both the PeMS and INRIX data sources provided traffic delay measures, PeMS from stationary source (loop) detectors and INRIX from probe vehicles, three different measures of vehicular delays were used in the regression analysis to gain insights on how the chosen delay data source affected the regression model goodness of fit and parameter estimates:

1. PeMS traffic delays: from stationary detectors, e.g., loops
2. INRIX traffic delays: from a relatively large sample of probe vehicles
3. Composite of INRIX (per-vehicle) delays & PeMS traffic volumes

Table 4 displays the FSP Evaluation model validation results.

TABLE 4 FSP Beat Evaluation Model Validation Results

Bay Area FSP Beat	FSPE Delay Savings (per min.)	Source of Traffic Delay Estimate	Regression Model Traffic Delay (per min.)	Regression Model Std Err of Delay	Regression Model Lower 95% Delay	Regression Model Upper 95% Delay	Regression Model F-Statistic
Beat #1 Weekday	11.44	PeMS	8.11	1.79	4.61	11.61	20.65
		INRIX	10.68	1.84	7.08	14.27	33.81
		PeMS+INRIX	12.77	2.00	8.86	16.68	40.96
Beat #1 Weekend	0.78	PeMS	-1.73	1.27	-4.22	0.77	1.84
		INRIX	-1.33	1.44	-4.15	1.48	0.86
		PeMS+INRIX	-0.48	1.68	-3.78	2.82	0.08
Beat #12 Weekday	5.26	PeMS	4.22	0.83	2.59	5.84	25.76
		INRIX	6.67	1.17	4.39	8.96	33.34
		PeMS+INRIX	6.56	1.08	4.44	8.67	36.83
Beat #12 Weekend	0.91	PeMS	0.20	0.46	-0.70	1.10	0.19
		INRIX	0.60	0.19	0.23	0.98	10.08
		PeMS+INRIX	0.91	0.33	0.26	1.55	7.66
Beat #16 Weekday	3.49	PeMS	n/a	n/a	n/a	n/a	n/a
		INRIX	2.09	0.72	0.68	3.50	45.70
		PeMS+INRIX	n/a	n/a	n/a	n/a	n/a
Beat #16 Weekend	0.75	PeMS	n/a	n/a	n/a	n/a	n/a
		INRIX	0.60	1.38	-2.11	3.31	0.19
		PeMS+INRIX	n/a	n/a	n/a	n/a	n/a
Beat #18 Weekday	7.37	PeMS	3.66	0.83	2.04	5.27	19.63
		INRIX	5.49	1.06	3.42	7.56	26.97
		PeMS+INRIX	5.13	1.01	3.15	7.11	25.79
Beat #22 Weekday	6.43	PeMS	7.61	1.15	5.36	9.86	43.87
		INRIX	17.53	2.16	13.29	21.76	65.77
		PeMS+INRIX	17.47	1.97	13.61	21.33	78.72
Beat #22 Weekend	0.45	PeMS	6.42	1.17	4.14	8.71	30.36
		INRIX	6.50	1.87	2.83	10.17	12.22
		PeMS+INRIX	8.40	1.79	4.88	11.92	21.92
Beat #29 Weekday	5.24	PeMS	1.22	0.71	-0.17	2.62	2.97
		INRIX	4.61	0.82	3.00	6.22	31.32
		PeMS+INRIX	2.00	0.43	1.16	2.85	21.52
Beat #29 Weekend	0.67	PeMS	2.01	0.98	0.09	3.93	4.19
		INRIX	1.95	0.94	0.11	3.78	4.30
		PeMS+INRIX	2.14	1.05	0.08	4.21	4.14

TABLE 4 FSP Beat Evaluation Model Validation Results (continued)

Bay Area FSP Beat	FSPE Delay Savings (per min.)	Source of Traffic Delay Estimate	Regression Model Traffic Delay (per min.)	Regression Model Std Err of Delay	Regression Model Lower 95% Delay	Regression Model Upper 95% Delay	Regression Model F-Statistic
Beat #34 Weekday	5.58	PeMS	2.87	0.53	1.83	3.90	29.29
		INRIX	12.92	2.04	8.93	16.92	40.23
		PeMS+INRIX	1.03	0.72	-0.38	2.44	2.04
Beat #34 Weekend	0.62	PeMS	-0.42	0.67	-1.74	0.90	0.39
		INRIX	1.08	0.94	-0.77	2.94	1.32
		PeMS+INRIX	0.17	0.21	-0.24	0.57	0.66
Beat #37 Weekday	5.77	PeMS	1.16	0.42	0.33	1.98	7.60
		INRIX	9.32	1.46	6.46	12.18	40.74
		PeMS+INRIX	6.73	1.14	4.49	8.97	34.65
Beat #37 Weekend	0.69	PeMS	0.89	0.74	-0.55	2.33	1.46
		INRIX	1.61	1.32	-0.98	4.21	1.49
		PeMS+INRIX	2.25	1.45	-0.60	5.09	2.40

The findings in Table 4 are consistent with the findings presented in Tables 1 and 2. For Beat #1, the model using "INRIX (per-vehicle) Delays & PeMS Traffic Volumes" performed best. For Beat #12, the model using "PeMS Traffic Delays" performed best. Beat #12 on I-80 has an average PeMS detector spacing of 0.5 miles/station whereas Beat #1 on SR-24 has an average of 1.7 miles between PeMS detector stations. These findings are consistent with the postulate that higher density of detector stations provides higher reliability in estimated performance measures.

The root mean squared error term was calculated from the empirical and FSPE model estimated delay values, and the average regression model F-Statistic was calculated for the FSPE model validation dataset (see Table 5). Overall, the INRIX delay data provided models with better model fit statistics than those created using the PeMS delay data and better those created using the composite PeMS volume and INRIX delays.

TABLE 5 Overall Regression Model Goodness of Fit Statistics

Average FSPE Model Delay Savings (per min.)	Source of Traffic Delay Estimate	Average Regression Model Delays (per min.)	Average Regression Model F-Statistic	FSPE Vs. Regression Model RSME
3.40	PeMS	2.79	14.48	2.72
	INRIX	5.35	23.22	4.42
	PeMS+INRIX	5.01	21.34	4.48

The overall average error term (RSME) was lowest for the PeMS delay based regression models.

Figure 4 shows a scatter plot comparing the FSPE model estimated delay savings against the empirically estimated traffic delays.

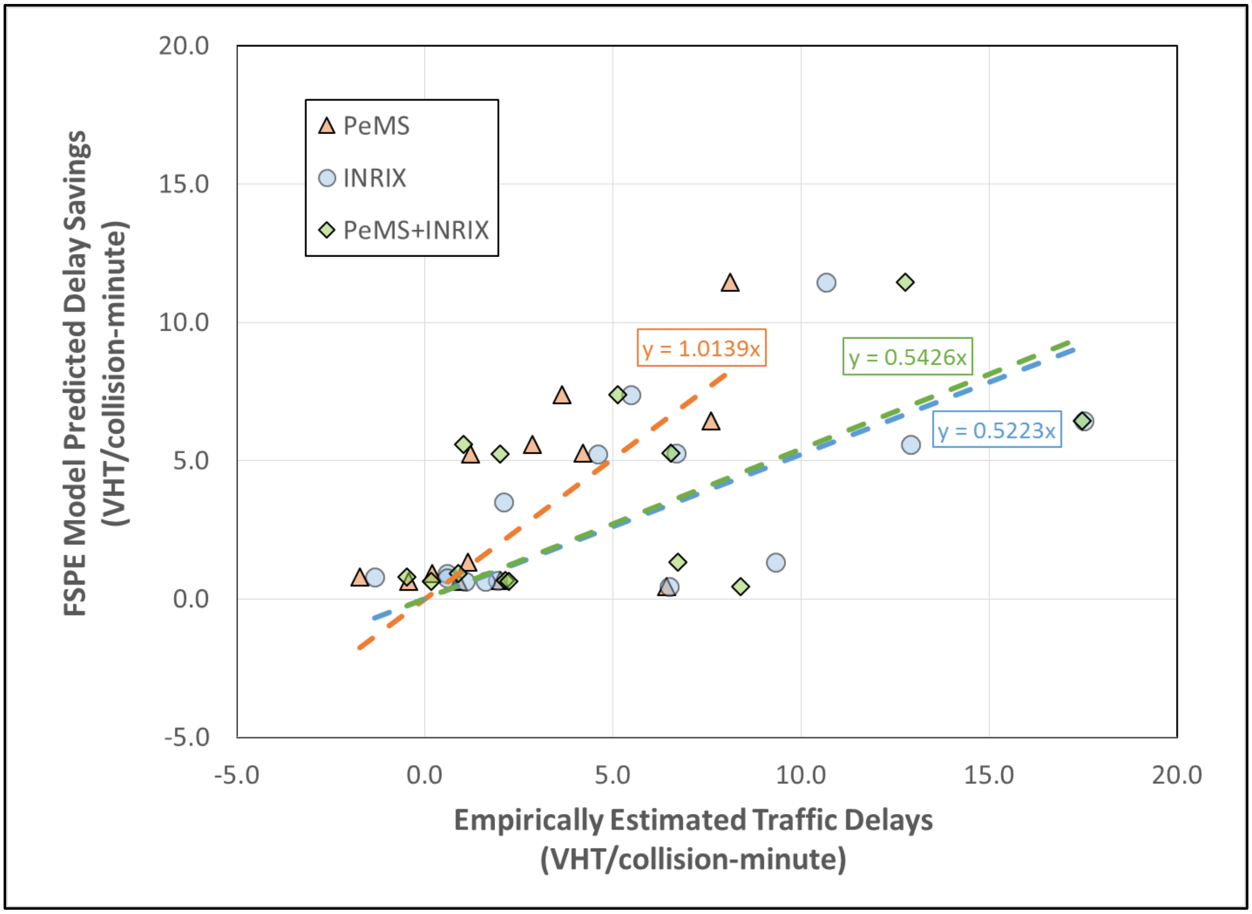

FIGURE 4 Empirically Estimated Traffic Delays Vs. FPSE Model Predicted Delay Savings

From the trend lines shown in Figure 4, the FSPE model predicts delay savings that are a very close match to the empirically estimated traffic delays using PeMS delay data. However, the FSPE model fairly significantly underestimates delay savings when compared to the traffic delays estimated using INRIX delay data. It is not clear which delay estimation (PeMS or INRIX) is more reliable without further probing into the PeMS and INRIX data collection and delay estimation procedures, and taking into account measurement and sampling errors associated with PeMS detector spacing and INRIX probe vehicle sample size.

6. CONCLUSIONS

Overall, the FSP beat evaluation model replicated delay savings estimates that were in the range of the empirically estimated traffic delays. However, there is some evidence that the delay savings component of the FSPE model might be underestimating overall delay-savings.

There are set of plausible factors that might be contributing to the FSPE model's underestimate of delay savings. For example, if the FSPE model's default capacities are higher than real world freeway capacities, or if the deterministic queueing methods used in the FSPE model tend to underestimate delays on congested freeway corridors by failing to capture the nonlinear nature of queueing, delays and delay savings.

It should be noted that for this model validation effort, the FSPE model's default capacity and other model parameters were used without calibration or adjustments. No fine tuning was done to the FSPE model's parameters or inputs to improve how well the FSPE model's delay savings compared to the empirically estimated delay estimates. Using the default capacity, like was done for this validation effort, might under estimate congestion for highly constrained merge, diverge or weaving sections. Likewise using the default capacity might result in underestimated FSP delay savings for freeway segments with hills, tight curves, narrow lanes, and other geometric conditions that impact the carrying capacity of freeways. Model users do not take adequate care in assuring the traffic volumes and other inputs are reasonable and in select capacity estimates that are representative of freeway geometry and traffic conditions.

The key to using any model, the FSP beat evaluation model included, is to understand the model's strengths and limitations, take care in preparing the model inputs, and perform reality checks on the model's outputs to assure consistency with observed real world traffic behavior.

Next Steps

These research efforts validated one of the components of the FSP Beat Evaluation (FSPE) model – the FSPE model's deterministic queueing techniques that estimate delay savings. Next steps with respect to FSPE model improvement include exploring whether using stochastic queueing methods instead of deterministic queueing methods would help to improve the FSPE model's ability to replicate real world traffic delays and FSP delay savings.

The research support efforts for the FSP program generally focus on providing information to enable performance based decision making. With this, two plausible and useful work efforts might be to:

- The INRIX Analytics datasets could be used to provide calibration targets for the FSPE model, or perhaps a method could be developed to directly incorporate the INRIX estimated delays into the FSP beat performance evaluation process. This would be especially helpful for freeway corridors (i.e., FSP beats) with limited or no PeMS coverage.
- Compile annual estimates for VMT, VHT and freeway incident for the complete set of California's FSP beats. Compare the level of FSP service provided on each Beat against the Beat's empirical VMT, VHT and incident totals as a performance measure to gauge "How closely does the allocation of FSP resources match demand for freeway incident management services?".
- Perform a "before and after" study on a freeway corridor, directly measuring and taking a detailed look at the overall and incident induced traffic delays along a freeway corridor with FSP service on the corridor and without FSP service on the corridor.

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