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MEMORANDUM

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Project #: 19632

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Project: Goleta Ramp Metering Study

Subject: Study Methodology

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This memorandum defines the study area and summarizes the analysis methodology and performance measures for the technical analysis associated with the Goleta Ramp Metering Study (referred to as "study"). Early agreement on the measures and methodology described in this memorandum will allow it to serve as a blueprint for the operational analysis and evaluation and avoid delays or the need for "do-overs."

The subsequent sections in this memorandum describe the following:

- Study Locations
- Data Collection
- Performance Measures
- Operational Analysis Methodology

Kittelson & Associates (KAI) is requesting review and comment on the proposed study locations, measures and methodologies.

STUDY LOCATIONS

The project area and recommended local study locations are illustrated in Figure 1. Generally, the project area includes the US 101 freeway from the Cathedral Oaks Road interchange to the Turnpike Road interchange, and SR 217 from the Sandpit Road interchange to the US 101 junction. The local study intersections and roadway segments were selected based on availability of traffic data and likelihood of potential diversion impacts due to ramp metering projects along the US 101 mainline.

Figure 1. Project Area and Recommended Local Study Locations

DATA COLLECTION

The existing traffic data will be used to establish the baseline performance. The data collection plan is comprised of the following:

1. **Freeway mainline volumes and speed:** A specialty data collection firm (Quality Counts) will install radar-based non-intrusive devices (Wavetronix) to capture vehicular volumes and speeds on the US 101 and SR 217 mainline. The Wavetronix units will be deployed for one week at the following three locations:
   a. US 101 at Cathedral Oaks Road
   b. US 101 at Turnpike Road
   c. SR 217 at Sandpit Road
2. **Ramp volumes:** The data collection firm (Quality Counts) will collect traffic volumes at the on and off-ramps in the project area. The counts will be conducted for the mid-weekdays (i.e. Tuesdays, Wednesday and Thursday) using the mechanical tubes.
3. **Mainline travel time:** A specialty data collection firm (Metro Traffic Data) will run GPS equipped floating cars to collect speed and travel time data on the US 101 and SR 217 mainlines. The travel time surveys will be conducted for three midweek days (Tuesday, Wednesday or Thursday) during the AM (7-9) and PM (3-6) peak periods.
4. **Vehicle occupancy counts:** A specialty data collection firm (Metro Traffic Data) will conduct manual vehicle occupancy counts on the eastbound SR 217 freeway upstream of the US 101 junction. The occupancy counts will be used to determine the proportions of High Occupancy Vehicles (HOV) and transit vehicles in the traffic stream. The surveys will be conducted for two midweek days during the AM (7-9) and PM (3-6) peak periods. The occupancy surveys will capture various vehicle classifications as well as the numbers of passengers within the autos (1, 2 or 3-plus persons).
5. **Local intersection and roadway traffic counts:** KAI conducted intersection and roadway segment counts for over 100 locations (including US 101 and SR 217 ramp intersections) in 2013 and 2014 throughout the City of Goleta as part of the Goleta Model Update process. KAI will leverage these counts to evaluate the potential for diversion-related impacts.

PERFORMANCE MEASURES

This section outlines the various performance measures to be used for the study.

Operational Performance

The operational performance measures provide the basis for objectively evaluating ramp metering strategies and for identifying potential impacts (Table 1).

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Table 1: Operational Performance Measures

Measurement Area	Operational Performance Measures		Usage	Tools/Methods
	Primary	Secondary		
REGIONAL FACILITIES				
Freeway Mainline	Travel Time (minutes)	Average speed (mph) Queue lengths (feet) Duration of congestion (hour) Estimated emissions (grams/vehicle-mile)	Operational benefits or dis-benefits at facility level	FREQ12
Freeway On-Ramps	Vehicular queues relative to available storage	Delays (minutes)		FREQ12
Freeway Ramp Merge-Diverge	Level of Service	Vehicle density (vphpl)		Highway Capacity Manual 2010
Transit	Person delays (person-hours) at meter locations	Total transit route travel times (minutes)	Operational benefits or dis-benefits for transit vehicles Benefit/cost analysis for HOV bypass	FREQ12, SBCAG regional travel demand model for vehicle occupancies
LOCAL FACILITIES				
Local Roadways	Changes in peak hour traffic volumes (vph)	Daily traffic volumes relative to Goleta ADT thresholds	Diversion analysis	Goleta travel model
Local Intersections	Peak Hour Level of Service	Critical Movement Volume to Capacity Ratio		Intersection Capacity Utilization (ICU) using Traffix 8.0
SYSTEM-WIDE				
Project Area	Total peak hour person-hours of travel time (including transit passengers)	Aggregate peak hour person-hours of travel time at facility level	Benefit/cost analysis	FREQ12 for freeway and ramps; SBCAG regional travel model for vehicle occupancies; Goleta travel model for local facilities

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The performance measures were classified in two categories: primary and secondary. The primary measures will be used as the key measures to delineate differences between the performance of the baseline (no metering) and ramp metering options. The secondary measures will be used to supplement the primary measures, but are intended to be used primarily if the primary measure is non-conclusive for defining the benefits or dis-benefits of a particular strategy.

The performance measures will be reported using the tables and/or other visuals (maps, charts, or graphs) that are easy to follow. These results will be summarized side-by-side when plausible to enable a comparison between with and without ramp metering, and between different ramp metering options.

Safety Performance

Travel safety is often measured through statistically documenting differences in the number of collisions between a "before" and "after" condition. The safety assessment will include a quantitative summary of existing conditions based on the collision statistics along US 101 and SR 217 for the past three years. The evaluation of ramp metering options will be a qualitative assessment based on the demonstrated changes (empirically based) in collisions due to similar ramp metering implementation in California and across the nation. The Federal Highway Administration[1] reported reductions in crashes ranging from 15% to 50%, as result of the ramp metering implementation.

OPERATIONAL ANALYSIS METHODOLOGIES

This section outlines the technical analysis methodologies to be used for the study. These methodologies will be applied to the existing and forecast traffic volumes to develop operational performance measures. The Goleta Travel Model will be used to forecast future traffic volumes.

Freeway Corridor

For many years, the Institute for Transportation Studies at the University of California at Berkeley with support and cooperation of Caltrans has developed, updated and applied a series of freeway simulation models, FREQ for the evaluation of various designs and operational improvements. The most current version, FREQ12 includes two models:

- FREQ12PE, an entry control model for analyzing ramp metering
- FREQ12PL, an on-freeway priority model for analyzing HOV facilities.

The FREQ12 system of models enables the user to enter data, simulate the existing operation of the freeway in order to check the input data, and calibrate the model before the addition of ramp

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[1] Ramp Management and Control Handbook, January 2006

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metering or an HOV facility. After FREQ12 is calibrated, the FREQ12PE model can be used to analyze more advanced scenarios, such as normal or HOV priority entry control options.

The study will employ the FREQ12PE model to measure the effectiveness of ramp metering options and estimate optimum metering rates at the on-ramp locations within the project area. The FREQ model also provides information on potential queues (frequency, length) at metered ramps based on the traffic simulation.

Freeway Merge-Diverge Areas

On freeways, the influence area of a merge (on-ramp) generally extends for 1,500 feet downstream of the ramp merge point. Similarly, the influence areas of diverge (off-ramp) movements extend for 1,500 upstream of the ramp diverge points. The mainline segments between merge and diverge influence areas are generally categorized as basic freeway. For US 101, the merge-diverge analysis methodologies published in the Highway Capacity Manual (HCM) 2010 will be applied. The HCM methods will be implemented using validated HCM-compatible spreadsheets for merge-diverge analysis. Table 2 presents the criteria used to determine the Level of Service (LOS) for the freeway merge-diverge facilities. All traffic volumes are adjusted to reflect passenger car equivalents based on the vehicle (including trucks and buses) classification data collected at/near each respective location.

Table 2: Freeway Merge-Diverge Level of Service Criteria

LOS	Density (pc/mi/ln)	Comment
A	≤ 10	Unrestricted operations
B	> 10-20	Merging and diverging maneuvers noticeable to drivers
C	> 20-28	Influence area speeds begin to decline
D	> 28-35	Influence area turbulence becomes intrusive
E	> 35	Turbulence felt by virtually all drivers
F	Demand exceeds Capacity	Ramp and freeway queues form
Source: *Highway Capacity Manual,* Transportation Research Board, Washington D.C, 2010		

Transit

The effects of various ramp metering strategies on transit service and passengers will be based on the traffic operations analysis combined with specific transit information.

Existing transit operations will be summarized in terms of numbers of transit vehicles accessing the SR 217 and US 101 highways, as well as current ridership statistics provided by the Santa Barbara Metropolitan Transit District. Future transit travel will be forecast based on the SBCAG regional travel model, applying growth forecasts from the model to the observed existing passenger data. The changes due to ramp metering scenarios will be based on two primary components:

- Specific delays at on-ramps used by transit vehicles
- Overall route run time based on ramp operations as well as freeway mainline flow

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The evaluation of potential HOV bypass lanes at ramp meter locations will also consider the number of transit vehicles and passengers predicted to use those ramps.

Local Roadway Segments

The City of Goleta's roadway classifications and level of service thresholds for segment analysis are provided in Table 3. These LOS thresholds provide a generalized estimate of operational performance and serve as a screen for existing and/or future year problem identification. Potential changes in traffic volumes will be evaluated for each scenario using the Goleta traffic model.

Table 3: Roadway Segment ADT Thresholds

Functional Street Classification	Purpose and Design Factors	ADT Design Capacity			LOS C ADT Threshold		
		2 Lanes	4 Lanes	4+ Lanes[1]	2 Lanes	4 Lanes	4+ Lanes[1]
Major Arterial (MA)	Continuous roadways that carry through traffic between various neighborhoods and communities, frequently providing access to major traffic generators such as shopping areas, employment centers, and higher density residential areas. Roadways would have a minimum of 12-foot wide lanes with shoulders. Signals are typically spaced at minimum 0.5-mile intervals.	17,900	42,480	58,750	14,300	34,000	47,000
Minor Arterial (MNA)	Roadways that serve as a secondary type of arterial facility carrying local and through traffic within communities, frequently connecting neighborhood areas within the City, providing access to shopping areas, employment centers, and higher density residential areas. Roadways would have minimum 12-foot wide lanes with shoulders. Signal intervals typically range from 0.25 to 0.5 mile.	15,700	37,680	NA	12,500	30,100	NA
Collector Streets (Col)	Roadways designated to collect traffic from local streets to connect to major or minor arterials. Collector Streets provide access to local streets within residential and commercial areas and connect streets of higher classifications to permit adequate traffic circulation. Generally no more than 2 travel lanes and signalized at intersections with arterial roadways.	11,600	NA	NA	9,280	NA	NA
Local Streets (L)	Roadways designed to provide access to individual properties carrying traffic to and from a collector street. Intended to serve adjacent uses and are not intended for through traffic. Designed with two lanes and close to moderately close driveways.	9,100	NA	NA	7,280	NA	NA

Source: City of Goleta, 2006
1 4+ Lanes includes 5 or 6 lane roadways

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Local Intersections

Signalized intersection Level of Service (LOS) calculations will be performed based on the Intersection Capacity Utilization (ICU) method[2]. The unsignalized intersection LOS analysis will be performed based on the Highway Capacity Manual (HCM) 2010 methodology. Both HCM and ICU LOS calculations will be conducted using TRAFFIX software developed by Dowling Associates, Inc. (now, Kittelson & Associates, Inc.). Table 4 shows the LOS criteria for intersections.

Table 4: Intersection Level of Service Criteria

LOS	Intersection Type		Description
	Signalized (volume to capacity ratio)	Unsignalized Average Delay (sec/veh)	
A	0.000 – 0.600	≤ 10.0	Very Low Delay: This occurs when progression is extremely favorable and most vehicles arrive during a green phase. Most vehicles do not stop at all.
B	0.601 – 0.700	>10.0 & ≤15.0	Minimal Delays: This generally occurs with good progression, short cycle lengths, or both. More vehicles stop than at LOS A, causing higher levels of average delay.
C	0.701 – 0.800	>15.0 & ≤25.0	Acceptable Delay: Delay increases due to only fair progression, longer cycle lengths, or both. Individual cycle failures (*to service all waiting vehicles*) may begin to appear at this level of service. The number of vehicles stopping is significant, though many still pass through the intersection without stopping.
D	0.801 – 0.900	>25.0 & ≤35.0	Approaching Unstable/Tolerable Delays: The influence of congestion becomes more noticeable. Longer delays may result from some combination of unfavorable progression, long cycle lengths, or high v/c ratios. Many vehicles stop, and the proportion of vehicles not stopping declines. Individual cycle failures are noticeable.
E	0.901 – 1.000	>35.0 & ≤50.0	Unstable Operation/Significant Delays: These high delay values generally indicate poor progression, long cycle lengths, and high v/c ratios. Individual cycle failures are frequent occurrences.
F	>1.000	>50.0	Excessive Delays: This level, considered to be unacceptable to most drivers, often occurs with oversaturation (i.e., when arrival flow rates exceed the capacity of the intersection). It may also occur at high v/c ratios below 1.00 with many individual cycle failures. Poor progression and long cycle lengths may also be major contributing causes to such delay levels.

Source: SBCAG and *Highway Capacity Manual*, Transportation Research Board, Washington DC, 2010

The ICU method calculates an intersection's LOS by taking the sum of intersection critical movements (movements that compete for the same space within the intersection) and dividing that value by the intersection's saturation flow rate (capacity). The saturation flow rate assumed for all City intersections is 1,600 vehicles per lane per hour. Each critical movement's volume to capacity ratio is then summed and a 10 percent lost time adjustment is added to yield a peak hour volume to capacity (V/C) ratio that is the basis for determining the intersection's LOS.

The City of Goleta endeavors to maintain a target LOS C at the city intersections.

[2] The ICU method was adopted as the Countywide methodology for signalized intersections by SBCAG in 2002

Potential changes in peak hour traffic volumes at the selected study intersections (Figure 1) will be evaluated for each scenario using the Goleta traffic model. The changes in traffic volumes identified by the traffic model will be converted to peak hour turn movements at each study intersection and used to determine LOS for each scenario.

System-wide Person Hours

The proposed system-wide measure which can be used to directly compare the operations of freeways, ramps and local streets is system-wide peak hour person-hours (as opposed to vehicle-hours) of travel for each scenario. Transit vehicles and passengers will be explicitly included in the aggregate calculations. The components of the person-hours will be calculated as follows:

Freeways and Ramps

Person-hours will be calculated based on vehicle-hours reported by the FREQ simulation, multiplied by vehicle occupancies based on the data collection and future changes predicted by the SBCAG regional model.

Local Streets

Person-hours will be estimated as the sum of vehicle hours (number of vehicles times congested segment travel time) on each street segment within the study area based on the Goleta traffic model, multiplied by the average vehicle occupancies. If necessary, a post-processor will be applied to the Goleta model output to provide congested travel times that are more consistent with the speed-volume relationships in the Highway Capacity Manual.

Reporting

The aggregate person-hours will be reported for each scenario, as well as tables and graphs showing the components of person-hours (freeway, ramp, and local streets) to visually illustrate the tradeoffs involved in different ramp metering strategies.

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