



US Department  
of Transportation

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# **Intelligent Transportation Systems**

## **Impact Assessment: Results**

Version A.4

**DRAFT**

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## **Executive Summary**

### ***Introduction***

The Volpe Center has developed an integrated Framework of traffic models to simulate a number of Intelligent Transportation System (ITS) services, specifically the user services related to Advanced Traffic Management Systems (ATMS). The Framework includes a regional planning model and traffic simulation models for freeway and signalized arterial streets, as well as modules to estimate the measures of effectiveness described below.

The Framework was applied to simulate ATMS user services on a 37 mile north-south corridor, comprising a freeway (I-880) and a major parallel arterial, in Alameda County near San Francisco, CA.

The results indicate that operational performance of the corridor is boosted in terms of increased speed and reduced total delay due to services such as dynamic coordination of signals on arterial streets. Additional benefits are seen when ramp metering and arterial signal coordination are simultaneously implemented.

### ***Scenarios***

Impacts of these services upon the network corridor for operational performance, total emissions and safety were measured across a matrix of alternative ATMS scenarios. Performance of the corridor under each simulated scenario was compared to the conditions obtained for a baseline (existing network). The six scenarios considered during the analysis are listed below and include high occupancy vehicle (HOV) lanes as part of the simulation.

Scenario 1 - (PIFI T2) Fixed time signal coordination based on morning peak volume.

Scenario 2 - (PI FIT3) Demand-based signal coordination over a 3 hour morning period from 7:00am to 10:00am.

Scenario 3 - (P2FIF2T2) Fixed time metered freeway ramps, based on morning peak volume, combined with fixed time signal coordination on the parallel arterial.

Scenario 4 - (P2FIF3T2) Synchronized freeway ramp metering, optimizing free flow, combined with fixed time signal coordination on the parallel arterial.

Scenario 5 - (P2FIF3T3) Synchronized freeway ramp metering combined with demand-based signal coordination.

Scenario 6 - (P2FIF2T3) Fixed time metered freeway ramps, based on morning peak volume, combined with demand-based signal coordination.

### ***Measures of Effectiveness***

Operational MOEs, used to quantify network characteristics, are vehicle miles traveled, average vehicle speed (mph), traffic volume, vehicle hours of delay and fuel consumption (gallons). Emission MOEs are expressed in units of kilo-grams and predict carbon

monoxide (CO), hydrocarbons HC) and nitrogen oxide (NO<sub>x</sub>) pollutants. The last MOE category deals with safety issues and predicts personal injury levels, property damage only (PDO), and total accident predictions. All safety MOEs are expressed in units of incidents per million miles traveled.

## **Corridor Study Area Results**

### Operational Measures

The impact of each scenario upon vehicle miles traveled, average vehicle speed, traffic volume, vehicle hours of delay and fuel consumption are documented below.

#### 1880 Freeway (excluding ramps)

- Fixed ramp metering led to overall average freeway speed increases in the range of 2.4% to 3%. Speed increases were sensitive to density with rural areas increasing by 11% to 12%.
- A decrease of 38% is observed in total VHD with the implementation of ramp metering. The largest impact is seen in rural areas where VHD improved by 65%.
- Implementing dynamic signal coordination alone will cause VHD to increase on the freeway by 15.7%. Some form of freeway ramp metering, combined with a signal coordination strategy, appears to reduce VHD by over 37%.
- Fuel consumption experiences an increase of 1.2% to 3%, depending on the scenario. The largest fuel increase occurs using dynamic ramp and fixed signal coordination.

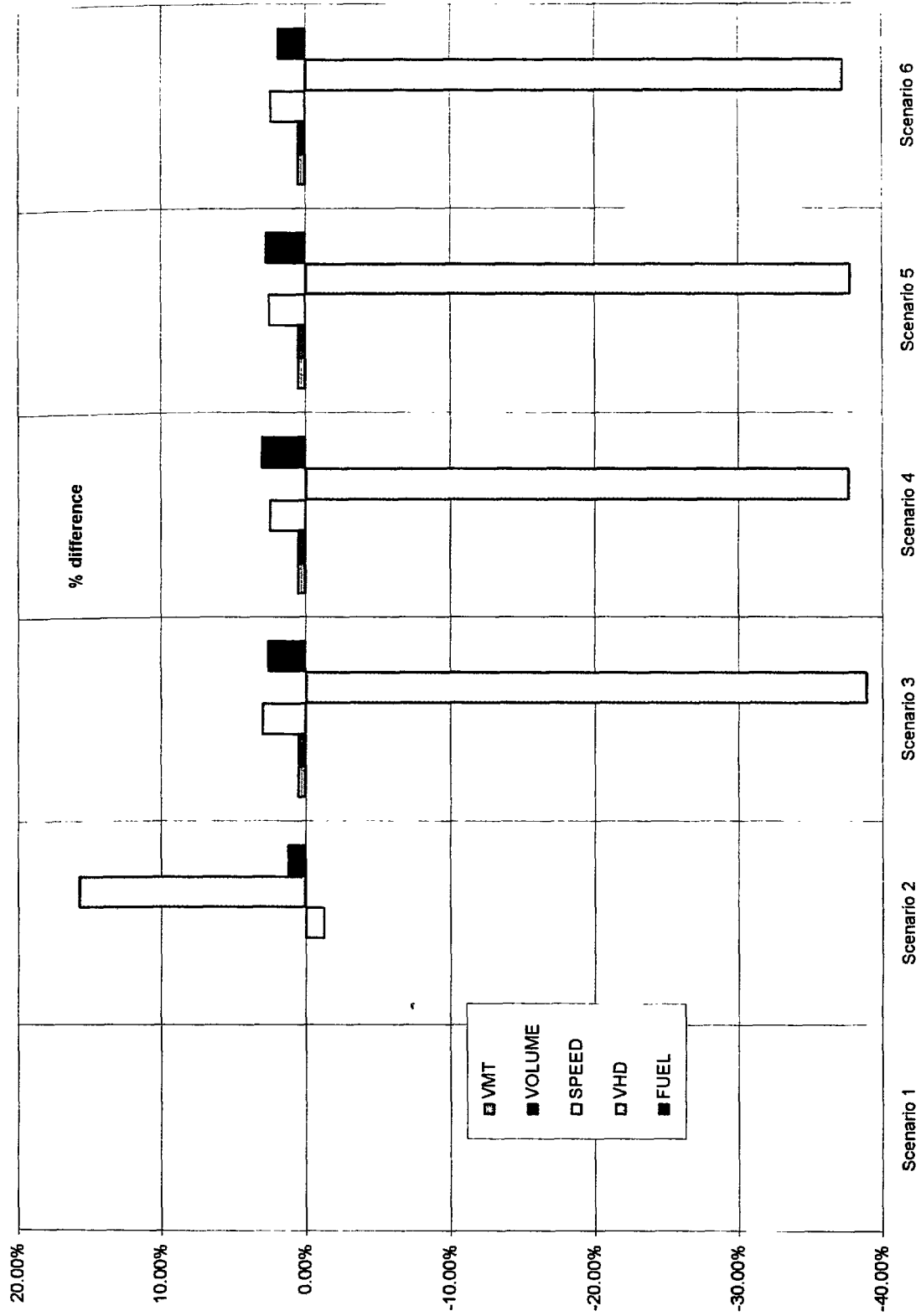
#### 1880 Freeway including

- Results are similar to the section above.

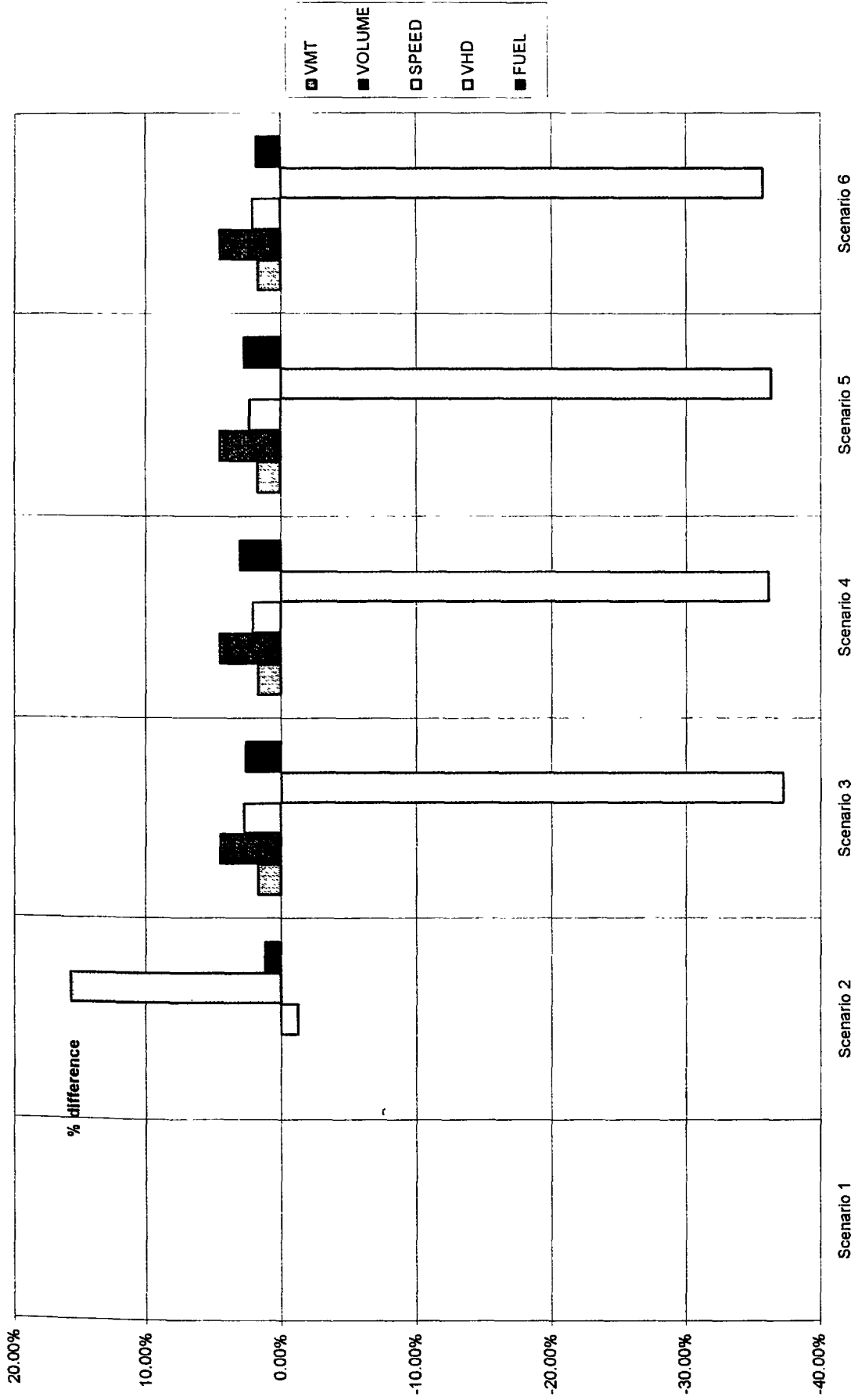
#### Parallel Arterials

- VMT and volume are generally unaffected on the parallel arterial when ramp metering is installed on the freeway. When dynamic signal coordination is introduced the business district VMT increases by 1.6% with a corresponding increase in total volume of 1.5%.
- Total average speeds improved by 2.6% to 4.4% when dynamic signal coordination is introduced on the parallel arterials. Speed improvements with fixed signal coordination are in the range of 0.5% to 1.2%.
- The greatest overall change in VHD occurs under dynamic signal conditions, with a reduction of between 18.6% to 24.6%.

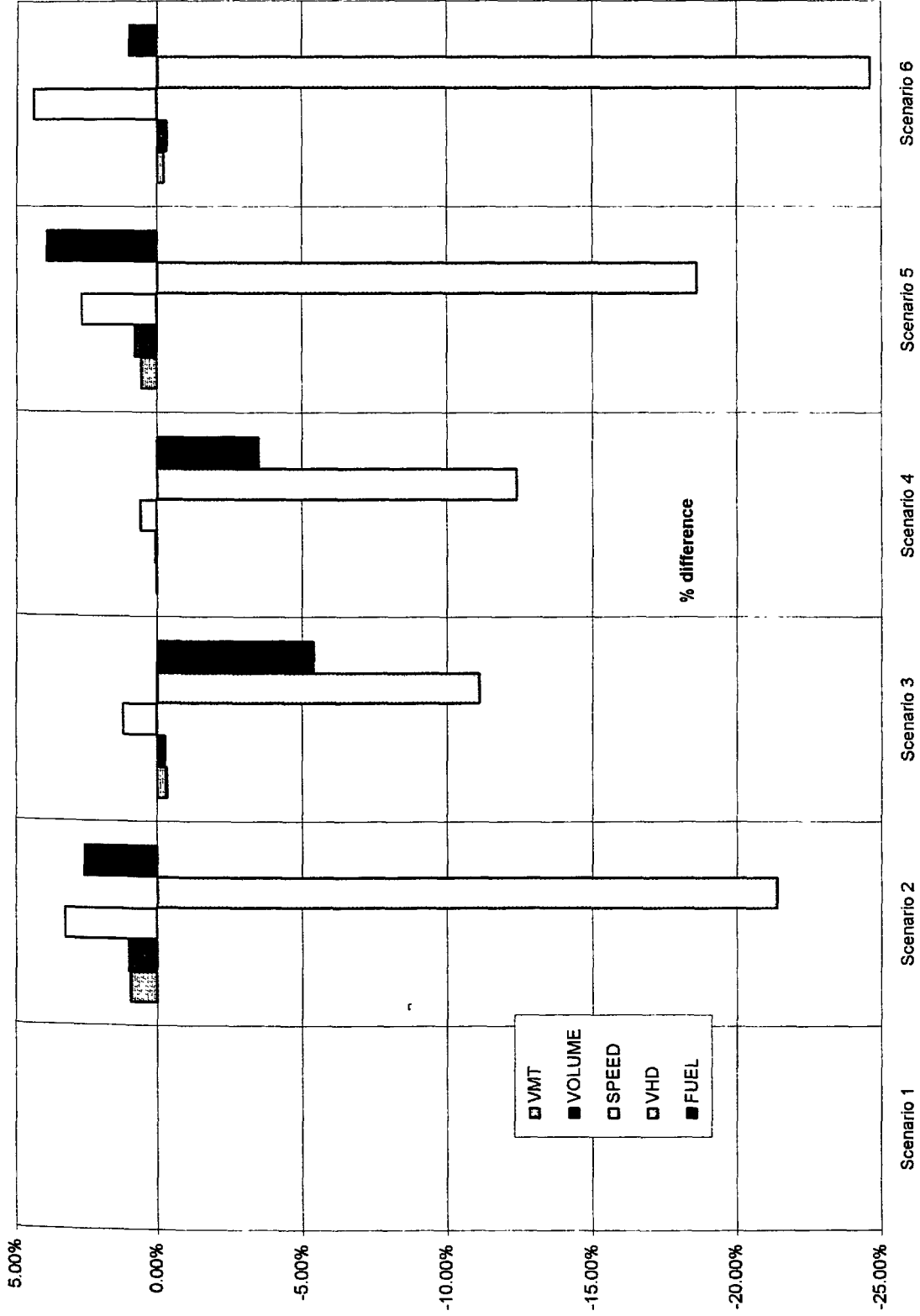
### FREEWAY OPERATIONAL MEASURES



FREEWAY w/ramps OPERATIONAL MEASURES



PARALLEL ARTERIAL OPERATIONAL MEASURES



## Emissions

Impacts in terms of the pollutants, carbon monoxide (CO), hydrocarbons (HC) and nitrogen oxide (NO<sub>x</sub>) are documented below.

### I880 Freeway (excluding ramps)

- CO and HC emissions decrease whenever ramp metering is available. Carbon monoxide emissions are reduced by 1% to 2%. Hydrocarbons are reduced by 1.6% to 2.7%.
- The rural area experiences the greatest improvement in emissions. Whenever ramp metering is available CO is reduced by 15% to 18.5% and HC is reduced by 17% to 20%.
- Nitrogen oxide emissions are increased by 7% to 10% under ramp metering conditions, probably due to slightly increased freeway speeds.

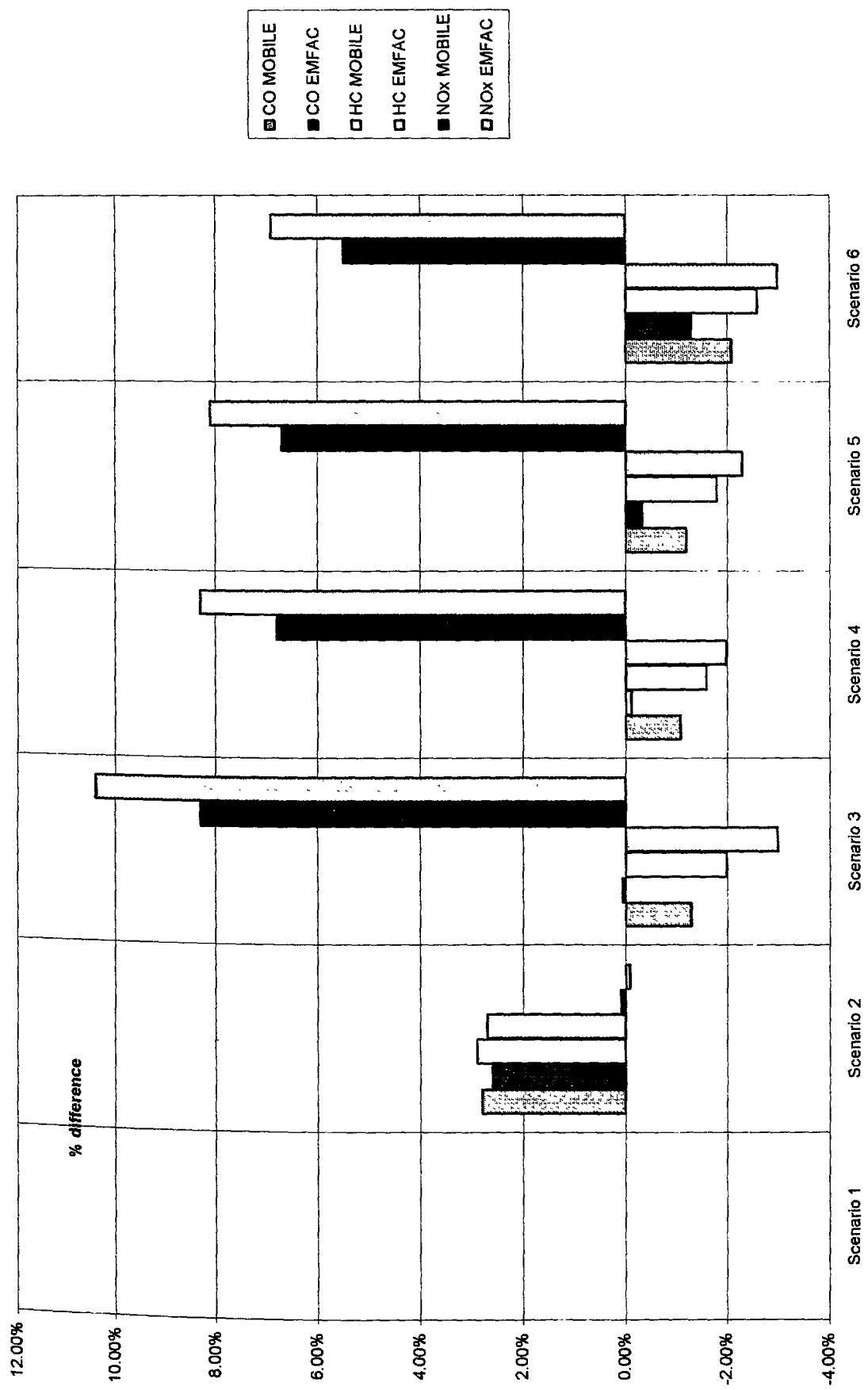
### I880 Freeway including ramps

- All results are similar to those stated above for the freeway (excluding ramps).

### Parallel Arterials

- CO, HC and NO<sub>x</sub> emissions all decrease when fixed signal coordination is installed with ramp metering. Rates of decline range from 3.6% to 13.8%.
- HC and NO<sub>x</sub> emissions appear to increase up to 4.5% using dynamic signal coordination with ramp metering.

### FREEWAY w/ramps EMISSIONS

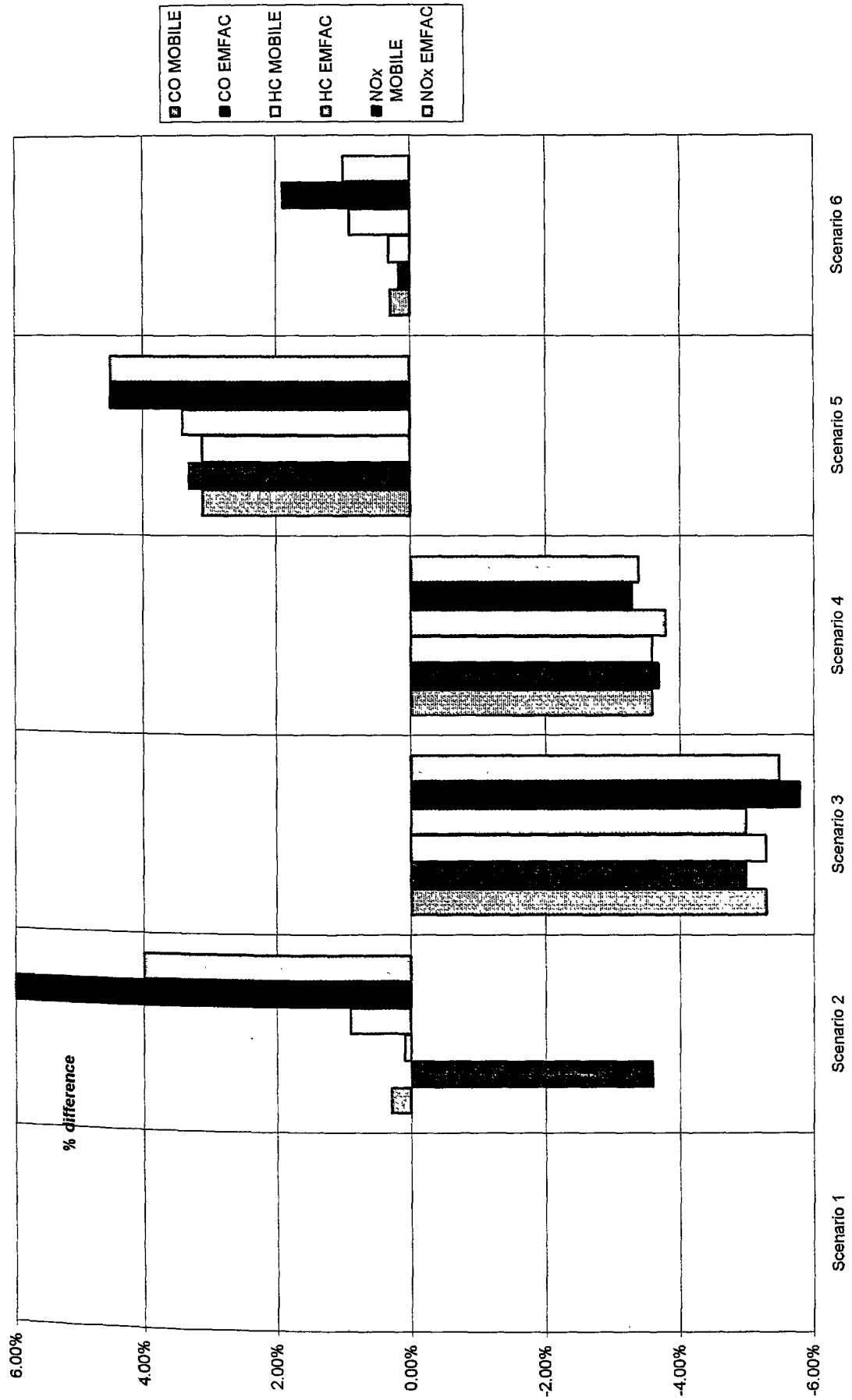




### FREEWAY EMISSIONS (wo/ramps)



### PARALLEL ARTERIAL EMISSIONS



### Safety

The MOEs relating to safety encompass personal injury, property damage only and total accidents. The impact of ATMS services upon the safety MOEs is discussed below.

#### 1880 Freeway (excluding ramps)

- The MOEs for personal injury and property damage (PDO) increase when ramp metering and signal coordination are used, due to increased speeds. No increase is observed with implementation of just dynamic signal coordination.
- Personal injury increased by 4.2% to 5.3% while PDO increased by 4.3% to 6%.
- The largest increase of 5.4% for total accident rate was observed utilizing fixed ramp fixed signal coordination. This scenario has the largest increase in average speeds.

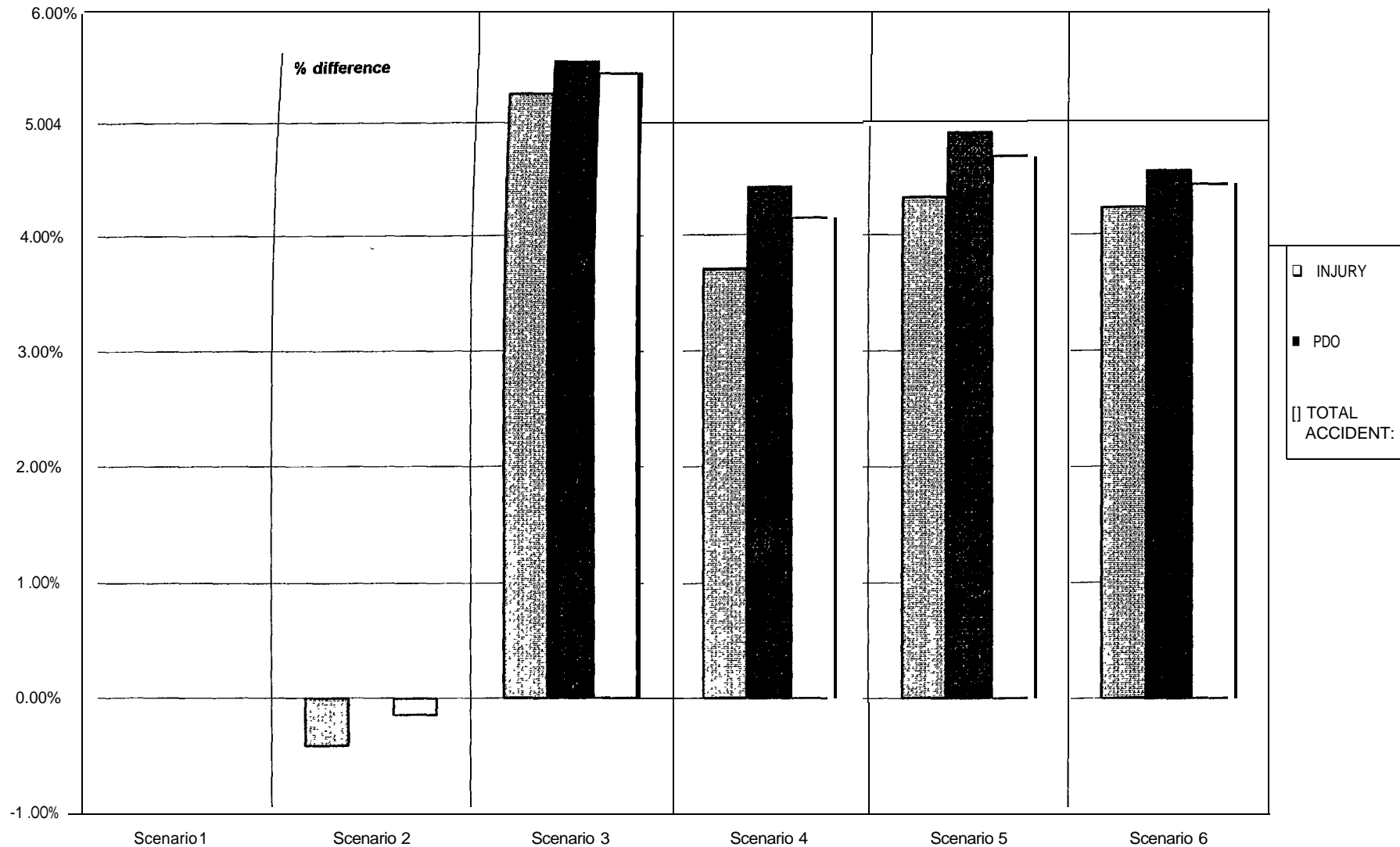
#### 1880 Freeway including ramps

- Results are similar to the section above.

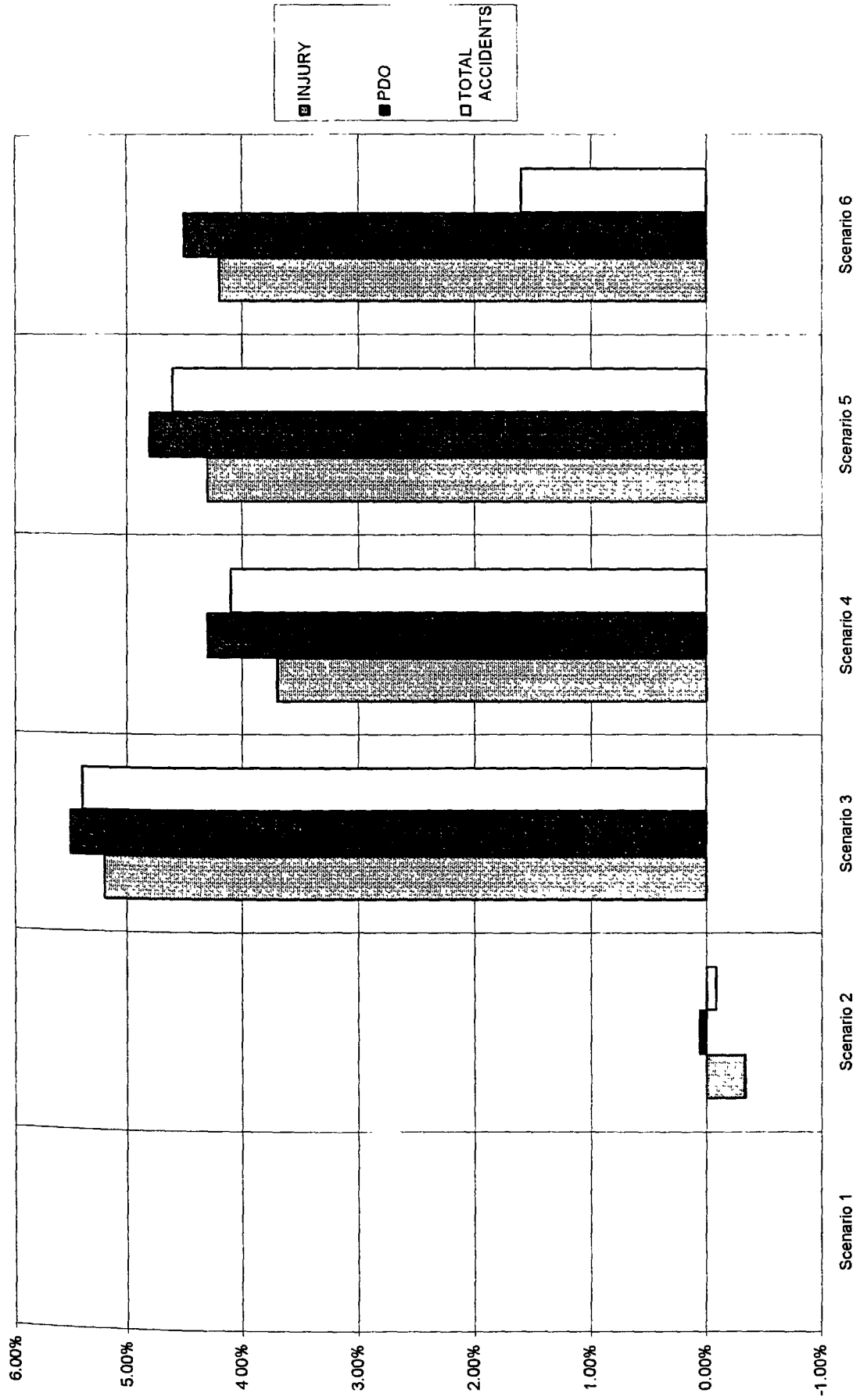
#### Parallel Arterials

- Personal injury, PDO and total accidents all decreased using a fixed signal coordination strategy. The improvements range between 3.6% to 5%, 1.7% to 4.9%, and 2.5% to 4.9%, respectively.
- Dynamic signal coordination, in isolation, produces the largest increase in personal injury, PDO and total accidents by 4.7%, 5.2% and 5% respectively.

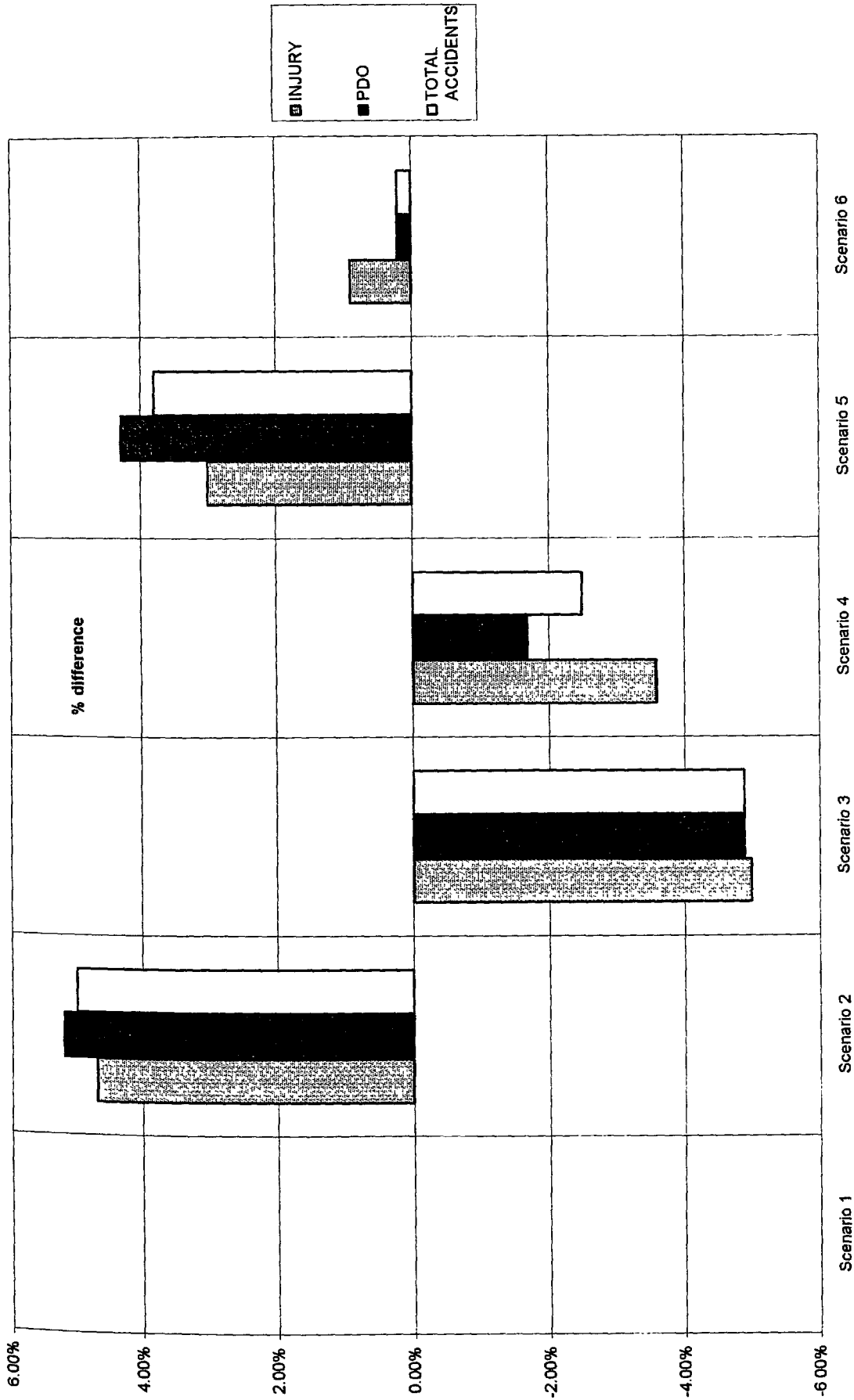
### FREEWAY SAFETY MEASURES



FREEWAY w/ramps SAFETY MEASURES



### PARALLEL ARTERIAL SAFETY MEASURES



## **Conclusion**

The study results indicate that a ramp metering strategy will have a positive impact upon freeway operational characteristics. The benefits obtained reflect a reduction in vehicle hours of delay without encountering an increase in freeway congestion. Application of fixed time and demand responsive signal coordination produces considerable improvements in speed and vehicle hours of delay on the parallel arterial.

The analyses suggest that MOEs should be considered collectively to determine ITS impact. The overall impacts of ITS technologies appear to be a compromise between many interdependent measures of effectiveness. For example, an improvement in speed and congestion will tend to have associated with them an increase in NOx emissions and vehicle incident rates.

The study demonstrated that the modeling Framework is a useful tool in evaluating the impacts related to several signal control strategies in a region with integrated networks of freeways and signalized arterials while considering the dynamics of the traffic environment. The ability of the Framework is not limited to assessing the impacts on a localized network. System-wide impact assessment analysis can be performed to selectively target specific MOE improvements for particular areas where they are most needed. This approach leverages the dependent nature of MOEs and allows a practitioner to select specific ATMS services for obtaining optimal network-wide results. Finally, the results from implementing any of the strategies described here will vary with local network geometries and other region-specific conditions.

## **Appendix A**

Data from all scenarios are listed on the following pages and are grouped by MOE category. Impact upon the 1880 freeway (without ramps), the freeway with ramps, and adjacent parallel arterials are the focus of the detailed data.



## OPERATIONAL MEASURES ON I880 (Excluding Ramps)

MOE	Area Type	Scenario					
		P1F1T2 Fixed Signal (Baseline)	P1F1T3 Dynamic Signal	P2F1F2T2 Fixed Ramp, Fixed Signal	P2F1F3T2 Dynamic Ramp, Fixed Signal	P2F1F3T3 Dynamic Ramp, Dynamic Signal	P2F1F2T3 Fixed Ramp, Dynamic Signal
Total VMT	Rural	234,017	234,017	235,492	235,492	235,492	235,492
	% Difference						
	Residential	1,181,925	1,181,925	1,187,774	1,187,774	1,187,774	1,187,774
	% Difference						
Total Volume	Total	1,415,942	1,415,942	1,423,266	1,423,266	1,423,266	1,423,266
	% Difference						
	Age	300,099	300,099	302,049	302,049	302,049	302,049
	% Difference						
Average Speed (MPH)	Residential	2,119,026	2,119,026	2,129,268	2,129,268	2,129,268	2,129,268
	% Difference						
	Total	2,419,125	2,419,125	2,431,317	2,431,317	2,431,317	2,431,317
	% Difference						
VHD	Rural	44.9	42.7	50.3	49.9	49.9	50.0
	% Difference		-4.9%	12.2%	11.3%	11.3%	11.4%
	Residential	47.9	47.5	48.8	48.6	48.6	48.6
	% Difference			1.9%	1.4%	1.4%	1.3%
Fuel	Total	47.6	47.0	49.0	48.8	48.8	48.7
	% Difference		-1.3%	3.0%	2.5%	2.5%	2.4%
	Rural	2,269	2,762	763	804	803	797
	% Difference		21.7%	-66.4%	-64.6%	-64.6%	-64.9%
Fuel	Residential	3,585	4,012	2,810	2,842	2,835	2,871
	% Difference		11.9%	-21.6%	-20.7%	-20.9%	-19.9%
	Total	5,854	6,774	3,573	3,646	3,638	3,668
	% Difference		15.7%	-39.0%	-37.7%	-37.9%	-37.3%
Fuel	Rural	3,868	4,052	3,701	3,864	3,870	3,797
	% Difference		4.8%	-4.3%			-1.8%
	Residential	36,487	36,784	37,693	37,720	37,580	37,310
	% Difference			3.3%	3.4%	3.0%	2.3%
Fuel	Total	40,355	40,836	41,394	41,584	41,450	41,107
	% Difference		1.2%	2.6%	3.0%	2.7%	1.9%

**Note: No % differences are displayed if they are <= 1.0%**

## SAFETY MEASURES ON I880 (Excluding Ramps)

MOE	Area Type	Scenario					
		P1F1T2 Fixed Signal (Baseline)	P1F1T3 Dynamic Signal	P2F1F2T2 Fixed Ramp, Fixed Signal	P2F1F3T2 Dynamic Ramp, Fixed Signal	P2F1F3T3 Dynamic Ramp, Dynamic Signal	P2F1F2T3 Fixed Ramp, Dynamic Signal
Fatal Injury Accidents / 1000 veh mi)	Rural % Difference	.0389	.0385 -1.0%	.0386	.0379 -2.4%	.0422 8.7%	.0415 6.7%
	Residential % Difference	.4449	.4433	.4707 5.8%	.4638 4.2%	.4625 4.0%	.4628 4.0%
	<b>Total</b> % Difference	<b>.4838</b>	<b>.4818</b>	<b>.5092</b> 5.3%	<b>.5017</b> 3.7%	<b>.5047</b> 4.3%	<b>.5043</b> 4.2%
Fatal PDO Accidents / 1000 veh mi)	Rural % Difference	.0646	.0634 -2.0%	.065	.0637 -1.4%	.0704 8.9%	.0692 7.0%
	Residential % Difference	.7418	.7431	.7861 6.0%	.7783 4.9%	.7755 4.5%	.774 4.3%
	<b>Total</b> % Difference	<b>.8064</b>	<b>.8064</b>	<b>.8512</b> 5.5%	<b>.8421</b> 4.4%	<b>.8459</b> 4.9%	<b>.8432</b> 4.6%
Fatal Accident Accidents / 1000 veh mi)	Rural % Difference	.1035	.1018 -1.6%	.1036	.1017 -1.8%	.1126 8.8%	.1106 6.9%
	Residential % Difference	1.1867	1.1864	1.2568 5.9%	1.2421 4.7%	1.238 4.3%	1.2368 4.2%
	<b>Total</b> % Difference	<b>1.2902</b>	<b>1.2882</b>	<b>1.3604</b> 5.4%	<b>1.3438</b> 4.2%	<b>1.3507</b> 4.7%	<b>1.3475</b> 4.4%

**Note: No % differences are displayed if they are <= 1.0%**

## EMISSIONS MEASURES ON I880 (Excluding Ramps)

MOE	Area Type	Scenario					
		P1F1T2 Fixed Signal (Baseline)	P1F1T3 Dynamic Signal	P2F1F2T2 Fixed Ramp, Fixed Signal	P2F1F3T2 Dynamic Ramp, Fixed Signal	P2F1F3T3 Dynamic Ramp, Dynamic Signal	P2F1F2T3 Fixed Ramp, Dynamic Signal
Total CO {Mobile} (Kg)	Rural	904	1,018	736	768	769	754
	% Difference		12.6%	-18.6%	-15.0%	-15.0%	-16.6%
	Residential	7,646	7,768	7,698	7,695	7,672	7,618
% Difference			1.6%				
Total		8,550	8,786	8,434	8,463	8,441	8,372
% Difference			2.8%	-1.4%	-1.0%	-1.3%	-2.1%
Total CO {EMFAC} (Kg)	Rural	461	520	384	399	399	392
	% Difference		12.9%	-16.6%	-13.4%	-13.3%	-14.9%
	Residential	3,820	3,872	3,894	3,873	3,862	3,832
% Difference			1.4%	1.9%	1.4%	1.1%	
Total		4,281	4,392	4,278	4,272	4,262	4,224
% Difference			2.6%				-1.3%
Total HC {Mobile} (Kg)	Rural	71	80	56	59	59	58
	% Difference		12.9%	-20.3%	-16.7%	-16.6%	-18.2%
	Residential	575	584	575	576	574	570
% Difference			1.7%				
Total		645	664	632	635	633	628
% Difference			2.9%	-2.1%	-1.6%	-1.9%	-2.7%
Total HC {EMFAC} (Kg)	Rural	36	40	29	31	31	30
	% Difference		10.4%	-20.0%	-15.7%	-15.6%	-17.3%
	Residential	305	310	301	304	303	301
% Difference			1.7%	-1.1%			-1.3%
Total		341	350	330	334	333	331
% Difference			2.7%	-3.1%	-2.0%	-2.3%	-3.0%
Total NOx {Mobile} (Kg)	Rural	196	197	215	220	220	216
	% Difference			9.7%	12.4%	12.5%	10.6%
	Residential	1,825	1,825	1,974	1,938	1,935	1,915
% Difference			8.2%	6.2%	6.0%	4.9%	
Total		2,020	2,022	2,188	2,158	2,155	2,131
% Difference				8.3%	6.8%	6.7%	5.5%
Total NOx {EMFAC} (Kg)	Rural	90	92	102	104	104	103
	% Difference		1.9%	13.0%	15.4%	15.5%	13.5%
	Residential	870	868	957	935	933	924
% Difference			10.0%	7.5%	7.3%	6.2%	
Total		960	960	1,059	1,040	1,038	1,026
% Difference				10.3%	8.3%	8.0%	6.9%

**Note: No % differences are displayed if they are <= 1.0%**

## OPERATIONAL MEASURES ON PARALLEL ARTERIALS

MOE	Area Type	Scenario					
		P1F1T2 Fixed Signal (Baseline)	P1F1T3 Dynamic Signal	P2F1F2T2 Fixed Ramp, Fixed Signal	P2F1F3T2 Dynamic Ramp, Fixed Signal	P2F1F3T3 Dynamic Ramp, Dynamic Signal	P2F1F2T3 Fixed Ramp, Dynamic Signal
Total VMT	Residential	131,195	131,799	130,467	131,176	130,994	130,841
	% Difference						
	OCBD	89,269	90,703	89,187	89,305	90,700	89,047
	% Difference		1.6%			1.6%	
	<b>Total</b>	<b>220,464</b>	<b>222,503</b>	<b>219,655</b>	<b>220,481</b>	<b>221,694</b>	<b>219,888</b>
	% Difference						
Total Volume	Residential	390,205	391,766	387,718	389,857	389,327	389,081
	% Difference						
	OCBD	515,937	523,790	515,732	516,795	523,858	513,827
	% Difference		1.5%			1.5%	
	<b>Total</b>	<b>906,142</b>	<b>915,556</b>	<b>903,450</b>	<b>906,652</b>	<b>913,185</b>	<b>902,908</b>
	% Difference		1.0%				
Average Speed (MPH)	Residential	23.7	24.4	24.0	23.8	24.6	24.8
	% Difference		3.0%	1.5%		3.7%	4.8%
	OCBD	18.4	19.0	18.6	18.5	18.7	19.1
	% Difference		3.5%			1.6%	4.0%
	<b>Total</b>	<b>20.7</b>	<b>21.4</b>	<b>21.0</b>	<b>20.9</b>	<b>21.3</b>	<b>21.7</b>
	% Difference		3.3%	1.2%		2.6%	4.4%
Total VHD	Residential	1,400	1,218	1,230	1,255	1,002	986
	% Difference		-13.0%	-12.1%	-10.4%	-28.5%	-29.6%
	OCBD	2,351	1,730	2,104	2,031	2,051	1,842
	% Difference		-26.4%	-10.5%	-13.6%	-12.8%	-21.7%
	<b>Total</b>	<b>3,752</b>	<b>2,948</b>	<b>3,334</b>	<b>3,285</b>	<b>3,053</b>	<b>2,827</b>
	% Difference		-21.4%	-11.1%	-12.4%	-18.6%	-24.6%
Total Fuel (l)	Residential	1,665	1,774	1,448	1,494	1,559	1,524
	% Difference		6.5%	-13.0%	-10.3%	-6.4%	-8.5%
	OCBD	2,265	2,257	2,269	2,296	2,525	2,445
	% Difference				1.4%	11.5%	7.9%
	<b>Total</b>	<b>3,930</b>	<b>4,031</b>	<b>3,717</b>	<b>3,790</b>	<b>4,084</b>	<b>3,969</b>
	% Difference		2.6%	-5.4%	-3.6%	3.9%	

**Note: No % differences are displayed if they are <= 1.0%**

## SAFETY MEASURES ON PARALLEL ARTERIALS

MOE	Area Type	Scenario					
		P1F1T2 Fixed Signal (Baseline)	P1F1T3 Dynamic Signal	P2F1F2T2 Fixed Ramp, Fixed Signal	P2F1F3T2 Dynamic Ramp, Fixed Signal	P2F1F3T3 Dynamic Ramp, Dynamic Signal	P2F1F2T3 Fixed Ramp, Dynamic Signal
Fatal Injury accidents / million veh mi)	Residential	.0432	.045	.0391	.04	.0414	.0392
	% Difference		4.1%	-9.5%	-7.4%	-4.2%	-9.4%
	OCBD	.0486	.0512	.0481	.0485	.0532	.0518
	% Difference		5.2%	-1.1%		9.4%	6.6%
	<b>Total</b>	<b>.0919</b>	<b>.0962</b>	<b>.0872</b>	<b>.0886</b>	<b>.0946</b>	<b>.091</b>
	% Difference		4.7%	-5.0%	-3.6%	3.0%	
Fatal PDO accidents / million veh mi)	Residential	.0601	.0626	.0546	.0562	.059	.0548
	% Difference		4.1%	-9.2%	-6.6%	-1.8%	-8.9%
	OCBD	.0676	.0717	.0669	.0694	.0741	.0733
	% Difference		6.2%	-1.0%	2.7%	9.7%	8.5%
	<b>Total</b>	<b>.1277</b>	<b>.1343</b>	<b>.1214</b>	<b>.1255</b>	<b>.1331</b>	<b>.128</b>
	% Difference		5.2%	-4.9%	-1.7%	4.3%	
Fatal Accident accidents / million veh mi)	Residential	.1033	.1076	.0937	.0962	.1004	.0939
	% Difference		4.1%	-9.3%	-6.9%	-2.8%	-9.1%
	OCBD	.1162	.1229	.115	.1179	.1274	.1251
	% Difference		5.8%	-1.0%	1.5%	9.6%	7.7%
	<b>Total</b>	<b>.2195</b>	<b>.2305</b>	<b>.2087</b>	<b>.2141</b>	<b>.2278</b>	<b>.219</b>
	% Difference		5.0%	-4.9%	-2.5%	3.8%	

*Note: No % differences are displayed if they are <= 1.0%*

## EMISSIONS MEASURES ON PARALLEL ARTERIALS

MOE	Area Type	Scenario					
		P1F1T2 Fixed Signal (Baseline)	P1F1T3 Dynamic Signal	P2F1F2T2 Fixed Ramp, Fixed Signal	P2F1F3T2 Dynamic Ramp, Fixed Signal	P2F1F3T3 Dynamic Ramp, Dynamic Signal	P2F1F2T3 Fixed Ramp, Dynamic Signal
Total CO {Mobile} (Kg)	Residential	486	517	419	434	447	438
	% Difference		6.4%	-13.8%	-10.7%	-8.0%	-10.0%
	OCBD	761	726	763	769	840	814
	% Difference		-4.6%			10.3%	6.9%
	<b>Total</b>	<b>1,248</b>	<b>1,244</b>	<b>1,182</b>	<b>1,203</b>	<b>1,287</b>	<b>1,252</b>
	% Difference			-5.3%	-3.6%	3.1%	
Total CO {EMFAC} (Kg)	Residential	227	224	195	203	210	204
	% Difference		-1.4%	-14.0%	-10.8%	-7.8%	-10.4%
	OCBD	360	342	362	363	397	384
	% Difference		-5.0%			10.2%	6.8%
	<b>Total</b>	<b>587</b>	<b>566</b>	<b>558</b>	<b>565</b>	<b>606</b>	<b>588</b>
	% Difference		-3.6%	-5.0%	-3.7%	3.3%	
Total HC {Mobile} (Kg)	Residential	36	39	31	32	33	33
	% Difference		6.3%	-13.8%	-10.6%	-8.0%	-10.0%
	OCBD	55	53	56	56	61	59
	% Difference		-4.3%		1.0%	10.4%	7.1%
	<b>Total</b>	<b>92</b>	<b>92</b>	<b>87</b>	<b>88</b>	<b>95</b>	<b>92</b>
	% Difference			-5.3%	-3.6%	3.1%	
Total HC {EMFAC} (Kg)	Residential	20	22	17	18	19	18
	% Difference		8.6%	-13.4%	-10.3%	-6.8%	-8.5%
	OCBD	32	30	32	32	35	34
	% Difference		-4.7%			9.8%	6.3%
	<b>Total</b>	<b>51</b>	<b>52</b>	<b>49</b>	<b>49</b>	<b>53</b>	<b>52</b>
	% Difference			-5.0%	-3.8%	3.4%	
Total NOx {Mobile} (Kg)	Residential	52	56	46	48	50	49
	% Difference		6.8%	-11.3%	-9.2%	-4.3%	-6.8%
	OCBD	57	60	56	58	64	62
	% Difference		5.3%		2.0%	12.5%	10.0%
	<b>Total</b>	<b>109</b>	<b>115</b>	<b>103</b>	<b>105</b>	<b>114</b>	<b>111</b>
	% Difference		6.0%	-5.8%	-3.3%	4.5%	1.9%
Total NOx {EMFAC} (Kg)	Residential	24	26	21	22	23	22
	% Difference		6.4%	-12.1%	-9.9%	-5.0%	-8.8%
	OCBD	29	30	29	30	33	32
	% Difference		2.1%		1.9%	12.4%	9.1%
	<b>Total</b>	<b>54</b>	<b>56</b>	<b>51</b>	<b>52</b>	<b>56</b>	<b>54</b>
	% Difference		4.0%	-5.5%	-3.4%	4.5%	1.0%

**Note: No % differences are displayed if they are <= 1.0%**

## OPERATIONAL MEASURES ON I880 (Including Ramps)

MOE	Area Type	Scenario					
		P1F1T2 Fixed Signal (Baseline)	P1F1T3 Dynamic Signal	P2F1F2T2 Fixed Ramp, Fixed Signal	P2F1F3T2 Dynamic Ramp, Fixed Signal	P2F1F3T3 Dynamic Ramp, Dynamic Signal	P2F1F2T3 Fixed Ramp, Dynamic Signal
Total VMT	Rural	241,875	241,875	247,632	247,632	247,632	247,632
	% Difference			2.4%	2.4%	2.4%	2.4%
	Residential	1,215,814	1,215,814	1,234,496	1,234,496	1,234,496	1,234,496
	% Difference			1.5%	1.5%	1.5%	1.5%
Total	1,457,690	1,457,690	1,482,128	1,482,128	1,482,128	1,482,128	
% Difference			1.7%	1.7%	1.7%	1.7%	
Total Volume	Rural	340,059	340,059	367,155	367,155	367,155	367,155
	% Difference			8.0%	8.0%	8.0%	8.0%
	Residential	2,278,326	2,278,326	2,369,028	2,369,028	2,369,028	2,369,028
	% Difference			4.0%	4.0%	4.0%	4.0%
Total	2,618,385	2,618,385	2,736,183	2,736,183	2,736,183	2,736,183	
% Difference			4.5%	4.5%	4.5%	4.5%	
Average Speed (MPH)	Rural	46.4	44.4	51.7	51.4	51.4	51.4
	% Difference		-4.3%	11.5%	10.7%	10.8%	10.9%
	Residential	47.9	47.4	48.6	48.4	48.4	48.3
	% Difference			1.5%	1.1%	1.1%	1.0%
Total	47.7	47.1	49.0	48.7	48.8	48.7	
% Difference		-1.3%	2.7%	2.1%	2.3%	2.1%	
Total VHD	Rural	2,269	2,762	763	804	803	797
	% Difference		21.7%	-66.4%	-64.6%	-64.6%	-64.9%
	Residential	3,669	4,110	2,961	2,987	2,974	3,014
	% Difference		12.0%	-19.3%	-18.6%	-18.9%	-17.8%
Total	5,938	6,872	3,724	3,791	3,778	3,812	
% Difference		15.7%	-37.3%	-36.2%	-36.4%	-35.8%	
Total Fuel (Gal)	Rural	3,913	4,095	3,729	3,891	3,897	3,823
	% Difference		4.7%	-4.7%			-2.3%
	Residential	36,933	37,246	38,178	38,189	38,054	37,770
	% Difference			3.4%	3.4%	3.0%	2.3%
Total	40,846	41,341	41,907	42,080	41,951	41,593	
% Difference		1.2%	2.6%	3.0%	2.7%	1.8%	

**Note: No % differences are displayed if they are <= 1.0%**

## SAFETY MEASURES ON I880 (Including Ramps)

MOE	Area Type	Scenario					
		P1F1T2 Fixed Signal (Baseline)	P1F1T3 Dynamic Signal	P2F1F2T2 Fixed Ramp, Fixed Signal	P2F1F3T2 Dynamic Ramp, Fixed Signal	P2F1F3T3 Dynamic Ramp, Dynamic Signal	P2F1F2T3 Fixed Ramp, Dynamic Signal
Total Injury Accidents / million veh mi)	Rural	.0393	.0389	.0388	.0382	.0425	.0417
	% Difference		-1.1%	-1.2%	-2.8%	8.1%	6.2%
	Residential	.4503	.449	.4764	.4693	.468	.4682
	% Difference			5.8%	4.2%	3.9%	4.0%
	<b>Total</b>	<b>.4896</b>	<b>.4879</b>	<b>.5152</b>	<b>.5074</b>	<b>.5105</b>	<b>.51</b>
	% Difference			5.2%	3.7%	4.3%	4.2%
Total PDO Accidents / million veh mi)	Rural	.0653	.064	.0654	.0641	.0708	.0695
	% Difference		-2.0%		-1.8%	8.4%	6.5%
	Residential	.7506	.7524	.7954	.7873	.7845	.7828
	% Difference			6.0%	4.9%	4.5%	4.3%
	<b>Total</b>	<b>.8159</b>	<b>.8164</b>	<b>.8608</b>	<b>.8514</b>	<b>.8553</b>	<b>.8524</b>
	% Difference			5.5%	4.3%	4.8%	4.5%
Total Accident Accidents / million veh mi)	Rural	.1046	.1029	.1042	.1023	.1133	.1113
	% Difference		-1.6%		-2.2%	8.3%	6.4%
	Residential	1.2009	1.2015	1.2718	1.2565	1.2526	1.2152
	% Difference			5.9%	4.6%	4.3%	1.2%
	<b>Total</b>	<b>1.3055</b>	<b>1.3043</b>	<b>1.376</b>	<b>1.3588</b>	<b>1.3658</b>	<b>1.3264</b>
	% Difference			5.4%	4.1%	4.6%	1.6%

**Note: No % differences are displayed if they are <= 1.0%**



## EMISSIONS MEASURES ON I880 (Including Ramps)

MOE	Area Type	Scenario					
		P1F1T2 Fixed Signal (Baseline)	P1F1T3 Dynamic Signal	P2F1F2T2 Fixed Ramp, Fixed Signal	P2F1F3T2 Dynamic Ramp, Fixed Signal	P2F1F3T3 Dynamic Ramp, Dynamic Signal	P2F1F2T3 Fixed Ramp, Dynamic Signal
Total CO {Mobile} (Kg)	Rural	918	1,032	745	776	777	762
	% Difference		12.4%	-18.9%	-15.4%	-15.4%	-17.0%
	Residential	7,741	7,868	7,803	7,797	7,775	7,719
	% Difference		1.6%				
<b>Total</b>		<b>8,659</b>	<b>8,900</b>	<b>8,548</b>	<b>8,574</b>	<b>8,552</b>	<b>8,481</b>
% Difference			<b>2.8%</b>	<b>-1.3%</b>		<b>-1.2%</b>	<b>-2.1%</b>
Total CO {EMFAC} (Kg)	Rural	468	527	388	403	404	396
	% Difference		12.7%	-16.9%	-13.8%	-13.7%	-15.3%
	Residential	3,869	3,923	3,951	3,928	3,918	3,886
	% Difference		1.4%	2.1%	1.5%	1.3%	
<b>Total</b>		<b>4,337</b>	<b>4,450</b>	<b>4,340</b>	<b>4,331</b>	<b>4,322</b>	<b>4,282</b>
% Difference			<b>2.6%</b>				<b>-1.3%</b>
Total HC {Mobile} (Kg)	Rural	71	80	57	59	59	58
	% Difference		12.7%	-20.5%	-16.9%	-16.9%	-18.5%
	Residential	582	592	583	583	582	578
	% Difference		1.7%				
<b>Total</b>		<b>653</b>	<b>672</b>	<b>640</b>	<b>643</b>	<b>641</b>	<b>636</b>
% Difference			<b>2.9%</b>	<b>-2.0%</b>	<b>-1.6%</b>	<b>-1.8%</b>	<b>-2.6%</b>
Total HC {EMFAC} (Kg)	Rural	37	40	29	31	31	30
	% Difference		10.2%	-20.2%	-16.0%	-16.0%	-17.6%
	Residential	309	314	306	308	307	305
	% Difference		1.8%	-1.0%			-1.2%
<b>Total</b>		<b>345</b>	<b>355</b>	<b>335</b>	<b>338</b>	<b>338</b>	<b>335</b>
% Difference			<b>2.7%</b>	<b>-3.0%</b>	<b>-2.0%</b>	<b>-2.3%</b>	<b>-3.0%</b>
Total NOx {Mobile} (Kg)	Rural	199	200	217	222	222	218
	% Difference			8.9%	11.5%	11.6%	9.7%
	Residential	1,847	1,848	2,000	1,963	1,961	1,939
	% Difference			8.3%	6.3%	6.1%	5.0%
<b>Total</b>		<b>2,046</b>	<b>2,048</b>	<b>2,217</b>	<b>2,185</b>	<b>2,183</b>	<b>2,158</b>
% Difference				<b>8.3%</b>	<b>6.8%</b>	<b>6.7%</b>	<b>5.5%</b>
Total NOx {EMFAC} (Kg)	Rural	92	94	103	105	105	104
	% Difference		1.8%	12.0%	14.4%	14.5%	12.5%
	Residential	881	879	970	948	946	936
	% Difference			10.2%	7.6%	7.4%	6.3%
<b>Total</b>		<b>973</b>	<b>972</b>	<b>1,073</b>	<b>1,053</b>	<b>1,051</b>	<b>1,039</b>
% Difference				<b>10.4%</b>	<b>8.3%</b>	<b>8.1%</b>	<b>6.9%</b>

**Note: No % differences are displayed if they are <= 1.0%**