Caltrans TOPS Evaluation: Assessing the Net Benefits of ITS Applications

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CALTRANS TOPS EVALUATION: ASSESSING THE NET BENEFITS OF ITS APPLICATIONS

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Executive Summary

This report describes the outcome of a set of experiments undertaken to assess the net benefits of ITS applications in a stylized urban and near urban highway network. The work was completed using the IDAS Build I package. Despite the limitations of this first generation package, we were able to assess a number of different ITS technologies including ramp meters, incident management, integrated technologies and synergies from multiple ITS applications.

The purpose of this set of experiments was not to test actual ITS applications but to assess how net benefits changed under a given set of traffic conditions. The original plan was to use Paramics, a sophisticated network simulation model, to simulate each of the experimental conditions. The value in this approach was that Paramics is one of the most advanced network simulation models and has [almost] the complete Orange County major roadway network including all current ITS applications such as ramp meters and ATMIS locations. It also contains the latest in parameters estimates for modeling behavioral responses to changes in system performance and relative prices. Unfortunately, the hoped for simulations were never undertaken and the fallback was to use IDAS as the vehicle for conducting the experiments. It was also unfortunate that IDAS Build II was just in the testing phase when this work was being completed so it was not possible to move beyond the set of experiments reported here.

The results reflect simulations of the application of ITS technology to a stylized network which contained expressways and urban arterial roads. The traffic matrix was fixed so no induced effects were considered in the analysis. However, redistribution across the network as a result of ITS applications was part of the analysis.

The first experiments were with introducing unlinked ramp meters at a successive series of ramps on an expressway. With <u>one ramp meter</u>, the Freeway gains but the expressways and ramps lose VMT goes down on the Expressways by 3% and on the Ramps by .5%. Speeds go down on the Expressways by 1% and on the Ramps by 5.9%. VHT goes down on the expressways by 2% and up on the ramps by 5.7%

With <u>two ramp meters</u>, Freeways also gain at the expense of Expressways and Ramps. Speeds go up on Expressways by .1% and on Ramps speed goes down by 9.7%. VMT goes down on Expressways by 2.1% and by 6.5% on Ramps. VHT goes down on Expressways by 2.2% but goes up on Ramps by 3.6%.

When we move to <u>5 pre-timed ramp meters</u>, we have average speeds on the Expressway going down by .1% but on ramps they go down by 57.2%. On Freeways, speed goes up 42.1%. VMT goes up on Freeways by 33.4%, on Expressways, it goes down 1.2% and on ramps it goes down 3.9%. VHT goes down on Expressways by 1.1%, down on Freeways by 6.1% and up on Ramps by 124.8%.

We see that with more pre-timed ramp meters, we are keeping cars off the Freeway and holding them on the ramps. Speeds rise but at the expense of huge cost in time for those on the ramps. This is why the BC ratio is negative.

When we shift from 5 pre-timed to 5 centrally controlled ramp meters we can see an increase in the B/C ratio. In-vehicle travel time goes down considerably. The shift to central control leads to a 62.9% increase in average speed on the Freeway (from 25.6 to 41.8), an increase of VMT of 31.7% and a decrease in VHT of 19.2%. The conclusion is that the shift from a pre-timed OLD TECHNOLOGY ramp meter to a CENTRAL CONTROL new technology results in considerable benefits. Furthermore, the benefits from new technology (i.e. ITS) exceed those of expanding the old technology (increasing the number of pre-timed ramp meters).

The shift from old technology to new technology, given you are using ramp meters, is clearly Pareto efficient. That is, the increase in benefits is sufficiently large that the gainers could compensate the losers and still be better off them selves.

Incident management was modeled as incident detection and incident response. Incident management was analyzed by adding incident detection, incident response, or a combination of the two to the freeway in the generic network. Incident detection involves investing in surveillance capital that will allow traffic managers to advise conventional accident management factors. This will result in a reduction in incident duration.

If we change the nature of the incident management to improving response which involves guidance to non-recurring incidence. This results in a larger gain than with simple surveillance and the marginal gain over surveillance is 12% improvement, in environmental costs. The combination of the two technologies results in a sizable improvement from a base case, of 42% reduction in environmental costs. The marginal gain from incident response is 15% and from surveillance is 27%. If we look at the B/C ratios for the various test if incident management they are 3.47 for a 40% reduction in response rate and 1.31 for incident detection. These do not change substantially when the time for the incident was reduced.

Three synergies were analyzed:

1. Combining the 5 central controlled ramp meters with the combination incident detection/response
1. Combining the 5 pretimed ramp meters with the combination incident detection/response
1. Combining the 3 pretimed ramp meters with just incident response

The comparison with the non-synergy outcomes shows that adding incident response to a 3 pre-timed ramp meter scenario actually results in a lower B/C ratio but speeds are higher, VMT is lower and VHT reduction is higher. It would appear the added benefits from the addition of incident management are low. However, the major beneficiaries are freeway users and not ramp or expressway users.

When we examine the 5 pre-timed with the 5 pre-timed with incident management there is still a negative B/C ratio but it is much lower. However, all the Freeway parameters are the same. The gainers are on the expressway.

If we compare just the synergy experiments, we find a mixed outcome. The move from old ramp metering technology with limited incident management to new ramp technology with extended incident management results in a sizable increase in speeds, and a doubling of the reduction of VHT and a sizable increase in VMT. The B/C ratio falls but is still sizable. It appears here is a case where there are significant benefits but still costs to some as we shift the burden onto ramp users and expressway users.

Introduction

This project was designed to examine the expected benefits and costs of different ITS applications that focus on traffic operations. The purpose of the research was to provide Caltrans Traffic Operations Group and New Technology Group with a measure of the expected net benefits with the application of some or all ITS projects to parts of the California highway system. The value of the research is that it would provide measures of the changes in benefits as the size of the project changes and as projects are introduced in combination with one another. In other words the synergies of projects.

This report provides a summary of the approach that involved undertaking simulations of some well defined experiments. The experiments are set out in detail. Next we report on the actual set of experiments, a limited subset of the original, that were completed using the IDAS Build I software package. The third section contains the description of the outcomes of the experiments. An appendix contains all of the output from the experiments, including benefit-cost information for each experiment undertaken.

Experimental Design and Simulation Approach

This project has a need to evaluate several projects in isolation and in combination. There are several approaches one could take to complete the evaluation. First, undertake a simulation of a transportation network which can provide a measure of the change in VMT on a network for a given trip table. The change in VMT can be used to establish user time savings. The change in VMT can also be used in conjunction with work by D. Gillen and D. Levinson on the *Full Costs of Highway Transportation* to measure the changes in emissions and levels of safety. Paramics provides an ideal simulation platform for this type of analysis. Paramics is a microscopic traffic simulation model, which is coded for Orange County. The coverage varies according to what issue is being investigated. Output is extensive. We can obtain it at the level of the passenger, link and network levels.

Second, we could use information from the current academic, professional and government literature to assemble the range of outcomes, benefits and costs that are reported from various studies. This can be used to set up a table of values for different projects that would provide orders of magnitude measures for each ITS application. While this is less satisfying than simulations, it still provides some range of values of the benefits and costs. A risk analysis added to this approach would provide policymakers with a good set of information on the magnitudes of benefits and costs and the likelihood of achieving them.

A third approach is to use IDAS, a software package being developed for the FHWA to assess ITS applications. IDAS provides a framework for undertaking this type of analysis. It is essentially a large accounting package in a spreadsheet platform. It contains information on the expected benefits and costs of different ITS applications. The information is based on the literature search as well as discussions with experts in focus group sessions.

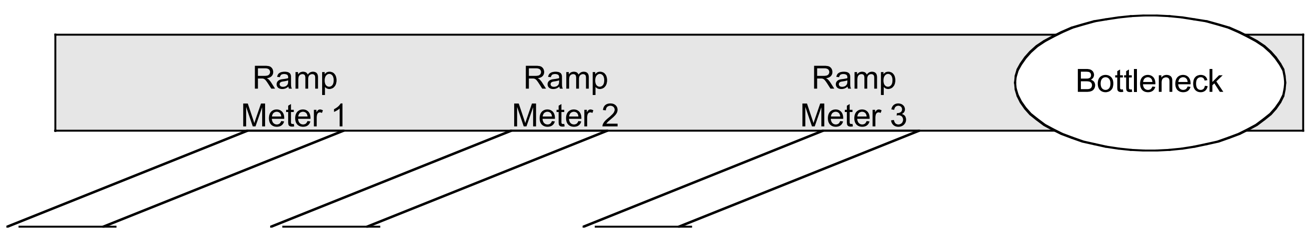
The intent was to use both the simulation and literature approaches in this study. The reasoning was that a parallel approach would assure some results in a timely fashion. Thirdly, it offers a means of comparison from two quite different ways of undertaking some analysis. The Paramics model is based on Orange County data and has built in behavioral relationships. It is an equilibrium model based on a beginning trip table. IDAS on the other hand uses information from around the United States to construct ranges of values for benefits and costs given the type of ITS project being undertaken. The experiments that were designed are described below.

***Ramp Metering**:* our intent was to analyze multiple or group meters. The figure below illustrates the test scenario. A downstream bottleneck on a freeway has three upstream ramp meters. We examine a situation of one ramp meter then a group of two then three meters so see how the benefits change. We take a given trip table for which the model is coded run the simulation to establish a base case. Next run the model with one, then 2 then 3 ramp meters on a given freeway. We did not have time to investigate different freeways or types of roadways although this would seem to be an interesting issue. However, we were able to examine the differences between linked and unlinked ramp metering systems.

Below is a complete test schema for 3 meters. It allows us to test for synergies within metering a bit more carefully

Run	Meter 1	Meter 2	Meter 3
1 Base Case	Off	Off	Off
2	On	Off	Off
3	On	On	Off
4	On	On	On
5	On	Off	On
6	Off	On	Off
7	Off	On	On
8	Off	Off	On

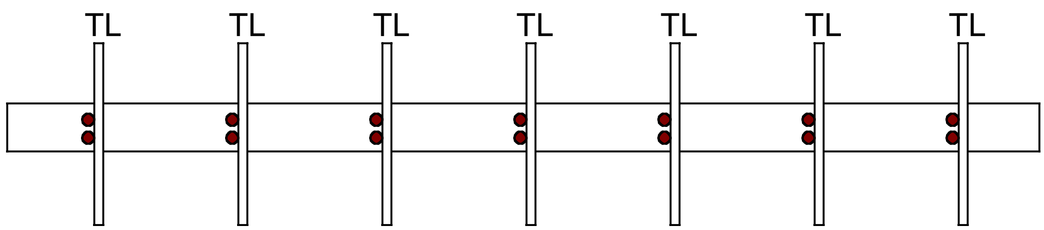
Ideally, we are looking at three meters in a series of on-ramps before the same bottleneck, or something like that, rather than three meters randomly placed. This is illustrated below.



It is not clear how many runs are necessary for each simulation.   To obtain a reliable answer, we need to do multiple runs of the same scenario and take an average. The road segment we see as being 2-5 miles in length. We analyze the effects of TOPS on one segment and extrapolate.

Signalization: we intended to analyze synchronized traffic signals however, this involved arterial roads which differs from all other applications (except perhaps ATMIS). We need to consider the type of roadway and the level of traffic. At what point does diminishing returns set in, for example. Again we need to run the model for a base case then with a specific roadway and number of synchronized signals, we re-calibrate the model. Augmenting the trip table in some way to reflect induced traffic would be desirable but may not be possible with time constraints.

Choose an arterial in the model that runs a long distance from an urbanized center (high volume) to a relatively undeveloped (low volume) area, about 8-10 miles. We could then test synchronized signals continuously along the road, extending synchronization one signal at a time and trace out a Marginal Benefits curve. In the experiment displayed below TL= Traffic Light. The test would be to turn on successively TL1 through TLn (n-tests where n will be some value greater than 10)



A second test might look at parallel arterials, and see if there are benefits in synchronizing parallel streets in a grid.

Arterial Roadway A

Arterial Roadway B

All the signals on an arterial would be synchronized. The test would be whether doing A + B is better than A or B separately, and whether it is more than twice as good.

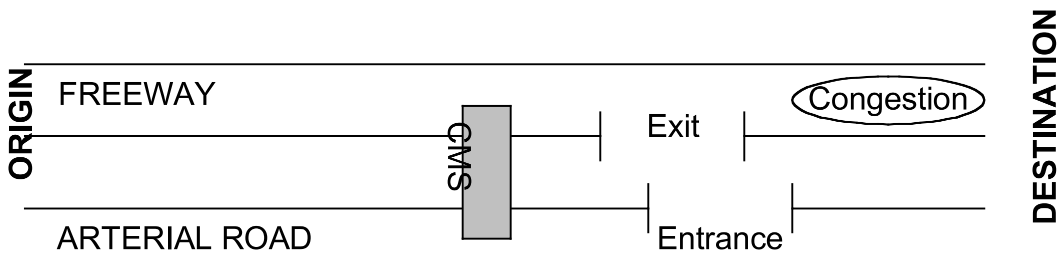
Test

Run	Arterial A	Arterial B
1 Base case	Off	Off
2	On	Off
3	On	On
4	On	Off

Output would be system travel time etc. We would not worry about variable demand at this point.

ATMIS: there are changeable message signs in the Paramics model. We can specify the proportion of traffic that receives the message and the probability of acting on it. The evaluation can be made for different proportions of people receiving and acting on the message and see how savings change as a result of these different proportions. One approach is CMS should have 100% informed drivers, but the percent trust (and thus acting on it) varies from 0 to 100%. We are interested in the effectiveness of different levels acting on it for different levels of freeway blockage (i.e. we can look at different congestion levels, whether cause is recurring or non-recurring.) Drivers are informed of the expected delay through the bottleneck.

One series of tests increased flow but kept capacity constant, a second series of tests kept flow constant and decreased capacity.



The experiments would be based on the information in the table below. It is displayed for a representative set of information with four elements in each cell.

		% Congestion (V/C)			
% Informed	0.5	0.67	0.95	1.0	1.05
0.17	D(I), D(U), V(I), V(U)				
0.33					
0.5					
0.67					
0.83					
1.00					

D(I) = Delay for informed travelers (in our case, those who accept CMS advice)
D(U) = Delay for uninformed travelers (in our case, ignore CMS advice)
V(I) = Std. Deviation in time for informed travelers
V(U) = Std. Deviation in time for uninformed travelers.

All travelers who see the CMS would need to be tracked.

Freeway Service Patrol: FSP is not in the Paramics model but can be modeled by injecting an incident and have some clearance rate. The clearance rate can be changed. We are able to define the vehicle type, route and we can have a fleet of FSP's.

To measure the delay reducing benefits of FSP we need to match clearance rate with a link's incident rate, and compare delay reduction benefits with FSP costs.
Is it possible to obtain a random incident generator in Paramics, where incident probabilities and severity are a function of link type? We test FSP system wide with various response rates: say averaging 1, 2, 3, 5, 10, 20, 30, 45, 60 minutes.

Synergies: a feature to be investigated is how the different applications of ITS projects will interact and result in positive or negative externalities. The approach for this would be to determine from the previous tests and other information what the best ramp strategy is (e.g. meters everywhere), the best signal strategy (e.g. synchronized everywhere), the best FSP strategy (FSP everywhere with X response rate), the best CMS strategy (e.g.. CMS everywhere with 100% compliance of people taking shortest route - whether that means changing or not). And do the following

Test	Best Ramp	Best Signal	Best FSP	Best CMS
1	Off	Off	Off	Off
2	On	Off	Off	Off
3	On	On	Off	Off
4	On	On	On	Off
5	On	Off	On	Off
6	Off	On	Off	Off
7	Off	On	On	Off
8	Off	Off	On	Off
9	Off	Off	Off	On
10	On	Off	Off	On
11	On	On	Off	On
12	On	On	On	On
13	On	Off	On	On
14	Off	On	Off	On
15	Off	On	On	On
16	Off	Off	On	On

Output from IDAS Experiments
The output of the files from IDAS-Build I permit some assessment of changes in speeds and volumes for the different runs. These are provided below for the different scenarios and combinations.

Ramp Metering

The first experiment was to move from no ramp meters to one pre-timed ramp meter. The outcome was:

An increase in average speed of 7.8% from 25.6 MPH to 27.6 MPH. VMT rose by 1.7% from 105,072 to 106,862. Vehicle Hours of Travel (VHT) went down 5.7%.

Incrementing to two pre-timed ramp meters has the following outcomes:

Increase in average speed of 21.3% (25.6 to 31.1 MPH), VMT increase of .8% and decrease of VHT of 16.9%.

Incrementing to 3 pre-timed ramp meters:

Increase in average speeds of 18.8% (25.6 to 30.5 MPH) an increase in VMT of 4.3% and a decrease in VHT of 12.2%.

		Percentage Change		
Facility	Speed Base	Speed Increase	VMT Increase	VHT Decrease
1 pre-timed RM	25.6	7.8	1.7	5.7
2 pre-timed RM	25.6	21.3	0.8	16.9
3 pre-timed RM	25.6	18.8	4.3	12.2
Increment 1-2		13.5	-0.9	11.2
Increment 2-3		-2.5	3.5	-4.7
Increment 1-3		11	2.6	6.5
5-pre-timed RM	25.6	42.1	33.4	6.1
5-Central Control	25.6	62.9	31.7	19.2
Delta on technology Shift		20.8	-1.7	13.1

With <u>one ramp meter</u>, the Freeway gains but the expressways and ramps lose VMT goes down on the Expressways by 3% and on the Ramps by .5%. Speeds go down on the Expressways by 1% and on the Ramps by 5.9%. VHT goes down on the expressways by 2% and up on the ramps by 5.7%

With two ramp meters, Freeways also gain at the expense of Expressways and Ramps. Speeds go up on Expressways by .1% and on Ramps speed goes down by 9.7%. VMT goes down on Expressways by 2.1% and by 6.5% on Ramps. VHT goes down on Expressways by 2.2% but goes up on Ramps by 3.6%.

With three ramp meters, average speeds go up on Expressways by .3% and down on ramps by 9.8%. VMT goes down on Expressways by .7% and on Ramps by 3.8%. VHT goes down on expressways by 1% but goes up on Ramps by 6.6%.

When we move to 5 pre-timed ramp meters, we have average speeds on the Expressway going down by .1% but on ramps they go down by 57.2%. On Freeways, speed goes up 42.1%. VMT goes up on Freeways by 33.4%, on Expressways, it goes down 1.2% and on ramps it goes down 3.9%. VHT goes down on Expressways by 1.1%, down on Freeways by 6.1% and up on Ramps by 124.8%.

We see that with more pre-timed ramp meters, we are keeping cars off the Freeway and holding them on the ramps. Speeds rise but at the expense of huge cost in time for those on the ramps. This is why the BC ratio is negative.

When we shift from 5 pre-timed to 5 centrally controlled ramp meters we can see an increase in the B/C ratio. In-vehicle travel time goes down considerably. The shift to central control leads to a 62.9% increase in average speed on the Freeway (from 25.6 to 41.8), an increase of VMT of 31.7% and a decrease in VHT of 19.2%. The conclusion is that the shift from a pre-timed OLD TECHNOLOGY ramp meter to a CENTRAL CONTROL new technology results in considerable benefits. Furthermore, the benefits from new technology (i.e. ITS) exceed those of expanding the old technology (increasing the number of pre-timed ramp meters).

With the move to central control, the users on the Freeway benefit. On the expressway average speed increase slightly, by .7%) and on the ramp it went down 31.1%. Note this is a vast improvement over the pretimed ramp meter ramp average speed decrease which was 57.2%. The same is true of the change in VHT. On the ramp with the central control ramp VHT went up 34.9% while with pre-timed ramp meters, VHT on the ramp went up 124.8%.

The shift from old technology to new technology, given you are using ramp meters, is clearly Pareto efficient. That is, the increase in benefits is sufficiently large that the gainers could compensate the losers and still be better off them selves.

Incident Management

Incident management was modeled as incident detection and incident response. Incident management was analyzed by adding incident detection, incident response, or a combination of the two to the freeway in the generic network. The values for the benefits associated with incident management are shown below.

	Incident Detection	Incident Response	Combination
Duration Reduction	9%	33%	55% (default), and 40%
Fatal Acc. Reduction	10%	10%	10%
Emissions Reduction (CO)	15%	27%	42%
Emissions Reduction (HC)	15%	27%	42%
Emissions Reduction (NO_x)	15%	27%	42%
Fuel Consumption Reduction	15%	27%	42%

An interpretation of these results is that detection involves investing in surveillance capital that will allow traffic managers to advise conventional accident management factors. This will result in a reduction in incident duration.

If we change the nature of the incident management to improving response which involves guidance to non-recurring incidence. This results in a larger gain than with simple surveillance and the marginal gain over surveillance is 12% improvement, in environmental costs.

The combination of the two technologies results in a sizable improvement from a base case, of 42% reduction in environmental costs. The marginal gain from incident response is 15% and from surveillance is 27%. Of course all this is based on default values from IDAS. In the process of doing this work, when changing the duration reduction values from the 55% default to 40% (and also to 20%-this was not included), the total overall benefits changed very little (less than .01%). However, if the type of incident management was changed to incident response, for example, the change in benefits was substantial. We even tried a run comparing the response with the combination and made all the percentage reductions equal, and the benefits were still very different. It is possible that there are other processes within IDAS (and beyond our control) that are affecting these results.

If we look at the B/C ratios for the various test if incident management they are 3.47 for a 40% reduction in response rate and 1.31 for incident detection. These do not change substantially when the time for the incident was reduced.

Synergies

Three synergies were analyzed:

1. Combining the 5 central controlled ramp meters with the combination incident detection/response
1. Combining the 5 pretimed ramp meters with the combination incident detection/response
1. Combining the 3 pretimed ramp meters with just incident response

In the table below the 3 synergy experiments are listed with the affect on freeway travel. In addition the outcomes from the non-synergy experiments are also listed for comparisons.

		Freeway		
Synergy Experiment	**B/C Ratio**	**Speed Change**	**VMT Change**	**VHT Change**
5 pre-timed with Indicent management	-29.47	42.1	33.4	-6.1
5-central control with incident management	127.94	91.9	24	-35.4
3 pre-timed with incident response only	1280.28	24.6	3.4	-17
3 pre-timed RM	3959.79	18.8	4.3	-12.2
5-pre-timed RM	-604.59	42.1	33.4	-6.1
5 central control	442.38	62.9	31.7	-19.2

Looking at the comparison with the non-synergy outcomes we see that adding incident response to a 3 pre-timed ramp meter scenario actually results in a lower B/C ratio but speeds are higher, VMT is lower and VHT reduction is higher. It would appear the added benefits from the addition of incident management are low. However, the major beneficiaries are freeway users and not ramp or expressway users.

When we examine the 5 pre-timed with the 5 pre-timed with incident management there is still a negative B/C ratio but it is much lower. However, all the Freeway parameters are the same. The gainers are on the expressway.

When we move from 5 central control to 5 central control with incident management we find B/C ratio is lower yet speeds with the synergy scenario are lower, VMT is higher (marginally) and VHT is lower. It appears the synergies are not there in this case. It may well be that the central control yields all the gains and there is relatively little to gain by adding incident management. I find this hard to believe and think IDAS has a feature that makes little sense.

If we compare just the synergy experiments, we find a mixed outcome. If we ignore the 5 pre-timed because of the negative B/C ratio, the move from old ramp metering technology with limited incident management to new ramp technology with extended incident management results in a sizable increase in speeds, and a doubling of the reduction of VHT and a sizable increase in VMT. The B/C ratio falls but is still sizable. It appears here is a case where there are significant benefits but still costs to some as we shift the burden onto ramp users and expressway users.

Conclusions

While not able to conduct the experiments we set out to do and not having been able to utilize Paramics as the preferred simulation tool, our experiments using IDAS have been successful. They have provided some insight into the application of ITS projects to a highway system. We examined the change in net benefits, resulting from expansion of the number of ramp meters as well as a shift in technology from moving from pretimed ramp meters to centrally controlled ramp meters. We were also able to look at incident management and the change in net benefits as the response time to the incident was reduced. Finally, we were able to examine the synergies that might arise as combinations of ITS applications are applied to the highway system.

What we found was there were diminishing returns to adding a given technology . with ramp meters we found there was a huge transfer in benefits from arterial road users to freeway users since traffic was held on the ramp to increase speeds on the freeway by a small amount. However, when we shift from 5 pre-timed to 5 centrally controlled ramp meters we can see an increase in the B/C ratio. The conclusion is that the shift from a pre-timed OLD TECHNOLOGY ramp meter to a CENTRAL CONTROL new technology results in considerable benefits. Furthermore, the benefits from new technology (i.e. ITS) exceed those of expanding the old technology (increasing the number of pre-timed ramp meters). The shift from old technology to new technology, given you are using ramp meters, is clearly Pareto efficient. That is, the increase in benefits is sufficiently large that the gainers could compensate the losers and still be better off them selves.

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Appendix A: Experience with IDAS

The following report summarizes the problems encountered during our various attempted builds and runs along with the circumstances under which they occurred. The machines used are enumerated as follows:

1 and 2. Pentium III 450 with 96 Meg of RAM. Running Windows 98 with a relatively sparse array of software. These machines were ITS Lab consoles so the drives were reasonably free of offending software (things like conversions, software emulators, etc.)

3. Pentium II 300 with 96 Meg of RAM. This unit is under the same conditions as above.

4. Dell Inspiron 7500 with Celeron processor and 128 Meg of RAM. Running Windows 98. This unit is nearly brand new and has only the preinstalled software and Micorsoft Office 2000.

We were completely unable to get Build 2 to make a run successfully. The importing of the network files and the creation of ITS Options were successful but running an analysis put machines 1 through 3 into loops. When we tried to End Task to escape, Windows described IDAS as [Not Responding]. All of the attempted runs stalled out in Step 2. We allowed the machines to continue for up to 12 hours without progress.

On machine four IDAS Builds 1 and 2 were unable to create new ITS Options. Importing a database and altering existing ITS Options was fine, but the creation of new ITS Options froze IDAS. This occurred in both Builds 1 and 2 and resulted in very similar screenshots once the loop had begun. Runs with an imported database yielded results similar to those described above.

Another difficulty was encountered when we tried to edit the volume delay curves in the Benefits module. This was necessary to account for some time-based links in the MTC data. First, changes made to the any instance of a volume delay curve was transported to all facility types using that curve. Changes to the arterial curve the centroid connectors were using also changed the curve used by the facility type arterial, which was of course specified to an arterial curve. Since there were only four curve types (freeway, ramp, arterial and not used) we were unable to flatten the curve for centroid connectors without also flattening the curve for another facility type. Furthermore, any attempt to alter the values within the volume delay table resulted in a value of 0.00 in both the Urban and Suburban columns of the first row, corresponding to a V/C ratio of 0.00. This value persisted despite any efforts to change it and appeared if we change **any** cells in the table. This phenomenon was present across all machines and both Builds.

A recurring error popped up during our use of Build 1. It may be moot as Build 2 may have already addressed the issue. Near the end of our simulations, we tried to create an ITS Option within the Alternative presently used. A window opened with the title ‘Powerbuilder Class Library’ and contained the following message:

"For certain functionalities the PFC DataStore requires a reference to its parent window. One of these cases has just been encountered. To let DataStore know its parent window call **_SetParentWindow(…)** *function after DataStore creation."*

Following this, a second message of:

"Predetermined message **pfc_dwdberror** *not found."*

The active Alternative was then left devoid of any ITS Options and all new ITS Options created prompted the same error message. However, the ITS Options were still present in the Benefits, Costs and AG modules. Similarly, if IDAS was shut down immediately following the error, the ITS Options would reappear but so would the error as soon as they were accessed. The ITS Options were not deleted, simply dereferenced somehow. Furthermore, the error occurred on all machines around the same time and repeatedly if restarted.

Appendix B: Selected Output from IDAS Experiments

Appendix B Figure 1

BASELINE VALUES RAMP METERING

Ramp Metering - Baseline Volumes		Pretimed		Central Control	
Benefits					
Change in User Mobility		$ -51,442.60		$ -17,630.42	
Change in User Travel Time					
In Veh Travel Time		$ 0.00		$ 0.00	
Out of Veh Travel Time		$ 0.00		$ 0.00	
Travel Time Reliability		$ 235,986.94		$ 269,402.27	
Change in Costs Paid By Users					
Fuel Costs		$ -24,097.93		$ -35,051.40	
Non Fuel Operating Costs		$ 466.83		$ -1,075.04	
Accident Costs (internal)		$ 237,621.88		$ 246,386.30	
Change in External Costs					
Accident Costs (external)		$ 41,932.41		$ 43,479.07	
Emissions					
Hydrocarbons		$ -296.23		$ -100.97	
NO_x		$ -594.21		$ -1,464.26	
CO		$ -8,395.00		$ -2,047.87	
PM_{10}		$ 0.00		$ 0.00	
CO_2		$ 0.00		$ 0.00	
Global Warming		$ 0.00		$ 0.00	
Noise		$ 13.73		$ -31.62	
Other Mileage Based External Costs		$ 0.00		$ 0.00	
Other Trip Based External Costs		$ 0.00		$ 0.00	
Change in Public Agencies Costs		$ 0.00		$ 0.00	
Total Annual Benefits		$ 431,195.82		501,866.06	
Costs					
Total Annual Cost		$ 11,755.63		$ 359,972.55	
Benefit/Cost Comparison					
Net Benefit		$ 419,440.19		$ 141,893.51	
B/C Ratio		36.68		1.39	
Freeway Impacts					
			(%)		(%)
VMT (mi)	Initial: 72,628	71,777	-1.2	72,591	-0.1
VHT (hrs)	Initial: 1,611	1,550	-3.9	1,544	-4.3
Average Speed (mph)	Initial: 45.1	46	2.6	47	4.0
Person-Hrs Trav.	Initial: 2,094	2,015	-3.9	2,007	-4.3
Notes: For 3 hour peak AM normal volumes, Winnipeg		Pretimed scheme is for **pre-existing** ramp meters		Central control scheme is for **pre-existing** ramp meters	

Appendix B Figure 2

Ramp Metering - 300 % Augmented Vols.		Pretimed		Central Control	
Benefits					
Change in User Mobility		$	-1,279,848.00	$	-4,806,774.00
Change in User Travel Time					
In Veh Travel Time		$	0.00	$	0.00
Out of Veh Travel Time		$	0.00	$	0.00
Travel Time Reliability		$	5,723,287.00	$	5,556,274.00
Change in Costs Paid By Users					
Fuel Costs		$	-77,663.00	$	-18,084.00
Non Fuel Operating Costs		$	-56,235.00	$	-71,879.00
Accident Costs (internal)		$	325,709.00	$	338,661.00
Change in External Costs					
Accident Costs (external)		$	57,476.00	$	59,762.00
Emissions					
Hydrocarbons		$	-12,347.00	$	-17,456.00
NO_x		$	-17,330.00	$	-22,585.00
CO		$	-107,438.00	$	-156,776.00
PM_{10}		$	0.00	$	0.00
CO_2		$	0.00	$	0.00
Global Warming		$	0.00	$	0.00
Noise		$	-1,654.00	$	-2,114.00
Other Mileage Based External Costs		$	0.00	$	0.00
Other Trip Based External Costs		$	0.00	$	0.00
Change in Public Agencies Costs		$	0.00	$	0.00
Total Annual Benefits		$	4,553,957.00		859,029.00
Costs					
Total Annual Cost		$	11,755.63	$	359,972.55
Benefit/Cost Comparison					
Net Benefit		$	4,542,201.37	$	499,056.45
B/C Ratio			387.39		2.39
Freeway Impacts					
			(%)		(%)
VMT (mi)	Initial: 161,730	154,763	-4.5	158,111	-2.3
VHT (hrs)	Initial: 7,719	6,684	-15.5	6,569	-17.5
Average Speed (mph)	Initial: 21.0	23.2	9.5	24.1	12.9
Person-Hrs Trav.	Initial: 10,035	8,690	-15.5	8,539	-17.5
Notes: For 3 hour peak AM augmented volumes, Winnipeg. For augmented volumes, O-D trip table values were inc. by		Pretimed scheme is for **pre-existing** ramp meters		Central control scheme is for **pre-existing** ramp meters	

Appendix B Figure 3

Incident Mgmt - Baseline Volumes			FSP	
Benefits				
Change in User Mobility		$	0.00	
Change in User Travel Time				
In Veh Travel Time		$	0.00	
Out of Veh Travel Time		$	0.00	
Travel Time Reliability		$	204,181.50	
Change in Costs Paid By Users				
Fuel Costs		$	400,494.00	
Non Fuel Operating Costs		$	0.00	
Accident Costs (internal)		$	14,196.00	
Change in External Costs				
Accident Costs (external)		$	2,505.00	
Emissions				
Hydrocarbons		$	11,951.00	
NO_x		$	48,867.00	
CO		$	138,950.00	
PM_{10}		$	0.00	
CO_2		$	0.00	
Global Warming		$	0.00	
Noise		$	0.00	
Other Mileage Based External Costs		$	0.00	
Other Trip Based External Costs		$	0.00	
Change in Public Agencies Costs		$	0.00	
Total Annual Benefits		$	821,144.50	
Costs				
Total Annual Cost		$	1,088,419.00	
Benefit/Cost Comparison				
Net Benefit		$	-267,274.50	
B/C Ratio			0.75	
Freeway Impacts				
				(%)
VMT (mi)	Initial:		no change	0.0
VHT (hrs)	Initial:		no change	0.0
Average Speed (mph)	Initial:		no change	0.0
Person-Hrs Trav.	Initial:		no change	0.0
Notes: For 3 hour peak AM normal volumes, Winnipeg				

Appendix B Figure 4

Incident Mgmt - Augmented Volumes			FSP		
Benefits					
Change in User Mobility			$	0.00	
Change in User Travel Time					
In Veh Travel Time			$	0.00	
Out of Veh Travel Time			$	0.00	
Travel Time Reliability			$	10,426,841.80	
Change in Costs Paid By Users					
Fuel Costs			$	1,460,700.71	
Non Fuel Operating Costs			$	0.00	
Accident Costs (internal)			$	36,218.42	
Change in External Costs					
Accident Costs (external)			$	6,391.47	
Emissions					
Hydrocarbons			$	48,230.03	
NO_x			$	117,944.60	
CO			$	787,861.32	
PM_{10}			$	0.00	
CO_2			$	0.00	
Global Warming			$	0.00	
Noise			$	0.00	
Other Mileage Based External Costs			$	0.00	
Other Trip Based External Costs			$	0.00	
Change in Public Agencies Costs			$	0.00	
Total Annual Benefits			$	12,884,188.35	
Costs					
Total Annual Cost			$	1,088,419.00	
Benefit/Cost Comparison					
Net Benefit			$	11,795,769.35	
B/C Ratio				11.84	
Freeway Impacts					
					(%)
VMT (mi)	Initial:	161,730		161,730	0.0
VHT (hrs)	Initial:	7,719		7,719	0.0
Average Speed (mph)	Initial:	21		21	0.0
Person-Hrs Trav.	Initial:	10,035		10,035	0.0
Notes: For 3 hour peak AM normal volumes, Winnipeg					

Appendix B Figure 5

Costs of ITS Services - Ramp Metering

	Element cost	Units	Source of Values	Lifespan (years)	Cost Range ($K)	Steady-State Cost($K)
Capitol Costs						
	Ramp metering system	interchange	CH2MHill			30
	Ramp metering system	↓	Transcore			40
	Ramp metering system		ITS Arch.		30-50	30
	Ramp metering system		FHWA Core Infra.			40
O&M Costs						
	Ramp metering system	interchange	CH2MHill			3
	Ramp metering system	↓	Transcore			4
	Ramp metering system		ITS Arch.		1.5-2.5	1.5
	Leased line costs borne by TMCS		ITS Arch.			0.1
	Ramp metering system		FHWA Core Infra.			2

Appendix B Figure 6

Costs of ITS Services - Traffic Signal Synchronization

	Element cost	Units	Source of Values	Lifespan (years)	Cost Range ($K)	Steady-State Cost($K)
Capitol Costs						
	Linked signal system LAN		ITS arch.	20	40-70	40
	Local controller upgrades	intersection	ITS arch.	20	10-May	5
O&M Costs						
	Linked signal system LAN maint.		ITS arch.		0.8-1.4	0.8

Appendix B Figure 7

Costs of ITS Services - ATMIS

	Element cost	Units	Source of Values	Lifespan (years)	Cost Range ($K)	Steady-State Cost($K)
Capitol Costs						
	Fixed VMS & Controllers w/ structure	1 sign	Core Infra.			200
	Full Matrix VMS & Controllers w/ structure	↓	CH2MHill			125
	Full Matrix VMS & Controllers w/0 structure		Transcore			80
	Mid-Range VMS and Controllers		Transcore			60
	4 lane overhead structure		Transcore			100
	6 lane overhead structure		Transcore			120
	Fixed HAR and Controllers		Transcore, CH2MH			20
O&M Costs						
	Fixed VMS & Controllers w/ structure	1 sign	Core Infra.			10
	Full Matrix VMS & Controllers w/ structure	↓	CH2MHill			4
	Full Matrix VMS & Controllers w/0 structure		Transcore			4
	Mid-Range VMS and Controllers		Transcore			3
	4 lane overhead structure		Transcore			5
	6 lane overhead structure		Transcore			6
	Fixed HAR and Controllers		Transcore			2
	Fixed HAR and Controllers		CH2MHill			1
	Fixed HAR and Controllers		Core Infra.			1

Appendix B Figure 8

Benefit/Cost Summary

Project: Generic Freeway Network

	Weight		Augmented Volumes Two Pretimed Ramp Meters		Augmented Volumes Three Pretimed
Annual Benefits					
Change in User Mobility	1.00	$	77,426,807.17	$	53,444,440.65
Change In User Travel Time					
In-Vehicle Travel Time	1.00	$	102,793,586.52	$	75,239,894.22
Out-of-Vehicle Travel Time	1.00	$	(0.00)	$	(0.00)
Travel Time Reliability	1.00	$	1,447,241.08	$	1,247,926.29
Change in Costs Paid by Users					
Fuel Costs	1.00	$	792,704.15	$	653,016.75
Non-fuel Operating Costs	1.00	$	1,882,905.91	$	1,243,625.96
Accident Costs (Internal Only)	1.00	$	1,711,159.60	$	1,275,322.28
Change in External Costs					
Accident Costs (External Only)	1.00	$	301,965.02	$	225,053.64
Emissions					
Hydro Carbons	1.00	$	348,103.86	$	268,033.09
NOx	1.00	$	146,022.31	$	101,094.05
CO	1.00	$	3,701,696.85	$	2,856,951.81
PM10	1.00	$	(0.00)	$	(0.00)
CO2	0.00	$	(0.00)	$	-0
Global Warming	0.00	$	(0.00)	$	-0
Noise	1.00	$	12,552.71	$	8,290.84
Other Mileage-Based External Costs	1.00	$	(0.00)	$	(0.00)
Other Trip-Based External Costs	1.00	$	(0.00)	$	(0.00)
Change in Public Agencies Costs (Efficiency Induced)		$	0.00	$	0.00
Total Annual Benefits		$	190,564,745.17	$	136,563,649.58
Annual Costs					
Average Annual Private Cost			0.00		0.00
Average Annual Public Cost			22,991.71		34,487.57
Total Annual Cost		$	22,991.71	$	34,487.57
Benefit/Cost Comparison					
Net Benefit (Annual Benefit - Annual Cost)		$	190,541,753.46	$	136,529,162.01
B/C Ratio (Annual Benefit/Annual Cost)			8,288.41		3,959.79

Appendix B Figure 9

Benefit/Cost Summary

Project: Generic Network

Annual Benefits	Weight		Augmented Volumes Five Central Control Ramps
Change in User Mobility	1.00	$	70,931,426.65
Change In User Travel Time			
In-Vehicle Travel Time	1.00	$	105,372,694.16
Out-of-Vehicle Travel Time	1.00	$	(0.00)
Travel Time Reliability	1.00	$	2,107,832.56
Change in Costs Paid by Users			
Fuel Costs	1.00	$	403,054.70
Non-fuel Operating Costs	1.00	$	168,540.86
Accident Costs (Internal Only)	1.00	$	1,065,910.28
Change in External Costs			
Accident Costs (External Only)	1.00	$	188,099.30
Emissions			
Hydro Carbons	1.00	$	304,538.12
NOx	1.00	$	32,253.62
CO	1.00	$	3,258,775.51
PM10	1.00	$	(0.00)
CO2	0.00	$	(0.00)
Global Warming	0.00	$	(0.00)
Noise	1.00	$	1,123.61
Other Mileage-Based External Costs	1.00	$	(0.00)
Other Trip-Based External Costs	1.00	$	(0.00)
Change in Public Agencies Costs (Efficiency Induced)		$	0.00
Total Annual Benefits		$	**183,834,249.38**

Annual Costs		
Average Annual Private Cost		0.00
Average Annual Public Cost		415,557.69
Total Annual Cost	$	**415,557.69**

Benefit/Cost Comparison		
Net Benefit (Annual Benefit - Annual Cost)	$	**183,418,691.69**
B/C Ratio (Annual Benefit/Annual Cost)		**442.38**

Appendix B Figure 10

Benefit/Cost Summary			
Project: Generic Network			
			Augmented Volumes
Annual Benefits	Weight		Incident Management 40Percent
Change in User Mobility	1.00	$	0.00
Change In User Travel Time			
In-Vehicle Travel Time	1.00	$	(0.00)
Out-of-Vehicle Travel Time	1.00	$	(0.00)
Travel Time Reliability	1.00	$	2,368,918.31
Change in Costs Paid by Users			
Fuel Costs	1.00	$	740,156.42
Non-fuel Operating Costs	1.00	$	(0.00)
Accident Costs (Internal Only)	1.00	$	23,530.33
Change in External Costs			
Accident Costs (External Only)	1.00	$	4,152.40
Emissions			
Hydro Carbons	1.00	$	37,666.17
NOx	1.00	$	100,186.24
CO	1.00	$	487,418.88
PM10	1.00	$	(0.00)
CO2	0.00	$	(0.00)
Global Warming	0.00	$	(0.00)
Noise	1.00	$	(0.00)
Other Mileage-Based External Costs	1.00	$	(0.00)
Other Trip-Based External Costs	1.00	$	(0.00)
Change in Public Agencies Costs (Efficiency Induced)		$	0.00
Total Annual Benefits		$	**3,762,028.75**
Annual Costs			
Average Annual Private Cost			0.00
Average Annual Public Cost			1,083,624.68
Total Annual Cost		$	**1,083,624.68**
Benefit/Cost Comparison			
Net Benefit (Annual Benefit - Annual Cost)		$	**2,678,404.07**
B/C Ratio (Annual Benefit/Annual Cost)			**3.47**

Appendix B Figure 11

Benefit/Cost Summary

Project: Generic Freeway Network

Annual Benefits	Weight		Old Alternative Control and Management Synergy
Change in User Mobility	1.00	$	62,378,456.20
Change In User Travel Time			
In-Vehicle Travel Time	1.00	$	110,750,242.32
Out-of-Vehicle Travel Time	1.00	$	(0.00)
Travel Time Reliability	1.00	$	11,400,928.82
Change in Costs Paid by Users			
Fuel Costs	1.00	$	2,879,300.06
Non-fuel Operating Costs	1.00	$	(2,155,173.42)
Accident Costs (Internal Only)	1.00	$	34,374.56
Change in External Costs			
Accident Costs (External Only)	1.00	$	6,065.81
Emissions			
Hydro Carbons	1.00	$	167,019.67
NOx	1.00	$	133,297.91
CO	1.00	$	1,825,624.85
PM10	1.00	$	(0.00)
CO2	0.00	$	(0.00)
Global Warming	0.00	$	(0.00)
Noise	1.00	$	(14,367.82)
Other Mileage-Based External Costs	1.00	$	(0.00)
Other Trip-Based External Costs	1.00	$	(0.00)
Change in Public Agencies Costs (Efficiency Induced)		$	0.00
Total Annual Benefits		$	**187,405,768.94**
Annual Costs			
Average Annual Private Cost			0.00
Average Annual Public Cost			1,464,780.06
Total Annual Cost		$	**1,464,780.06**
Benefit/Cost Comparison			
Net Benefit (Annual Benefit - Annual Cost)		$	**185,940,988.89**
B/C Ratio (Annual Benefit/Annual Cost)			**127.94**

Appendix B Figure 12

Benefit/Cost Summary

Project: Generic Freeway Network

Annual Benefits	**Weight**		**Augmented Volumes Pretimed-Management Synergy**
Change in User Mobility	1.00	$	(4,482,967.58)
Change In User Travel Time			
In-Vehicle Travel Time	1.00	$	(28,682,820.77)
Out-of-Vehicle Travel Time	1.00	$	(0.00)
Travel Time Reliability	1.00	$	2,685,456.37
Change in Costs Paid by Users			
Fuel Costs	1.00	$	418,421.38
Non-fuel Operating Costs	1.00	$	(1,662,623.86)
Accident Costs (Internal Only)	1.00	$	(125,409.12)
Change in External Costs			
Accident Costs (External Only)	1.00	$	(22,130.85)
Emissions			
Hydro Carbons	1.00	$	(24,152.41)
NOx	1.00	$	23,330.83
CO	1.00	$	(194,640.64)
PM10	1.00	$	(0.00)
CO2	0.00	$	(0.00)
Global Warming	0.00	$	(0.00)
Noise	1.00	$	(11,084.16)
Other Mileage-Based External Costs	1.00	$	(0.00)
Other Trip-Based External Costs	1.00	$	(0.00)
Change in Public Agencies Costs (Efficiency Induced)		$	0.00
Total Annual Benefits		$	**(32,078,620.80)**

Annual Costs			
Average Annual Private Cost			0.00
Average Annual Public Cost			1,088,359.47
Total Annual Cost		$	**1,088,359.47**

Benefit/Cost Comparison			
Net Benefit (Annual Benefit - Annual Cost)		$	**(33,166,980.27)**
B/C Ratio (Annual Benefit/Annual Cost)			**(29.47)**

Appendix B Figure 13

Performance Summary Project: Generic Freeway Network, ITS Option(s): Five Pretimed Ramps By: Facility Type	Arterial	Centroid Connector	Expressway	Freeway	Ramp	Transit	Total
Vehicle Miles of Travel							
Control Alternative	1,193,519	126,604	231,829	105,072	4,593		1,661,617
ITS Option	1,206,388	126,576	228,976	140,138	4,414		1,706,492
Difference (%)	12,869(1.1%)	-28(0.0%)	-2,853(-1.2%)	35,066(33.4%)	-179(-3.9%)		44,875(2.7%)
Vehicle Hours of Travel							
Control Alternative	349,804	8,440	6,654	4,100	1,511		370,510
ITS Option	363,957	8,438	6,582	3,849	3,398		386,223
Difference (%)	14,152(4.0%)	-2(0.0%)	-72(-1.1%)	-251(-6.1%)	1,886(124.8%)		15,714(4.2%)
Average Speed							
Control Alternative	3.4	15.0	34.8	25.6	3.0		4.5
ITS Option	3.3	15.0	34.8	36.4	1.3		4.4
Difference (%)	0(-2.9%)	0(0.0%)	0(-0.1%)	11(42.1%)	-2(-57.2%)		0(-1.5%)
Person Hours of Travel							
Control Alternative	349,804	8,440	6,654	4,100	1,511		370,510
ITS Option	363,957	8,438	6,582	3,849	3,398		386,223
Difference (%)	14,152(4.0%)	-2(0.0%)	-72(-1.1%)	-251(-6.1%)	1,886(124.8%)		15,714(4.2%)
Number of Trips							
Control Alternative	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
ITS Option	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
Difference (%)	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
Number of Fatality Accidents							
Control Alternative	7.8772E-03		1.5301E-03	4.2029E-04			9.8276E-03
ITS Option	7.9622E-03		1.5112E-03	3.9011E-04			9.8635E-03
Difference (%)	8.493E-05(1.1%)		1.883E-05(-1.2%)	3.018E-05(-7.2%)			3.593E-05(0.4%)
Number of Injury Accidents							
Control Alternative	1.8767E+00		3.6453E-01	7.4010E-02			2.3152E+00
ITS Option	1.8969E+00		3.6004E-01	6.7725E-02			2.3247E+00
Difference (%)	2.023E-02(1.1%)		4.486E-03(-1.2%)	5.285E-03(-8.5%)			9.464E-03(0.4%)
Number of PDO Accidents							
Control Alternative	2.6197E+00		5.0884E-01	1.2325E-01			3.2517E+00
ITS Option	2.6479E+00		5.0258E-01	1.1276E-01			3.2632E+00
Difference (%)	2.825E-02(1.1%)		5.261E-03(-1.2%)	1.048E-02(-8.5%)			1.15E-02(0.4%)
Hydrocarbon Emissions (tons)							
Control Alternative	7.699	0.372	0.377	0.205	0.048		8.700
ITS Option	7.828	0.372	0.372	0.226	0.052		8.850
Difference (%)	0.13(1.7%)	0.00(0.0%)	0.00(-1.2%)	0.02(10.4%)	0.00(9.2%)		0.15(1.7%)
Carbon Monoxide Emissions (tons)							
Control Alternative	41.629	2.454	2.022	1.208	0.238		47.552
ITS Option	42.331	2.454	1.994	1.253	0.249		48.281
Difference (%)	0.70(1.7%)	0.00(0.0%)	-0.03(-1.4%)	0.05(3.7%)	0.01(4.3%)		0.73(1.5%)
Nitrous Oxide Emissions (tons)							
Control Alternative	3.016	0.285	0.513	0.259	0.013		4.086
ITS Option	3.052	0.285	0.507	0.351	0.013		4.208
Difference (%)	0.04(1.2%)	0.00(0.0%)	-0.01(-1.2%)	0.09(35.6%)	0.00(-1.5%)		0.12(3.0%)
PM10 Emissions (tons)							
Control Alternative							
ITS Option							
Difference (%)							

Appendix C: Report on Cost and Benefit Data: Literature values

<u>Costs</u>

Reports gathered on cost data have been gone through and the data summarized in the attached Excel spreadsheet for the various TOPS strategies. The ranges of values for the ITS service are quite large in some cases, and it is somewhat unclear what particular strategies entail when developing the cost estimates. However, some form of reasonably good estimates was found, although it may not be in the correct form. For example, ATMIS is defined as encompassing practically everything that relates to traveler information systems, but it appears that for our purposes we are only analyzing CMS's. Below is a summary of the information that has been organized into the spreadsheet. Much of the info is incomplete, but hopefully it will provide a good starting point for delving further into the costs of the TOPS elements.

Ramp Metering

The estimates obtained for ramp metering systems range from $30,000 to $50,000 per interchange, with steady state estimates all between 30 and 40K dollars. O&M costs range from 1.5 to 4K per year. I was unable to find any estimates of specific components to ramp metering systems, besides loop detectors, but could look more into that if it were necessary to do so.

Freeway Service Patrol

The estimates for a FSP program were not nearly as well-defined as for ramp metering. One report I gathered info from gave specific cost for a FSP in Los Angeles, but I am not sure how applicable it can be to our cost estimates. It contains a somewhat detailed cost breakdown for the 150 truck patrol in terms of operating and capitol costs in the report; I just included the total costs in the attached spreadsheet.

Other estimates found were for various services related to FSP, but some may fall under the category of emergency management instead. I was not sure if a FSP program would need some of the services I included in the spreadsheet, such as a portable CMS (or VMS) or HAR. I would need to get some further information of the actual components needed to implement a FSP before going much further with this.

ATMIS

Since it looks as though in the report we will only be looking at CMS's for traveler information, I only included those in the ATMIS cost estimates (actually some HAR info as well). Numbers seemed to range greatly depending on the size and type of the CMS, so I imagine we will have to specify for a particular kind. I guess there are also aspects to ATMIS that cost data would be needed for as well, such as CCTV with incident detection or costs to operate a CMS from a TMC.

TSS

Traffic signal synchronization is somewhat nebulous when it comes to cost data for it. There is a scarcity of reports pertaining to it, and the few that I have found provide little in terms of costs. The ITS architecture provides some measure of costs, "for traffic signal control at major intersections and on arterial roadways for urban areas….for a single jurisdiction." Hopefully I will be able to find some more specific data on TSS through Caltrans or other sources.

Benefits

There are significantly more reports on the benefits of TOPS strategies than there are on costs. I have not gone through the ones I have found in great depth yet, but some of the benefits are listed below.

Ramp Metering

Denver, CO
- 5-50% crash rate reduction
- 27-37% travel time savings
- 13% reduction in delay

Portland, OR
- 43% reduction in crashes
- 7% reduction in transit travel time

Minneapolis, MN
- 27% reduction in crash rate

Seattle, WA
- 48% increase in avg speed
- 38% reduction in crash rate
- 48% reduction in travel time

Freeway Service Patrol

Los Angeles, CA
- B/C ratio of 3.8 to 5.6 for reductions of 10-15 minutes in incident duration

Automated Traffic Signal Control (same as signal synchronization?)

Los Angeles, CA
- 41% reduction in stops
- 13% reduction in travel time

- 14% increase in avg speed
- 13% reduction in fuel consumption
- 20% decrease in delay

Abilene, TX

- 13% reduction in travel time
- 22% increase in avg speed
- 37% decrease in delay

Table 1. Measured Safety Benefits by User Services

User Services	**Safety Benefits**	**Location**	Source
Traffic control	• Accident response time: -20 min. • Accident reduction: 27%/Y (drop from 421 to 308 accidents/Y) • Collision reduction: 1.29/Mil.VMT/Y (drop from 3.4 to 2.1 Mil.VMT/Y)	Minneapolis, MN	Minnesota Department of Transportation Freeway Operations Meeting Minutes. January, 1994
Electronic payment services	• Accident reduction: 100% 1st Year	Oklahoma Turnpike Authority, OK	Spasovic et.al. 1995.
Intersection crash warning & control	• Accident reduction: 20% (When system was deployed for half the total fleet size)	Greyhound	Renforth, James D. February, 1994.
Public Transportation Management + Public Travel Security	• Accident response time: - 40 ~ 75%	Unknown	
Public Transportation Management + Public Travel Security	• Accident response time: - 2 ~ 9 min.	Kansas, KS	
AVCSS (Collision Warning Device)	• Accident reduction: 33%	Transport Besner Trucking Co.	Lareau, Daniel. February, 1996.
ATMS	• Freeway accidents: - 15 ~ 50%	A Group of TMCs surveyed	Robinson, J., and Piotrowit

			cz, G. June, 1995.
Incident Management Program	• Incident response time: - 5 ~ 7 min.	City of Richmond, TX	
ATIS + ATMS + APTS	• Injury Accident: -6% • # Injuries: -27% • # serious injuries: -100% • # L-turn accident: -89%	Oakland County, MI	

Table 2. Measured Efficiency Benefits by User Services

User Services	Benefits	Location	Source
• ATIS	Travel Time: -19% ~ -20% Prob. of missing turn: -1.8%	Orlando, FL	Inman, V., et.al. 1996.
• Traffic Control	• Travel Time: -13% • Veh. Stops: -41% • Avg. Speed: +14% • Int. Sec. Delay: -20%	Los Angeles, CA	
• Traffic Control	• Travel Time: -13.8% • Delay: -37.1% • Speed: +22.2%	Abilene, TX	Orcutt Associates. 1994.
• Traffic Control	• Avg.delay/Ramp: =< 3 min. • Speed: upto +20% while traffic increased 10%~100%	Seattle, WA	Henry, K. And Meyhan, O. January, 1989.
• Traffic Control	• Travel Time: -20% • Veh. Stops: -93%	Australia; U.K; Scotland	
• Traffic Control	• Avg. Speed/Peak Hour: +35% while traffic increased 32% • Fwy Capacity: +22% • Throughout: +400 Veh./lane.hr	Minneapolis, MN	Minnesota Department of Transportation Freeway Operations Meeting Minutes. January, 1994
• Electronic Payment Services	• Throughput: +600~650 Veh./lane.hr compared to a staffed lane (Improved from 350-400 to 1000 veh./lane.hr) • Speed: + 13 ~ 17 mph (Improved from 8-12 to 25 mph, when 8 manual lanes were replaced with 5 ETC lanes)	Tappan Zee Bridge, NY	Gallagher, M., Zimmerman, M. February, 1996.
• Electronic Payment Services	• Time Savings: 1 mil. Hrs/Y • Operating $: -91%/Y	Oklahoma, OK	
• Bus priority + traffic signal	• Travel time: range from 5% reduction (10min30s trip reduced to 10 min trip) To 7.8% reduction (9min45s trip reduced to 9 min trip)	Portland, OR	Kloos, W., et.al. July, 1994.
• APTS (CAD System)	• Operating $: -2% per passenger trip -9% per vehicle mile	Winston-Salem Transit Authority, NC	Stone, J. 1995.
• APTS	• Operating $: -50% per passenger mile in 5 years	Sweetwater County, WY	
• CHART program	• Delay Associate with non-recurrent congestion: -5%/Y (= 2	Maryland, MD	COMSIS Corporatio

	mil. VH/Y)		n. May, 1996.
• CVO	• Operation $: -$0.12 ~ $0.20 per truck mile	Telesat, Canada	Hallowell, S., and Morlok, E. January, 1992.
• SCOOT	• Travel time: -8% • Delay: -17% • Veh. Stops: -22%	Toronto, Canada	Siemens Automotive. 1995.
• ATMS	• Speed: +16~62% while traffic increased 17~25%	A Group of TMCs surveyed which used ramp metering	Robinson, J. And Piotrowicz. June, 1995.
• ATMS+ATIS+APTS	• Speed (Pk. Hrs): +19% • Int. Sec. Delay: -30%	Oakland County, MI	
• ETC	• Cost savings: $160,000/lane/Y (For replacing a single manual lane with ETC, FY 1993 dollars).	Oklahoma Turnpike Authority	PATH website (http://www.its.berkeley.edu/path), Spasovic et.al. 1995.
• EMS (Incident Management?)	• Delay: -48% ~ 64% hours/Y • Cost savings: $20.5 ~ $27.3 mil./Y	Northern Virginia, VA	Maas, G. 1996.
• Helper Program	• Reduction of duration of a stall: -8 min.	Minnesota	
• INFORM (Traveler Service Information + Traffic Control)	• Time savings for incident related delay: 300,000 VH/Y, or 1,900 VH per Peak Hour incident • Fwy speed: +13%/PkHr while VMT increased 5% in PM Peak • Avg. Queue: 1.2 ~ 3.4 Vehicles • Throughput: Max. +7%	Long Island, NY	Smith, S., and Perez, C. January, 1992.

Table 3. Measured Productivity Benefits by User Services

User Services	Benefits	Location	Source
• ATIS (??)	• Prob. of missing turn: -1.8%	Orlando, FL	Inman, V., et.al. January, 1996.
• En-Route Driver Information • Route Guidance (??)	• # of getting lost: -4.5% • Prob. of diverting: +40%	Los Angeles, CA	
• Public transportation management • Public travel security	• Bus on-time performance: +23% (AVL-equipped buses)	Baltimore, MD	Jones, W. November, 1995.
• Public transportation management • Public travel security	• Bus on-time performance: +12% in the 1st year • Equipment req.: -10%	Kansas City, KS	Jones, W. November, 1995.
• CVO	• Fleet utilization: +13%	Mets of Indianapolis, ID	Hallowell, S., and Morlok, E. January, 1992.
• CVO	• $ savings: $10,000/Month	Best line of Minnesota, MN	Hallowell, S., and Morlok, E. January, 1992.
• CVO	• Fleet productivity: +4% • Fleet utilization: 20-25 miles/per truck per day	J.B. Hunt Trucking of Lowell, AR	
• CVO	• Loaded miles: +20% • $ savings: +$50/Wk	Schneider, Green Bay, WI	Hallowell, S., and Morlok, E. January, 1992.
• CVO	• Labor productivity: +50~100 miles/day per driver	Trans-Western Ltd. Lerner, CO	Hallowell, S., and Morlok, E. January, 1992.
• CVO	• # pickup or delivers per truck per day: + 5%~25% • Time savings: 30 min per day	Survey from 69 trucking companies in 1992	
• CVO	• Loaded miles: +20% • Tel. $: -$30~$150/Month • Load factor: +0.7% • Total miles traveled: +9%	Frederick Transport of Dundas, Ontario, Canada	Hallowell, S., and Morlok, E. January, 1992.

Table 4. Measured Mobility/Accessibility Benefits by User Services

User Services	Benefits	Location	Source
TravTek, ATIS	• 63% local drivers & 38% rental driver find the service is helpful in finding destination	Orlando, FL	Inman, V. et al. March, 1996
Pathfinder	• increase in diversion: 40%	Los Angeles, CA	JHK & Associates. February, 1993.
TravTek, ATIS	• access times: 1660/month	Minneapolis, MN	Remer, M., and Atherton, T., and Gardner, W. November, 1995.
Genesis, ATIS	• % daily users: 65% • % occasional users: 88%	Minneapolis, MN	Wetherby, B. March, 1996.
ATIS	• increase in calling vol. 80%	Rochester-Genesee RTA	US DOT Federal Transit Administration. November, 1995.
ATIS	• AVG caller wait time: - 58 Second • caller hang-up rate: - 7%	New Jersey	Passenger Transport. January, 1994.
SmarTraveler	• increase in usage: 138% (In one year, from October 1994 to October 1995, monthly calls increased from 176,943 to 244,182)	Boston, MA	US DOT Federal Transit Administration. November, 1995.
Electronic fare payment	• usage on express routes: 90%	Phoenix, AZ	

Appendix D: Experiments to Run with IDAS

First step is to load the network and to ensure it is operating with the speeds and congestion levels we want. Each of us should e working with a common data set and network so our experiments are comparable.

Need to decide the degree of deployment (i.e. how broadly deployed in the network), what the degree of congestion is.

We have to consider how to 'mimic' the Orange County setting so the results are comparable with to those of Will Recker.

Ramp Metering

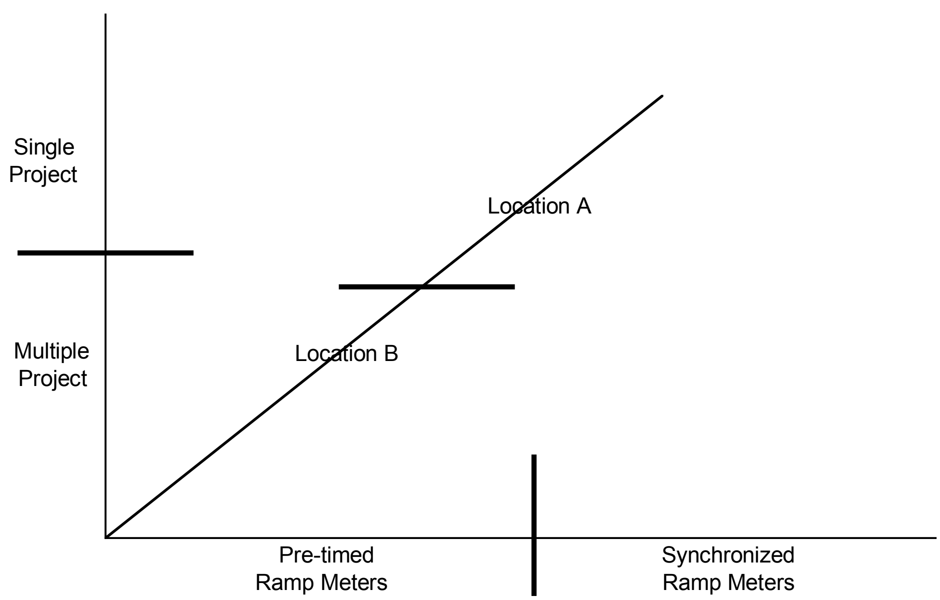
Three steps to be explored. First, run the model to establish the base case for traffic lows and speeds. Next, introduce simple ramp meters at two or three locations in the network. These meters will not be integrated. We have to also consider how spread out we want the ramp meters. Next, introduce the newer technology of ramp meters so they are integrated.

<u>Out put:</u>

1. Benefits of introducing ramp meters as distinct from none
2. Benefits of moving to new technology ramp meters

Process for Experiment

We want output in three dimensions single project versus multiple projects, old technology versus new technology and location. The diagram illustrates where e should place our experiments



User Inputs
1. Load data set and network
2. Place ramp meters at desired locations
3. Specify freeway links affected by the ramp meters
4. Specify year opened mid-year of construction, corridor number, number of controlling TMC

Changes to default Values
1. Capacity reduction at metered on-ramp (default is 50%)
2. Capacity increase in Freeway links affected by ramp meter
   - 5.5% for timed ramp meter
   - 13.5% for traffic adaptive ramp meter
3. accident rate reduction of 38% at ramp and on freeways
4. emission rates
5. fuel consumption rates
6. value of time
7. other user costs

Traffic Management Systems (TMS)

Range of investments to evaluate is

1. communications Equipment and TMS (Traffic Monitoring Station) for TMC and hubs
2. install communication/TOS filed hardware
3. install CCTV and other communications system
4. Upgrade surveillance system (**Of questionable value**)

Freeway Service Patrols (FSP) (Incident Management)

1. Incident detection
2. Incident response/management
3. Incident detection/verification/response/management combined

User Input

1. Load data and network
2. Indicate links containing IM components, which links are impacted
3. Deployment information for each IM component, year of deployment, mid-year construction improvement description
4. Review default values

Default values
1. Change in incident duration
2. Change in emissions
3. Change in fuel consumption rate
4. Change in fatality rate
5. Value of time

ATMIS (Changeable Message Signs)

Project found in 'Regional Intermodal Traveler Information Systems'. We would like to explore signs versus FM radio broadcast.

Look at assumptions of traffic diversion with message signs. The assumptions needing scrutiny are:

- What percentage of vehicles react to information
- What percentage of the time is the sign activated
- How much time is saved if heed the signs information

With Highway advisory radio the same idea of assumptions must be examined;

- Percent of people reacting
- Percent of people listening
- Percent of time information is relevant
- How much time saved

Synergies

We turn on

1. Ramp metering with new technology with TMC
2. Use number 1 and add incident management
3. Use number 2 and add in message signs