Final report of ITS Center project: IDAS as a prioritizing tool

A Research Project Report

For the National ITS Implementation Research Center

A U.S. DOT University Transportation Center

Feasibility Assessment of ITS Deployment Analysis System (IDAS) for ITS Evaluation

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16. Abstract

This study investigated the feasibility of utilizing the ITS Deployment Analysis System (IDAS) program version 2.2 as a tool for evaluating ITS deployment plans. Firstly, an online survey was conducted among MPO staff in the US in order to understand the usage and the issues in the IDAS for the ITS deployment plan evaluation. Secondly, case studies were carried out to examine the benefits of deploying several popular ITS options.

The survey results indicated that the usage of the IDAS program was somewhat limited among MPOs. The survey results also indicated that the most desired updates in the IDAS program were (i) elaborating ITS impact methodologies, (ii) upgrading default values in the cost and benefit modules and (iii) incorporating emission factors based on MOBILE 6. The case studies of Hampton Roads area and a simple network with six popular ITS options identified the following three issues: (i) overestimation of ITS option benefits when the benefits are estimated from travel time savings, (ii) incorrect interpolation on travel time reliability rates for non-integer V/C ratios, and (iii) insensitive cost savings for combined ITS options.

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Abstract

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Table of Contents

Table of Figures

Table of Tables

1 Introduction

During past two decades the Intelligent Transportation System (ITS) has been deployed throughout major metropolitan areas and a few selected urban and rural areas. With considerable benefits reported from such deployments, more ITS implementation plans are expected to be developed and these plans need to be evaluated for prioritization and feasibility testing. As traditional transportation planning models are not readily applicable for such evaluations and the use of microscopic simulation tools is somewhat limited due to the significant efforts required for the network coding, simulation calibration and validation, and computation time, the Federal Highway Administration (FHWA) supported the development of a sketch-level tool called ITS Deployment Analysis System (IDAS) for the evaluation of ITS deployments. The IDAS program has capabilities of (i) screening and prioritizing ITS alternatives and (ii) calculating relevant benefits and costs for such alternatives.

A few studies utilized the IDAS program for the evaluation of ITS projects. Sadek and Baah (*1*) used the IDAS program to estimate the benefits of deploying three ITS improvements: smart corridor project, transit vehicle AVL and I-89 ATMS in Chittenden County, Vermont. In order to examine IDAS's applicability in evaluating ITS benefits, they performed sensitivity analyses of a few selected parameters and found certain parameters tend to have more significant impacts on the results. Heither and Thomas (*2*) tested the IDAS software through analyzing several types of ITS deployments (electronic toll collection and freeway variable message signs for highway deployments, and electronic transit fare collection system and transit vehicle signal priority for transit deployment) in the northeastern Illinois case study. In the report, they provided the detailed explanations for IDAS's methodologies for ITS benefits, IDAS's parameter settings and the process for modeling ITS deployments in IDAS. In addition, they summarized several technical issues and recommendations found during their study.

This study aims to assess the feasibility of the IDAS program for evaluating ITS deployments. The assessment of the feasibility of IDAS was conducted in two fold. Firstly, a survey on the IDAS usage among the Metropolitan Planning Organizations (MPOs) was conducted. The MPOs were selected since they are the main user group of the IDAS program. Secondly, a case study using an actual transportation planning model was conducted. The purpose of the case study was to test the feasibility of IDAS by examining the effects of combining multiple ITS elements into a single ITS deployment (a.k.a., ITS options according to the definition of the IDAS manual) in terms of changes in the relevant benefits and costs. For the case study, the following steps were implemented: i) selecting a site for the case study, ii) importing a transportation planning model into IDAS, iii) building various ITS options, and iv) evaluating these options via IDAS. In addition to the real world network used in the case study, a manageable simple test network was also utilized to further investigate a few issues identified during the case study evaluation.

2 ITS Deployment Analysis System (IDAS)[1]

IDAS is a sketch-level ITS analysis tool that is designed to measure various ITS benefits and costs based on transportation planning model and three major resources – default ITS impact settings, the IDAS Equipment Database Spreadsheet, and the ITS Library for benefit measures (*3*). These three resources are the results of several years' efforts by IDAS developers on in-depth studies of the ITS deployments in the US.

2.1 Structure

The IDAS program consists of five analysis modules:

- An Input/Output Interface Module (IOM),
- An Alternative Generator Module (AGM),
- A Benefit Module,
- A Cost Module, and

[1] Cambridge Systematics, the developer of the IDAS program, had an opportunity to review this report. The comments from Cambridge Systematics are shown in footnote with Bold and Italic font style.

- An Alternative Comparison Module (ACM).

The IOM supports importing a transportation planning model, which usually consists of node data (node number and its coordination), link data (from node, to node, distance, capacity, the number of lanes, speed and district information, mode information, area information, and so on), zone data and trip tables. The benefit module includes four submodules – the travel time/throughput submodule, emission submodule, energy submodule, safety submodule and travel time reliability submodule. Each submodule quantifies the resulting benefits from various ITS deployments using imported transportation planning model, ITS impact settings and ITS library. The cost module is used to determine the cost for various ITS elements based on the IDAS Equipment Database Spreadsheet. The ACM conducts benefit/cost analysis and risk analysis for selected ITS options based on results from the benefits module and the cost module (*3*).

2.2 Benefit-Cost Summary and Performance Summary

The results of the IDAS analysis can be summarized with three major categories: annual benefits, annual costs and benefit cost comparison as shown below:

- Annual Benefits
  - Change in User Mobility,
  - Change In User Travel Time,
  - Change in Costs Paid by Users,
  - Change in External Costs,
  - Change in Public Agencies Costs, and
  - Other Calculated Benefits.
- Annual Costs
  - Average Annual Private Sector Cost, and
  - Average Annual Public Sector Cost.
- Benefit/Cost Comparison
  - Net Benefit (Annual Benefit - Annual Cost), and
  - B/C Ratio (Annual Benefit/Annual Cost).

The above values are provided in 1995 dollars based on selected discount and inflation rates.[2] In addition, IDAS produces performance summary such as vehicle miles of travel, vehicle hours of travel, accidents and emissions for control alternative (baseline without any ITS options) and ITS option (improvement from selected ITS option) and their differences.[3]

3 IDAS Usage Survey

3.1 Survey

The IDAS program was developed under the technical guidance from a committee comprised of representatives from a variety of MPOs. Thus, it is logical to conduct a survey on the IDAS program from MPO staff. In order to conduct an online survey, the email addresses of MPO staff who are in charge of either ITS or transportation planning were obtained from the official Website of Association of Metropolitan Planning Organizations (AMPO)[4]. A total of 291 contacts were gathered and an on-line survey (see the Appendix A) was sent to these addresses using a commercial survey Website[5].

The survey consists of three parts of questionnaires. The first part asks the awareness of IDAS in "Yes" or "No" answer. When the response is "No", the survey is ended. If the response were "Yes", then the user was further inquired of the second part of the survey

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[2] ***IDAS can reflect benefits and cost in any year dollars, default is 1995 dollars*** [comment from Cambridge Systematics].

[3] According to the IDAS manual, the control alternative means the baseline for building and comparing ITS options. The Control alternative is based on the traffic assignment of imported transportation planning model without any ITS options. The ITS option is an ITS deployment alternative. The performance measures of the ITS option are produced directly from the control alternative with related parameter setting or new traffic assignment with improvement from the ITS option (for example, the increase of capacity in the arterial traffic management systems). The benefits of ITS option are based on the difference between the control alternative and the ITS option. More explanation is prepared in Chapter 3.

[4] Association of Metropolitan Planning Organizations (http://www.ampo.org/index.html)

[5] Zoomerang (http://www.zoomerang.com)

asking the usage of the IDAS. Again, when the answer is "No", the survey is ended. When the answer is "Yes", the main questionnaire was surveyed. The third part of the survey included the feasibility of IDAS. The questionnaire used in the survey is attached in Appendix A.

3.2 Survey Results

A total of 76 MPO staff responded on the survey. Table 1 summarizes the responses to the first two questions about awareness and experience of using IDAS.

Table 1. Responses of Awareness and Experience of Using IDAS

Survey Question	Answer	Response
Are you aware of ITS Evaluation Tool called IDAS (ITS Deployment Analysis System)?	Yes	33 (43%)
	No	43 (57%)
Have you or your agency ever used IDAS (ITS Deployment Analysis System) in any projects?	Yes	8 (24%)
	No	25 (76%)

Table 2 summarizes the opinions of the IDAS program usage from the eight those who stated they have used the IDAS program. It is noted that the response rate means the percentage of people who selected the answer, out of the number of people who answered that question. For example, 100% at the sixth row of the third column under response rate in Table 2 indicates that seven people answered this question out of eight people and all seven people selected the answer.

Table 2. Responses about Usage of IDAS

Question	Answer	Response	Response Rate
What was the purpose of using IDAS in the project? (Check all that apply)	Screening ITS alternatives	5	71%
	Prioritizing ITS alternatives	4	57%
	Estimating life-cycle costs of ITS alternatives	3	43%
	Scheduling ITS deployment	3	43%
	Estimating emissions from ITS deployment	2	43%
Which of the following ITS elements from the IDAS have you used in the project? (Check all that apply)	Arterial Traffic Management Systems	7	100%
	Freeway Management Systems	4	57%
	Advanced Public Transit Systems	4	57%
	Incident Management Systems	6	86%
	Electronic Payment Systems	1	14%
	Railroad Grade Crossing Monitors	1	14%
	Emergency Management Services	2	29%
	Regional Multimodal Traveler Information Systems	1	14%
	Commercial Vehicle Operations	1	14%
	Advanced Vehicle Control and Safety Systems	1	14%
	Supporting Deployments	1	14%
	Generic Deployments	1	14%
Would you recommend an improvement in any of the following functions of IDAS? (Check all that apply)	Upgrade Input/Output Interface Module	4	57%
	Upgrade default values in the Cost and Benefit Modules	5	71%
	Upgrade default values in the Alternative Comparison Module	4	57%
	Elaborate ITS Impact Methodologies	6	86%
	Incorporate emission factors based on MOBILE 6	5	71%

It is found that screening ITS alternatives was the most popular purpose of using IDAS and it was followed by prioritizing ITS alternatives. The most frequently used ITS elements in IDAS was Arterial Traffic Management Systems and the second was Incident Management Systems. In the future upgrade desired by respondents, elaborating ITS Impact Methodologies was dominant and followed by upgrading default values in the Cost and Benefit Modules and incorporating emission factors based on MOBILE 6. The confidence on the IDAS results was surveyed and summarized in Table 3.

Table 3. Confidence on IDAS Results

Questions	Answers	Number of Responses (Response Rates)				
		Outstanding	Excellent	Good	Average	Poor
How confident were you about the results of the following alternative comparison analyses, if you had used?	Changes in User Mobility and Travel Time	1 (14%)	1 (14%)	4 (57%)	0 (0%)	0 (0%)
	Changes in User Costs (including accident cost)	0 (0%)	4 (50%)	2 (25%)	2 (25%)	0 (0%)
	Emissions	0 (0%)	2 (29%)	1 (14%)	2 (29%)	1 (14%)
	Average Annual Costs of ITS Alternatives	1 (14%)	2 (29%)	3 (43%)	1 (14%)	0 (0%)

In Table 3, respondents seem to be quite confident on the IDAS results. All responses except for emissions have better than average rate. In the case of emissions, the half of respondents selected average or poor. According to Megan (*4*), MOBILE 6 generally estimates higher emissions for past years and lower emissions for future years when compared to those of MOBILE 5. This is because MOBILE 6 was developed under more elaborated and acceptable methods than MOBILE 5 and it considers recent technical improvements related to making vehicle and fuel. Furthermore, since IDAS is usually used to evaluate future ITS deployments, the respondents seems to utilize more accurate emission rates based on MOBILE 6 rather than the current MOBILE 5 (See Table 2 for desired future updates in IDAS).

4 Hampton Roads Case Study for IDAS Feasibility

4.1 Hampton Roads Area

As shown in Figure 1, Hampton Roads, Virginia, is compromised of the independent communities including Chesapeake, Franklin, Hampton, Newport News, Norfolk, Poquoson, Portsmouth, Suffolk, Virginia Beach, and Williamsburg, and the Counties of Gloucester, Isle of Wight, James City, Southampton, Surry, and York. Total population of Hampton Roads is 1,574,801 people in 2000 (the nation's 31st largest metropolitan area ranked by population).[6] Norfolk is famous for the home of naval vessels. There are three waterfront Marine Terminals (Virginia International Terminal, Newport News Marine Terminal and Portsmouth Marine Terminal) in Hampton Roads area. Furthermore, Virginia Beach and Williamsburg are well known the nation's tourist attractions.

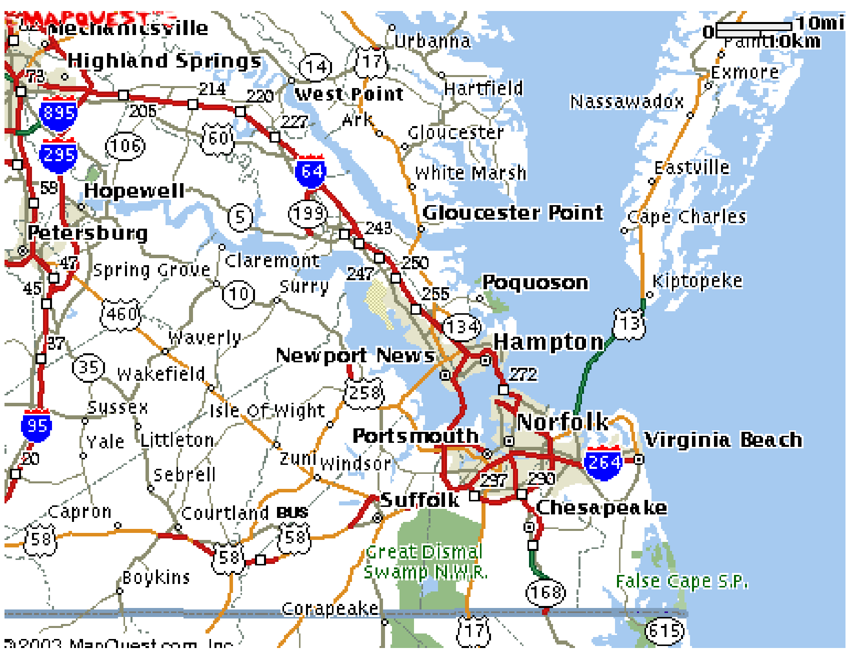

Figure 1. Location of Hampton Roads Area

(Source: www.mapquest.com)

[6] US Census Bureau (http://www.census.gov/population/www/cen2000/phc-t3.html)

4.2 Strategic ITS Deployment Plan in Hampton Roads

4.2.1 COMPARE

The Hampton Roads Planning District Commission (HRPDC) serves as the Metropolitan Planning Organization (MPO) for Hampton Roads area. Hampton Roads agencies realized the need for ITS in order to support the region's growth and the quality of life. As a result of that, the HRPDC established the Hampton Roads regional long-range ITS plan, COMPARE (COngestion management Plan: A Regional Effort) in 1995 and then updated it in May 2000. The COMPARE included the ITS long-range plan for the region that can be incorporated with the regional long-range transportation plan (*5*).

4.2.2 Current ITS Deployments

Hampton Roads area has recently introduced various ITS elements, especially those for managing traffic congestion. The major feature of the ITS deployments is the connection among agencies' individual systems to enhance the efficiency and service of the deployment according to geographical necessary. The major ITS deployments are the follows (*5*):

- The Hampton Roads Smart Traffic Center,
- The VDOT Suffolk District Smart Traffic Center,
- Transportation Operation Center (TOC) in the City of Norfolk,
- Freeway Incident Management System,
- Dynamic Message Sing on city arterial approaching the interstates,
- A Cellular phone freeway incident call-in system (#77),
- Phase 1 of the freeway Transportation Management System (TMS) on for portion of I-64, I-264, and I-564 in Norfolk, and
- Electronic toll collection on the Coleman Bridge.

4.3 Modeled ITS Options

According to COMAPRE, the ITS deployment plan can be divided into short-term (0 to 5 years) and long-term (6 to 20 years) plans as mentioned Table 4 (*5*). It should be noted that the category for ITS User Services follows the definition of Virginia DOT user Services.

Table 4. List of Priority User Services

User Services	Short Term	Long Term
System Management	• Traffic Control and Management • Incident Management • Regulatory Functions • Emergency Management • Administrative Functions and Asset Management • Public Transit Management • Demand management	• None recommended
Personal Travel	• Pre-trip Traveler Information • En-route Driver Information • Ride Matching and Reservation • Electronic Payment System	• Route Guidance • Traveler Service Information • Emergency Notification and Personal Security
Commercial Vehicle Operation	• Commercial Vehicle Electronic Clearance • Commercial Vehicle Administrative Processes	• Automatic Roadside Safety Inspection • Intermodal Connections
Advanced Vehicle Control and Safety Systems	• None recommended	• Automated Highway System

After considering current ITS deployments in Hampton Roads area and the User Services in the above table, the four User Services (six ITS elements) are selected for modeling in

IDAS for the case study.[7] Table 5 listed the selected User Services and related ITS elements in IDAS.

Table 5. Selected User Services and ITS Elements

User Services	ITS Elements	Type
Traffic Control and Management	- Central Control Signal Coordination	Arterial Traffic Management Systems
Incident Management	- Incident Detection/Verification /Response/Management combined	Incident Management Systems
Pre-trip Traveler Information	- Telephone-based Traveler Information System - Web/Internet-based Traveler Information Systems	Regional Multimodal Traveler Information Systems
En-route Driver Information	- Highway Advisory Radio - Freeway Dynamic Message Sign	Regional Multimodal Traveler Information Systems

4.3.1 Central Control Signal Coordination

Central Control Signal Coordination is part of the Arterial Traffic Management Systems in IDAS and used to measure the effects of coordinated and actuated signals controlled by traffic management center such as the Transportation Operation Center (TOC) in the City of Norfolk. In order to deploy this ITS element, three parameters are required: i) variability of travel time, ii) overall level of congestion, and iii) time interval between signal timing plan modifications. According to selected parameter values, IDAS determines the increase in the capacity. Here, 11 % of capacity increase was selected based on the following parameters.

[7] These ITS elements were selected for only the assessment of feasibility of IDAS. Thus, these ITS elements don't represent an actual ITS deployment plan in Hampton Roads area.

- Travel time variability: Predictable,
- Average congestion: Heavy (v/c > 0.9), and
- Time interval between signal timing plan modifications: Average impact (>2 years).

Based on the selected parameter settings, IDAS conducts trip assignment, mode choice and temporal choice (if the transportation planning model includes peak-hour demand) for control alternative, this constitutes baseline case (or control alternative), and then IDAS increases the capacities of selected links belonging to this ITS element, and then conducts again the first step (trip assignment, mode choice and temporal choice) to make a improvement case (or ITS option). Finally the differences between the baseline and improvement can be quantified as related benefits. Among available benefits (change in user mobility, change in user travel time, fuel consumption, emission, accident and other benefits) to this ITS element, the change in user mobility is calculated based on the concept of "consumer surplus." According to the IDAS manual, it is calculated as follows:

$$B = (C_b - C_i)(T_b + T_i)/2 \qquad (1)$$

Where, C_b and C_i are the cost per trip and T_b and T_i are the number of trips in the baseline case and improvement case. For each market sector analyzed, these are calculated for each zone pair and then summed over all zone pairs.[8]

4.3.2 Incident Detection/Verification/Response/Management combined

The ITS element of Incident Detection/Verification/Response/Management combined is selected from three types of incident management systems available in IDAS. This ITS element requires four parameters shown below. It is noted that default parameter values are used in this study.

[8] ***Link travel times can be used instead of mobility by setting the weight equal to 0 in the benefit-cost summary table*** [Comment from Cambridge Systematics].

- Change in incident duration: 55%,
- Change in emissions: 42%,
- Change in fuel use: 42%,
- Change in fatality rate: 10%,

IDAS provides the change in travel time reliability and change in accident costs as benefits. In order to calculate travel time reliability, IDAS uses the following steps:

- Calculate travel time reliability for all vehicles for baseline case using Vehicle-Hours in Incident Delay per Mile Vehicle table (See Table 12),
- Reduce incident duration by 55%, and
- Recalculate the travel time reliability for the impacted links in the ITS option using the revised incident duration value.

4.3.3 Highway Advisory Radio (HAR)

Highway Advisory Radio is a type of Regional Multimodal Traveler Information Systems. This ITS option requires three parameters as the follows:

- Percent vehicle that tune to broadcast: 25%,
- Percent vehicle hearing broadcast that save time: 25%,
- Percent time that extreme traffic condition are occurring: 10%, and
- Average amount of time saved by each traveler saving time under extreme traffic condition: 4 minutes.

Based on the above parameter settings, for each HAR-equipped link IDAS calculated estimate of person-hour saved as a result of HAR installed using the following equation:

$$\begin{aligned}\text{[Person-hour saved]} = \; & \text{[traffic volume]} \times \\ & \text{[HAR usage percentage]} \times \\ & \text{[Percent time that extreme traffic condition are occurring]} \times \\ & \text{[Average amount of time saved in hour]}\end{aligned} \tag{2}$$

This calculated person-hour saved is provided in the column of change in User mobility of ACM.

4.3.4 Dynamic Message Sign (DMS)

DMS follows a similar process as that of HAR. This ITS option requires three parameters as the follows:

- Percent time sign is turned on and is disseminating information that can be used to save travel time: 10%,
- Percent vehicle passing sign that save time: 20%, and
- Average amount of time saved by each traveler saving time: 3 minutes.

Based on the above parameter settings, for each DMS-equipped link, IDAS calculates estimated person-hour saved using the following equation

$$\begin{aligned}[\text{Person-hour saved}] = {} & [\text{Traffic volume}] \times \\ & [\text{Percent time sign is turned on}] \times \\ & [\text{Percent vehicle passing sign that save time}] \times \\ & [\text{Average amount of time saved in hour}]\end{aligned} \qquad (3)$$

This calculated person-hour saved is provided in the column of change in User mobility of ACM.

4.3.5 Telephone-based Traveler Information System

Telephone-based Traveler Information System belongs to the Regional Multimodal Traveler Information Systems. This ITS option produces only changes in user mobility as an annual benefit based on the following two parameter settings:

- Market penetration: 1%, and
- Maximum amount of time saved by each traveler saving time: 15% of in-coverage delay time.

Here, in-coverage delay time means that the difference between the loaded travel time and the free-flow travel time + the incident delay from travel time reliability submodule for all links affected by this ITS option. IDAS calculates the avoided delay from this ITS option using the following equation for each O-D pair and then sums up the avoided delay across all O-D pairs.

$$\begin{aligned}\text{[Avoided delay]} = \;& \text{[O-D trips]} \times \\ & \text{[Market penetration]} \times \\ & \text{[In-coverage delay time]} \times \\ & \text{[Maximum delay saving]}\end{aligned} \tag{4}$$

This calculated person-hour saved is provided in the column of change in User mobility of ACM.

4.3.6 Web/Internet-based Traveler Information System

Web/Internet-based Traveler Information System follows a similar process as that of Telephone-based Traveler Information Systems in terms of methodology and process for calculating related benefits. This ITS option also calculates only the change in user mobility as an annual benefit based on the following two parameter settings:

- Market penetration: 5%, and
- Maximum amount of time saved by each traveler saving time: 20% of in-coverage delay time.

This calculated person-hour saved is provided in the column of change in User mobility of ACM.

4.3.7 Setting for Running the IDAS Benefits Module

IDAS prepares the setting for running the IDAS Benefits Module. Based on selected settings, IDAS produces relevant benefits. This study used the settings recommended in the IDAS manual as shown in Table 6. However, Mode Choice, Temporal Choice and Induced/Foregone Demand in the application of Central Control Signal Coordination were excluded because the results of the IDAS running with these three settings showed negative benefits caused from huge induced demands. No further attempts were made to adjust these three parameters.

Table 6. Selected Settings for IDAS Benefits Analysis

ITS Option	Trip Assignment	Mode Choice	Temporal Choice	Induced/Foregone Demand	Emissions	Safety	Energy	Travel Time Reliability
Central Control Signal Coordination	O				O	O	O	O
Freeway Incident Detection/Verification/Response/Management Combination						O		O
HAR								
DMS								
Telephone-Based TIS	O					O		O
Web/Internet-Based TIS	O					O		O

4.4 Running IDAS Analysis

4.4.1 Transportation Planning Model

In this study, a transportation planning model for year 2005 developed and maintained by the HRPDC was used. The original transportation planning model consists of six elements:

- Zone to district equivalence information,
- Node information,
- Link information,
- Trip matrix information for auto trip,
- In-vehicle time information for auto trip, and
- Trip matrix information for bus trip.

Among the above elements, the trip matrix information for bus trip was not used because the scope of this project was confined into ITS elements related to only auto trip.

4.4.2 IDAS Analysis

These six ITS options as mentioned in Section 4.3 and their combinations were used to examine the IDAS feasibility on evaluating ITS benefits and costs.[9] The years of opening and mid-point of construction of all ITS options are assumed to be 2005 based on the model year of the transportation planning model. The combinations of the six ITS options were prepared to examine the effects of combining the multiple ITS elements into a single ITS deployment (or ITS options in the IDAS definition) in terms of changes in relevant benefits and costs. In addition, the functionality of equipment sharing settings in IDAS was also tested. First, the six ITS options consisted of six individual ITS element, with the transportation models, parameter settings as mentioned in Section 4.3 was tested. Each ITS option is assumed to be installed on the following links:[10, 11]

- Central Control Signal Coordination: major arterial links
- Incident Detection/Verification/Response/Management combined: freeway links
- Telephone-based Traveler Information System: major arterial and freeway links

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[9] Sadek and Baah (*1*) examined the performance of IDAS by different parameter settings through sensitivity analysis.

[10] When Highway Advisory Radio and Freeway Dynamic Message Sign are analyzed in IDAS, users should pay cares in selection of representative links required by IDAS. In this report, selections of representative links followed the explanations on the -IDAS manual.

[11] ***The deployment of some of the ATIS components in IDAS requires special consideration which is not apparent when using the tool. Cambridge Systematics are in the process of creating a user tip for deploying ATIS as it is an issue that tends to come up by many users. The methodologies for analyzing ATIS deployments in IDAS are very simple as specified by FHWA and the task force during the development of the tool. This is because evaluation data and analysis methodologies were not available in the travel demand structure at the time of development. For example, when deploying HAR, a "representative" link in each direction for each roadway should be selected to realize the benefit of the system. If every link for a roadway segment is selected for deployment, time savings would be double counted over and over again as the same traveler would have 4 minute time savings*** **[**Comment from Cambridge Systematics]**.**

- Web/Internet-based Traveler Information Systems: major arterial and freeway links
- Highway Advisory Radio: freeway links
- Freeway Dynamic Message Sign: freeway links

Table 7 summaries the results of IDAS for the six selected ITS options. It is noted that the monetary values are reported in 1995 dollar.

Table 7. Summary of Benefits and Costs for Six ITS Options

Benefits and Costs		ITS Option					
		Signal	Telephone	Internet	Incident	HAR	DMS
Annual Benefits							
Change in User Mobility	$	0	2,775,171,850	18,501,116,273	0	706,616	8,844,007
Change In User Travel Time	$						
In-Vehicle Travel Time	$	12,031,797,804	0	0	0	0	0
Out-of-Vehicle Travel Time	$	0	0	0	0	0	0
Travel Time Reliability	$	0	0	0	26,365	0	0
Change in Costs Paid by Users							
Fuel Costs	$	-3,329,262	0	0	0	0	0
Non-fuel Operating Costs	$	0	0	0	0	0	0
Accident Costs (Internal Only)	$	926,185	0	0	4,121,149	0	0
Change in External Costs	$						
Accident Costs (External Only)	$	163,440	0	0	727,260	0	0
Emissions							
HC/ROG	$	1,789,133	0	0	0	0	0
NOx	$	322,420	0	0	0	0	0
CO	$	20,814,540	0	0	0	0	0
PM10	$	0	0	0	0	0	0
CO2	$	0	0	0	0	0	0
Global Warming	$	0	0	0	0	0	0
Noise	$	0	0	0	0	0	0
Other Mileage-Based External Costs	$	0	0	0	0	0	0
Other Trip-Based External Costs	$	0	0	0	0	0	0
Change in Public Agencies Costs (Efficiency Induced)	$	0	0	0	0	0	0
Other Calculated Benefits	$	0	0	0	0	0	0
User Defined Additional Benefits	$	0	0	0	0	0	0
Total Annual Benefits	$	**12,052,484,260**	**2,775,171,850**	**18,501,116,273**	**4,874,774**	**706,616**	**8,844,007**
Annual Costs							
Average Annual Private Sector Cost	$	0	305,821	305,821	0	0	0
Average Annual Public Sector Cost	$	1,368,592	219,276	512,055	1,046,064	158,847	1,169,572
Total Annual Cost	$	**1,368,592**	**525,097**	**817,876**	**1,046,064**	**158,847**	**1,169,572**
Benefit/Cost Comparison							
Net Benefit (Annual Benefit - Annual Cost)	$	**12,051,115,668**	**2,774,646,752**	**18,500,298,397**	**3,828,710**	**547,768**	**7,674,436**
B/C Ratio (Annual Benefit/Annual Cost)		**8,806.48**	**5,285.06**	**22,620.94**	**4.66**	**4.45**	**7.56**

As shown in Table 7, suspiciously huge benefits were noticed from three ITS options: Central Control Signal Coordination, Telephone-based Traveler Information System and Web/Internet-based Traveler Information System. In order to determine the cause of such huge benefits, input data including transportation planning model and parameter settings and selected links and methodologies for the ITS options were examined. Two possible reasons for the huge benefits were identified. First, lots of links showed volume to capacity ratio (V/C) of 1.0 or above in the baseline case (control alternative). Second, the three ITS options commonly use travel time related information to estimate the benefits. The Central Control Signal Coordination uses travel time as a travel cost in the calculation for the changes in user mobility using "consumer surplus," while, Telephone-based Traveler Information System and Web/Internet-based Traveler Information Systems directly calculate benefits from the avoided delay. For travel time calculation, IDAS uses the following default volume delay curve (*3*): [12]

[12] ***It appears as though the unexpected results are due to the incorrect volume-delay function being used in the Benefits module run. Version 2.3 uses standard BPR. The default curves in IDAS are much steeper. For more information, refer to "Importance of Validating the IDAS Control Alternative to the Local Travel Demand Model Results" and "Adjusting Volume Delay Curve Defaults" user tips on the IDAS website under FAQ/User Tips*** [Comment from Cambridge Systematics]. Note: The incorrect volume-delay function, mentioned in the Cambridge Systematics comment, was the default volume-delay curve (see Figure 2) provided in the IDAS version 2.2 [Authors' comment]. During teleconference call between research team and Cambridge Systematics, ***Cambridge Systematics further emphasized that the volume-density curve should be identical to that of transportation planning model.*** The authors believe the volume-density curve should be carefully chosen to reflect local traffic conditions.

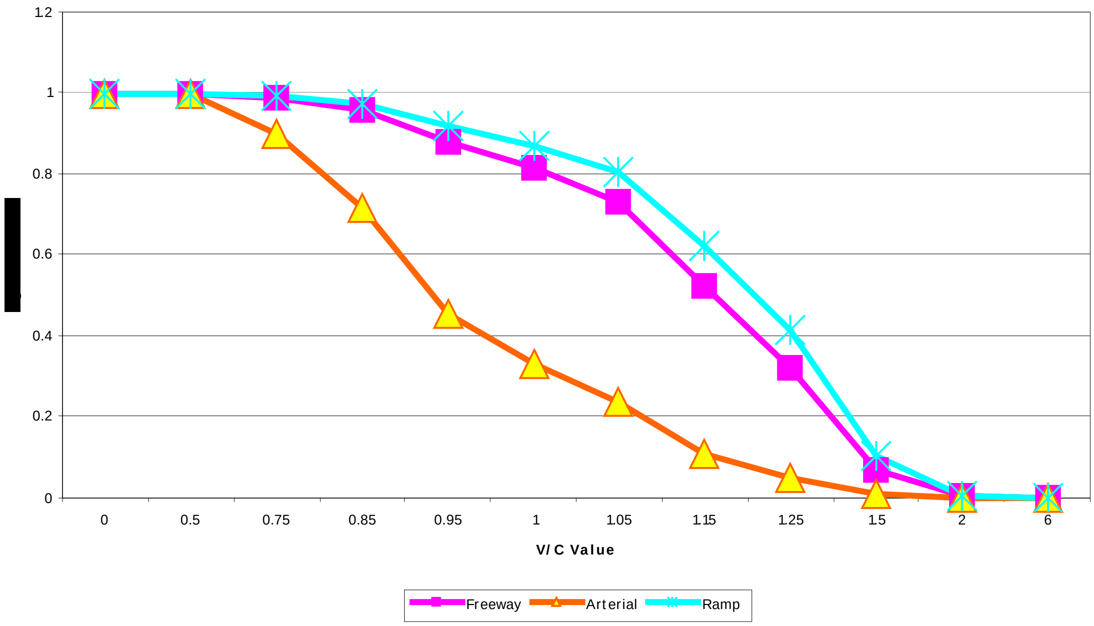

Figure 2. Volume Delay Curve for Urban Area

In Figure 2, speed factor indicates the fractional speed at a given V/C level. For example, the speed factor of 0.33 at V/C ratio of 1.0 for urban arterial means that the travel speed of a link with V/C ratio of 1.0 is 33% of its free-flow speed. Thus, for higher V/C values, the speeds reduce dramatically and result in higher travel time. Conclusively, as the transportation planning model used in this project shows higher V/C values on most links, the ITS options, that use performance measures related to travel time (or delay) for benefit calculation, produce huge benefits. On the contrary, the other three ITS options (Incident Detection/Verification/Response/Management combined, Highway Advisory Radio and Dynamic Message Sign) which use traffic volumes for benefit calculation in their methodologies, show reasonable benefits. This is further explained in Chapter 5.

4.4.3 Feasibility assessment using the effects of combining multiple options

In this section, the effects of combining multiple ITS options into a single ITS deployment were tested. For this comparison, only three ITS options that showed reasonable benefits and costs were selected. They are Incident

Detection/Verification/Response/Management combined, Highway Advisory Radio and Dynamic Message Sign. Furthermore, in order to investigate the effects of Equipment Sharing setting (share to maximum extent possible and no sharing in the IDAS setup menu) on total annual cost, “share to maximum extent possible” option in IDAS runs was selected and then the resulting benefits and costs are shown in Tables 8 and 9.

Table 8. Summary of Benefits and Costs with Sharing Option

Benefits and Costs		ITS Option			Combination of ITS Options		
		Incident	HAR	DMS	Incident & HAR	Incident & DMS	Incident & HAR & DMS
Annual Benefits							
Change in User Mobility	$	0	706,616	8,844,007	705,652	8,434,800	9,140,453
Change In User Travel Time							
In-Vehicle Travel Time	$	0	0	0	0	0	0
Out-of-Vehicle Travel Time	$	0	0	0	0	0	0
Travel Time Reliability	$	26,365	0	0	25,710	25,710	25,710
Change in Costs Paid by Users							
Fuel Costs	$	0	0	0	0	0	0
Non-fuel Operating Costs	$	0	0	0	0	0	0
Accident Costs (Internal Only)	$	4,121,149	0	0	4,213,632	4,213,632	4,213,632
Change in External Costs							
Accident Costs (External Only)	$	727,260	0	0	743,580	743,580	743,580
Emissions							
HC/ROG	$	0	0	0	0	0	0
NOx	$	0	0	0	0	0	0
CO	$	0	0	0	0	0	0
PM10	$	0	0	0	0	0	0
CO2	$	0	0	0	0	0	0
Global Warming	$	0	0	0	0	0	0
Noise	$	0	0	0	0	0	0
Other Mileage-Based External Costs	$	0	0	0	0	0	0
Other Trip-Based External Costs	$	0	0	0	0	0	0
Change in Public Agencies Costs (Efficiency Induced)	$	0	0	0	0	0	0
Other Calculated Benefits	$	0	0	0	0	0	0
User Defined Additional Benefits	$	0	0	0	0	0	0
Total Annual Benefits	$	**4,874,774**	**706,616**	**8,844,007**	**5,688,575**	**13,417,723**	**14,123,375**
Annual Costs							
Average Annual Private Sector Cost	$	0	0	0	0	0	0
Average Annual Public Sector Cost	$	1,046,064	158,847	1,169,572	1,204,911	2,215,635	2,374,483
Total Annual Cost	$	**1,046,064**	**158,847**	**1,169,572**	**1,204,911**	**2,215,635**	**2,374,483**
Benefit/Cost Comparison							
Net Benefit (Annual Benefit - Annual Cost)	$	**3,828,710**	**547,768**	**7,674,436**	**4,483,664**	**11,202,088**	**11,748,893**
B/C Ratio (Annual Benefit/Annual Cost)		**4.66**	**4.45**	**7.56**	**4.72**	**6.06**	**5.95**

Table 9. Change in Benefits and Costs with Sharing Option

Benefit & Cost	ITS Option		Value	Remark
Total Annual Benefit ($)	Incident		4,874,774	(1)
	HAR		706,616	(2)
	DMS		8,844,007	(3)
	Incident + HAR	Individual SUM	5,581,390	(1) + (2)
		IDAS Result	5,688,575	
		Difference	+107,185	
	Incident + DMS	Individual SUM	13,718,781	(1) + (3)
		IDAS Result	13,417,723	
		Difference	-301,058	
	Incident + HAR + DMS	Individual SUM	14,425,397	(1) + (2) + (3)
		IDAS Result	14,123,375	
		Difference	-302,022	
Total Annual Cost ($)	Incident		1,046,064	(4)
	HAR		158,847	(5)
	DMS		1,169,572	(6)
	Incident + HAR	Individual SUM	1,204,911	(4) + (5)
		IDAS Result	1,204,911	
		Difference	0	
	Incident + DMS	Individual SUM	2,215,635	(4) + (6)
		IDAS Result	2,215,635	
		Difference	0	
	Incident + HAR + DMS	Individual SUM	2,374,483	(4) + (5) + (6)
		IDAS Result	2,374,483	
		Difference	0	

As shown in Table 9, the estimated benefits from combined ITS deployment options differ from those benefits summed up from identical individual ITS options. For example, the benefits of incident + HAR deployment are bigger than those from two individual deployments. This makes sense as the combined implementation can generate higher benefits than two individually deployed ITS options. However, this was not the case for Incident + DMS and Incident + HAR + DMS deployments.

The estimated costs of the combined deployments did not produce any savings compared to the total costs of individually deployed ITS options even though the Equipment Sharing was set to "share to maximum extent possible."[13]

4.5 Issues Identified from the Case Study

The following two issues were identified from the case study. First, the estimated benefits of certain ITS options (e.g., Central Control Signal Coordination, Telephone-based Traveler Information System and Web/Internet-based Traveler Information System) are extremely high and they heavily rely on the level of V/C. Second, the Equipment Sharing option in the IDAS did not reduce the cost of the combined ITS deployment option even though the ITS options commonly cover the freeway links

5 Simple Network Case Study for IDAS Validation

5.1 Network

This section is to investigate the performance of IDAS under various V/C levels. In order to expedite the examination, a simple network as shown in Figure 3 was developed.

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[13] ***This was a bug in Version 2.2 and should be fixed in Version 2.3*** **[**Comment from Cambridge Systematics]**.**

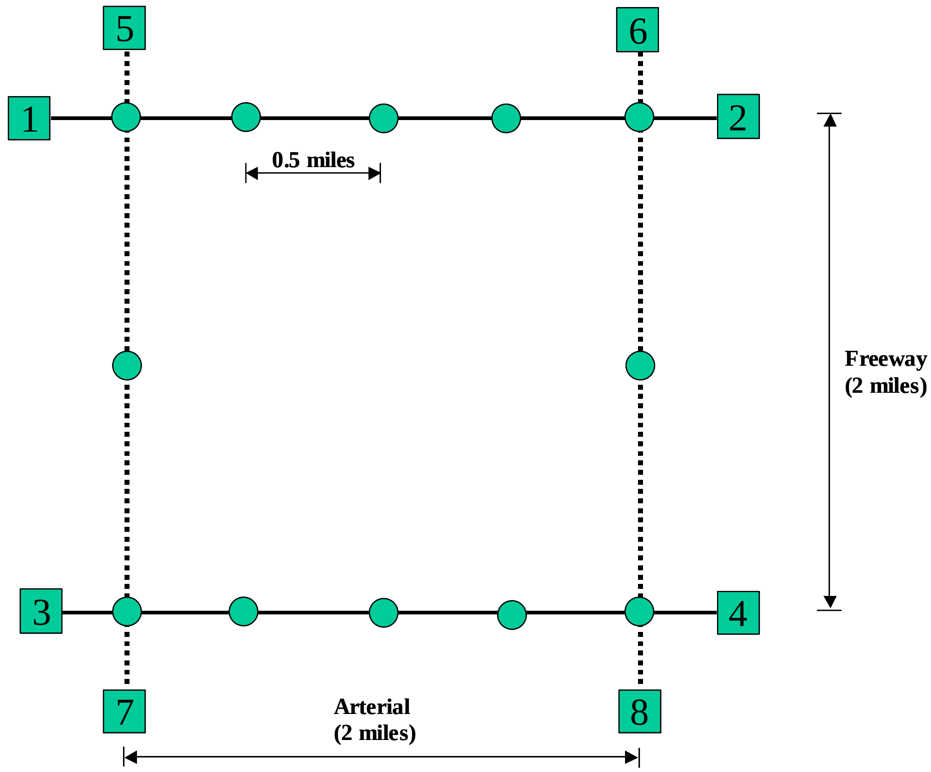

Figure 3. Simple Network

The network consists of 8 zones, 12 nodes and 38 links. In Figure 3, dotted and solid lines illustrate links on freeway and arterial, respectively. For each link, the following link attributes were used.

- Capacity: 22,500 vehicles per day
- Speed: 55 mile per hour
- Number of lane: 2 lanes

In order to maintain the identical V/C ratios across all links, the OD demand as shown Table 10 was used. It is noticed that the values on OD demand should be changed according to the desired V/C level.

Table 10. Trip Table for V/C = 1.0

Zone	1	2	3	4	5	6	7	8
1	-	45,000	-	-	-	-	-	-
2	45,000	-	-	-	-	-	-	-
3	-	-	-	45,000	-	-	-	-
4	-	-	45,000	-	-	-	-	-
5	-	-	-	-	-	-	45,000	-
6	-	-	-	-	-	-	-	45,000
7	-	-	-	-	45,000	-	-	-
8	-	-	-	-	-	45,000	-	-

5.2 IDAS Analysis under varying V/C Ratios

Using the transportation planning model explained in the above section, the six ITS options used in Chapter 4 were built into the IDAS program with default parameter settings. For the Central Control Signal Coordination, 11% of increased capacity was identically used. The coverage of each ITS option is same as that used in Chapter 4:

- Central Control Signal Coordination: major arterial links
- Incident Detection/Verification/Response/Management combined: freeway links
- Telephone-based Traveler Information System: major arterial and freeway links
- Web/Internet-based Traveler Information Systems: major arterial and freeway links
- Highway Advisory Radio: freeway links
- Freeway Dynamic Message Sign: freeway links

Table 11 shows the IDAS (version 2.2) results of six ITS options with varying V/C levels (see the Appendix B for detailed summary).

Table 11. Changes in Total Annual Benefits by different V/C Levels

ITS Options		V/C Level									
		0.50	0.75	0.85	0.95	1.00	1.05	1.25	1.50	2.00	6.00
Signal	$	0	517,622	3,250,463	12,731,919	22,336,704	36,433,313	219,021,099	1,799,753,416	47,564,241,078	307,452,208,225
Telephone ATIS	$	6	86	293	886	289,896	2,394	13,689	84,667	2,048,175	14,921,719
Internet ATIS	$	40	574	1,955	5,905	1,932,642	15,963	91,263	564,446	13,654,504	99,478,121
Incident	$	78,354	117,532	133,203	148,873	19,324,471	164,704	196,832	237,333	38,648,941	115,946,827
HAR	$	236,194	354,291	401,529	448,768	472,388	496,007	590,484	708,581	944,775	2,834,325
DMS	$	566,865	850,298	963,671	1,077,044	1,133,730	1,190,417	1,417,163	1,700,595	2,267,460	6,802,380

As shown in Table 11, the first three ITS options, which utilize the travel time and avoided travel delay for benefit estimations, showed dramatic increase in benefits as the V/C value increases. While other three ITS options, which use volume for calculating benefits, showed gradual increase in benefits as the V/C value increases. As mentioned earlier, the IDAS (version 2.2) overestimates the travel time related benefits. This is due to the nature of the speed factor and Volume Delay Curve (see Figure 2) used in the speed calculation.[14]

The benefits of ITS options whose benefits are based on the travel time reliability measures showed huge jumps in their benefit values for V/C at 1.0, 2.0 and 6.0 (see the shaded cells in Table 11). It is noted that the travel time reliability measures were estimated from the travel time reliability rate at a given V/C ratio as shown in Table 12.

The IDAS (version 2.2) applies the travel time reliability rates in Table 12 to the freeway links with integer V/C ratios. However, it seems that the links with non-integer V/C

[14] ***The travel time reliability had a bug that was fixed in a patch to Version 2.2 and in Version 2.3*** **[**Comment from Cambridge Systematics]**.**

ratios were not correctly applied. This finding is consistent with that of Heither and Thomas (*2*).

Table 12. Travel Time Reliability Rate by the Number of Lanes and V/C

Number of Lanes	V/C Ratio					
	1.0	2.0	3.0	4.0	5.0	6.0
2	1.17E-007	1.17E-07	1.79E-06	8.81E-06	2.73E-05	6.56E-05
3	8.46E-009	8.46E-09	2.73E-07	2.08E-06	8.78E-06	2.69E-05
4+	8.16E-011	8.16E-11	1.08E-08	1.89E-07	1.43E-06	6.91E-06

6 Conclusions and Recommendations

6.1 Conclusions

This study examined the feasibility of the IDAS program (version 2.2), a sketch level tool for the evaluation of the ITS deployments, in two ways: (i) a survey among the MPO staff and (ii) case studies – the Hampton Roads area and a simple network.

The survey on the IDAS usage among MPO staff in the United State indicated that the use of IDAS by MPOs was somewhat limited – about 10% (8 out of 76 MPOs). Among the ITS options available in the IDAS, Arterial Traffic Management Systems and Incident Management Systems were most common ITS elements by MPOs. It was also found that the most desired update in the IDAS program was elaborating ITS impact methodologies and followed by upgrading default values in the cost and benefit modules and incorporating emission factors based on MOBILE 6.

The case studies of the Hampton Roads and a simple network with six ITS options identified the following three issues:

- The IDAS overestimates ITS option benefits when the benefits are estimated from travel time savings.

- The IDAS incorrectly interpolates travel time reliability rates for non-integer V/C ratios.
- The IDAS is insensitive to cost savings for combined ITS options.

6.2 Recommendations

Based on the results of the survey and case studies, the following recommendations are made:

1. The IDAS (version 2.2) should be used with extreme caution. It is recommended the cost benefit ratio be used for ITS evaluations only if the benefits were estimated from identical measures. In other words, two ITS options should not be compared if the benefits were estimated from different measures.
2. Even though the IDAS version 2.3 has adopted a standard BPR function as a default volume delay function to improve its performance, the volume delay function parameters should be carefully determined. This is because (i) those parameters are critical in the benefit estimations and (ii) the default parameters may differ from those in transportation planning model and they may not be representative to local conditions.
3. The anomalies identified in this study should be verified by the IDAS developer and, if confirmed, they need to be corrected for the next version of the IDAS.[15]
4. The IDAS developer should consider incorporating the findings from the survey in the next version upgrade.[16]
5. Even though parameter values in the IDAS program can be modified by the end user, it is desirable to provide guidance for changing the default parameters.

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[15] ***The analysis should be re-done based on use of the correct volume delay functions in the model. Cost sharing and travel time reliability issues should have been addressed in the updated version of IDAS (Version 2.3)*** [Comment from Cambridge Systematics].

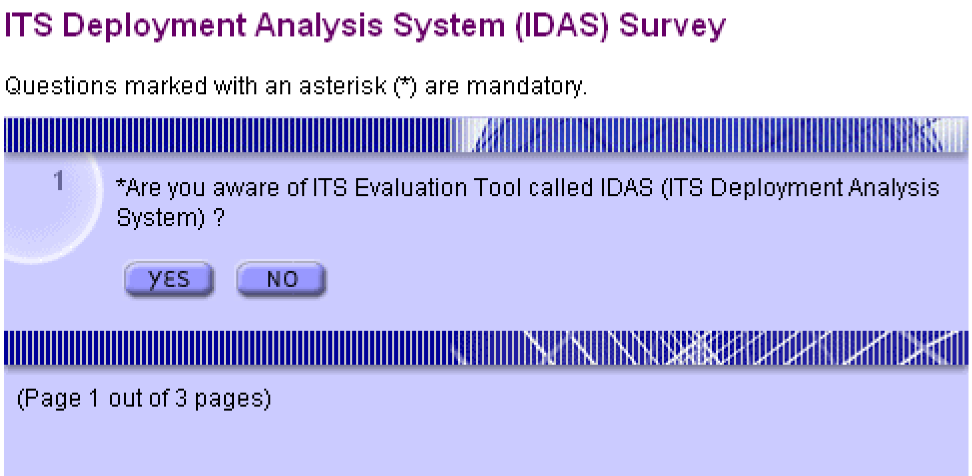
[16] ***We will use this information for a User Assessment study we are doing as part of the maintenance contract with FHWA*** [Comment from Cambridge Systematics].

References

1. Sadek, A. W. and B. Baah. Cost-Effectiveness of Intelligent Transportation System (ITS) Deployment in a Medium-Sized Area – Case Study with ITS Deployment Analysis System. *Transportation Research Record* No. 1826 (Paper No. 03-3253), TRB, National Research Council, Washington D.C., 2003.
2. Heither, C. and M. Thomas. *Testing of IDAS Capabilities Using Northeastern Illinois ITS Deployments*. Working Paper 03-06, Chicago, Illinois, August 2003.
3. *ITS Deployment Analysis System User's Manual*. Cambridge Systematics and ITT Industries, Cambridge, Mass., Nov. 2001.
4. Beardsley Megan, MOBILE6 EPA's Highway Vehicle Emissions Model – Presentation, *North American Vehicle Emission Control Conference*, Atlanta, April 2, 2001 (downloaded from http://www.epa.gov/otaq/models/mobile6/namfin.pdf).
5. *COMPARE ITS Strategic Deployment Plan Update 2000 - Final Report*, PB Farradyne, May 2000.

Appendix A. Result of ITS Deployment Analysis System (IDAS) Survey

A.1 Question about the Awareness of IDAS


ITS Deployment Analysis System (IDAS) Survey

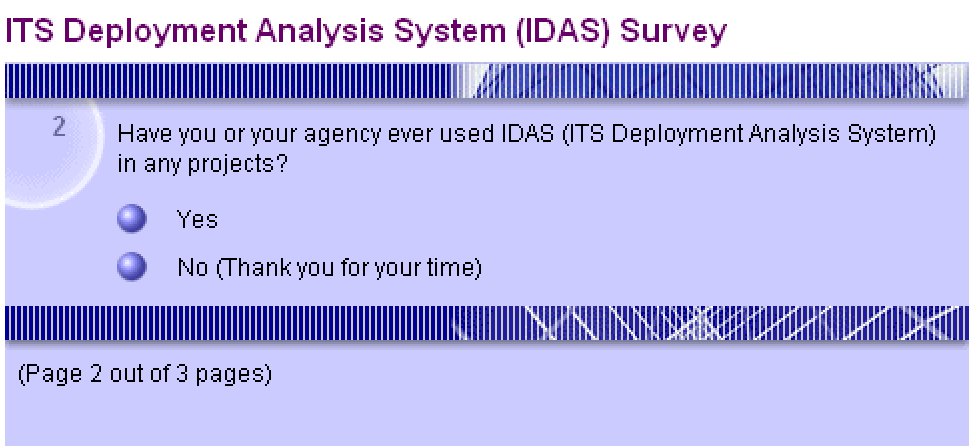
Questions marked with an asterisk (*) are mandatory.

1 *Are you aware of ITS Evaluation Tool called IDAS (ITS Deployment Analysis System) ?

YES NO

(Page 1 out of 3 pages)

A.2 Question about the Use of IDAS


ITS Deployment Analysis System (IDAS) Survey

2 Have you or your agency ever used IDAS (ITS Deployment Analysis System) in any projects?

Yes

No (Thank you for your time)

(Page 2 out of 3 pages)

A.3 Question about the Feasibility of IDAS

ITS Deployment Analysis System (IDAS) Survey

3 What was the purpose of using IDAS in the project? (Check all that apply)

- Screening ITS alternatives
- Prioritizing ITS alternatives
- Estimating life-cycle costs of ITS alternatives
- Scheduling ITS deployment
- Estimating emissions from ITS deployment
- Other, Please Specify

4 Which of the following ITS elements from the IDAS have you used in the project? (Check all that apply)

- Arterial Traffic Management Systems
- Freeway Management Systems
- Advanced Public Transit Systems
- Incident Management Systems
- Electronic Payment Systems
- Railroad Grade Crossing Monitors
- Emergency Management Services
- Regional Multimodal Traveler Information Systems
- Commercial Vehicle Operations
- Advanced Vehicle Control and Safety Systems
- Supporting Deployments
- Generic Deployments

5 Would you recommend an improvement in any of the following functions of IDAS? (Check all that apply)

- Upgrade Input/Output Interface Module
- Upgrade default values in the Cost and Benefit Modules
- Upgrade default values in the Alternative Comparison Module
- Elaborate ITS Impact Methodologies
- Incorporate emission factors based on MOBILE6
- Other, Please Specify

6 How confident were you about the results of the following alternative comparison analyses, if you had used?

	1 Outstanding	2 Exellent	3 Good	4 Average	5 Poor	
Changes in User Mobility and Travel Time	1	2	3	4	5	N/A
Changes in User Costs (including accident cost)	1	2	3	4	5	N/A
Emissions	1	2	3	4	5	N/A
Average Annual Costs of ITS Alternatives	1	2	3	4	5	N/A

7 Please, enter your name and contact information. (Optional)

Name

Agency

E-mail Address

(Page 3 out of 3 pages)

Appendix B. Result of IDAS Performance by V/C Ratio

B.1 Traffic Signal Coordination (Central Control – Corridor)

Benefits and Costs		V/C Ratios									
		0.50	0.75	0.85	0.95	1.00	1.05	1.25	1.50	2.00	6.00
Annual Benefits											
Change in User Mobility	$	0	377,910	2,837,474	10,112,242	17,698,785	30,421,755	213,912,806	1,787,230,868	47,562,114,990	307,452,090,088
Change In User Travel Time											
In-Vehicle Travel Time	$	0	0	0	0	0	0	0	0	0	0
Out-of-Vehicle Travel Time	$	0	0	0	0	0	0	0	0	0	0
Travel Time Reliability	$	0	0	0	0	0	0	0	0	0	0
Change in Costs Paid by Users											
Fuel Costs	$	0	0	19,253	754,809	1,337,170	2,466,525	-8,669,530	0	0	0
Non-fuel Operating Costs	$	0	0	0	0	0	0	0	0	0	0
Accident Costs (Internal Only)	$	0	137,912	63,130	427,880	838,966	525,868	0	0	0	0
Change in External Costs	$										
Accident Costs (External Only)	$	0	24,336	11,140	75,508	148,050	92,797	0	0	0	0
Emissions											
HC/ROG	$	0	890	14,763	53,066	90,068	132,180	1,064,185	1,280,579	217,418	12,079
NOx	$	0	-20,215	-23,620	-14,482	2,762	42,322	200,606	158,315	26,879	1,493
CO	$	0	-3,212	328,322	1,322,897	2,220,904	2,751,866	12,513,032	11,083,654	1,881,792	104,565
PM10	$	0	0	0	0	0	0	0	0	0	0
CO2	$	0	0	0	0	0	0	0	0	0	0
Global Warming	$	0	0	0	0	0	0	0	0	0	0
Noise	$		0	0	0	0	0	0	0	0	0
Other Mileage-Based External Costs	$		0	0	0	0	0	0	0	0	0
Other Trip-Based External Costs	$		0	0	0	0	0	0	0	0	0
Change in Public Agencies Costs (Efficiency Induced)	$			0	0	0	0	0	0	0	0
Other Calculated Benefits	$			0	0	0	0	0	0	0	0
User Defined Additional Benefits	$			0	0	0	0	0	0	0	0
Total Annual Benefits	$			**0**	**517,622**	**3,250,463**	**12,731,919**	**22,336,704**	**36,433,313**	**219,021,099**	**1,799,753,416**
Annual Costs											
Average Annual Private Sector Cost	$	0	0	0	0	0	0	0	0	0	0
Average Annual Public Sector Cost	$	612,368	612,368	612,368	612,368	612,368	612,368	612,368	612,368	612,368	612,368
Total Annual Cost	$	**612,368**	**612,368**	**612,368**	**612,368**	**612,368**	**612,368**	**612,368**	**612,368**	**612,368**	**612,368**
Benefit/Cost Comparison											
Net Benefit (Annual Benefit - Annual Cost)	$	**-612,368**	**-94,746**	**2,638,095**	**12,119,552**	**21,724,336**	**35,820,945**	**218,408,731**	**1,799,141,048**	**47,563,628,710**	**307,451,595,857**
B/C Ratio (Annual Benefit/Annual Cost)		**0.00**	**0.85**	**5.31**	**20.79**	**36.48**	**59.50**	**357.66**	**2,939.01**	**77,672.67**	**502,071.14**

Note: for this run, in-vehicle travel time was not used in the transportation planning model, which is different from IDAS run conducted in Chapter 4 so that the MOE, produced by IDAS, of benefit summary is different from Table 7.

B.2 Incident Management Systems (Combination Detection & Response)

Benefits and Costs		V/C Ratios									
		0.50	0.75	0.85	0.95	1.00	1.05	1.25	1.50	2.00	6.00
Annual Benefits											
Change in User Mobility	$	0	0	0	0	0	0	0	0	0	0
Change In User Travel Time											
In-Vehicle Travel Time	$	0	0	0	0	0	0	0	0	0	0
Out-of-Vehicle Travel Time	$	0	0	0	0	0	0	0	0	0	0
Travel Time Reliability	$	106	159	180	201	19,167,973	381	1,210	2,586	38,335,946	115,007,839
Change in Costs Paid by Users											
Fuel Costs	$	0	0	0	0	0	0	0	0	0	0
Non-fuel Operating Costs	$	0	0	0	0	0	0	0	0	0	0
Accident Costs (Internal Only)	$	66,511	99,767	113,070	126,371	133,023	139,675	166,279	199,535	266,046	798,140
Change in External Costs	$										
Accident Costs (External Only)	$	11,737	17,606	19,953	22,301	23,475	24,648	29,343	35,212	46,949	140,848
Emissions											
HC/ROG	$	0	0	0	0	0	0	0	0	0	0
NOx	$	0	0	0	0	0	0	0	0	0	0
CO	$	0	0	0	0	0	0	0	0	0	0
PM10	$	0	0	0	0	0	0	0	0	0	0
CO2	$	0	0	0	0	0	0	0	0	0	0
Global Warming	$	0	0	0	0	0	0	0	0	0	0
Noise	$	0	0	0	0	0	0	0	0	0	0
Other Mileage-Based External Costs	$	0	0	0	0	0	0	0	0	0	0
Other Trip-Based External Costs	$	0	0	0	0	0	0	0	0	0	0
Change in Public Agencies Costs (Efficiency Induced)	$	0	0	0	0	0	0	0	0	0	0
Other Calculated Benefits	$	0	0	0	0	0	0	0	0	0	0
User Defined Additional Benefits	$	0	0	0	0	0	0	0	0	0	0
Total Annual Benefits	$	**78,354**	**117,532**	**133,203**	**148,873**	**19,324,471**	**164,704**	**196,832**	**237,333**	**38,648,941**	**115,946,827**
Annual Costs											
Average Annual Private Sector Cost	$	0	0	0	0	0	0	0	0	0	0
Average Annual Public Sector Cost	$	1,046,064	1,046,064	1,046,064	1,046,064	1,046,064	1,046,064	1,046,064	1,046,064	1,046,064	1,046,064
Total Annual Cost	$	**1,046,064**	**1,046,064**	**1,046,064**	**1,046,064**	**1,046,064**	**1,046,064**	**1,046,064**	**1,046,064**	**1,046,064**	**1,046,064**
Benefit/Cost Comparison											
Net Benefit (Annual Benefit - Annual Cost)	$	**-967,709**	**-928,531**	**-912,861**	**-897,190**	**18,278,407**	**-881,359**	**-849,232**	**-808,730**	**37,602,878**	**114,900,763**
B/C Ratio (Annual Benefit/Annual Cost)		**0.07**	**0.11**	**0.13**	**0.14**	**18.47**	**0.16**	**0.19**	**0.23**	**36.95**	**110.84**

B.3 Highway Advisory Radio

Benefits and Costs		V/C Ratios									
		0.50	0.75	0.85	0.95	1.00	1.05	1.25	1.50	2.00	6.00
Annual Benefits											
Change in User Mobility	$	236,194	354,291	401,529	448,768	472,388	496,007	590,484	708,581	944,775	2,834,325
Change In User Travel Time											
In-Vehicle Travel Time	$	0	0	0	0	0	0	0	0	0	0
Out-of-Vehicle Travel Time	$	0	0	0	0	0	0	0	0	0	0
Travel Time Reliability	$	0	0	0	0	0	0	0	0	0	0
Change in Costs Paid by Users											
Fuel Costs	$	0	0	0	0	0	0	0	0	0	0
Non-fuel Operating Costs	$	0	0	0	0	0	0	0	0	0	0
Accident Costs (Internal Only)	$	0	0	0	0	0	0	0	0	0	0
Change in External Costs	$	0	0	0	0	0	0	0	0	0	0
Accident Costs (External Only)	$	0	0	0	0	0	0	0	0	0	0
Emissions											
HC/ROG	$	0	0	0	0	0	0	0	0	0	0
NOx	$	0	0	0	0	0	0	0	0	0	0
CO	$	0	0	0	0	0	0	0	0	0	0
PM10	$	0	0	0	0	0	0	0	0	0	0
CO2	$	0	0	0	0	0	0	0	0	0	0
Global Warming	$	0	0	0	0	0	0	0	0	0	0
Noise	$	0	0	0	0	0	0	0	0	0	0
Other Mileage-Based External Costs	$	0	0	0	0	0	0	0	0	0	0
Other Trip-Based External Costs	$	0	0	0	0	0	0	0	0	0	0
Change in Public Agencies Costs (Efficiency Induced)	$	0	0	0	0	0	0	0	0	0	0
Other Calculated Benefits	$	0	0	0	0	0	0	0	0	0	0
User Defined Additional Benefits	$	0	0	0	0	0	0	0	0	0	0
Total Annual Benefits	$	**236,194**	**354,291**	**401,529**	**448,768**	**472,388**	**496,007**	**590,484**	**708,581**	**944,775**	**2,834,325**
Annual Costs											
Average Annual Private Sector Cost	$	0	0	0	0	0	0	0	0	0	0
Average Annual Public Sector Cost	$	130,594	130,594	130,594	130,594	130,594	130,594	130,594	130,594	130,594	130,594
Total Annual Cost	$	**130,594**	**130,594**	**130,594**	**130,594**	**130,594**	**130,594**	**130,594**	**130,594**	**130,594**	**130,594**
Benefit/Cost Comparison											
Net Benefit (Annual Benefit - Annual Cost)	$	**105,600**	**223,697**	**270,936**	**318,174**	**341,794**	**365,413**	**459,891**	**577,988**	**814,181**	**2,703,731**
B/C Ratio (Annual Benefit/Annual Cost)		**1.81**	**2.71**	**3.07**	**3.44**	**3.62**	**3.80**	**4.52**	**5.43**	**7.23**	**21.70**

B.4 Dynamic Message Sign

Benefits and Costs		V/C Ratios									
		0.50	0.75	0.85	0.95	1.00	1.05	1.25	1.50	2.00	6.00
Annual Benefits											
Change in User Mobility	$	566,865	850,298	963,671	1,077,044	1,133,730	1,190,417	1,417,163	1,700,595	2,267,460	6,802,380
Change In User Travel Time											
In-Vehicle Travel Time	$	0	0	0	0	0	0	0	0	0	0
Out-of-Vehicle Travel Time	$	0	0	0	0	0	0	0	0	0	0
Travel Time Reliability	$	0	0	0	0	0	0	0	0	0	0
Change in Costs Paid by Users											
Fuel Costs	$	0	0	0	0	0	0	0	0	0	0
Non-fuel Operating Costs	$	0	0	0	0	0	0	0	0	0	0
Accident Costs (Internal Only)	$	0	0	0	0	0	0	0	0	0	0
Change in External Costs	$	0	0	0	0	0	0	0	0	0	0
Accident Costs (External Only)	$	0	0	0	0	0	0	0	0	0	0
Emissions											
HC/ROG	$	0	0	0	0	0	0	0	0	0	0
NOx	$	0	0	0	0	0	0	0	0	0	0
CO	$	0	0	0	0	0	0	0	0	0	0
PM10	$	0	0	0	0	0	0	0	0	0	0
CO2	$	0	0	0	0	0	0	0	0	0	0
Global Warming	$	0	0	0	0	0	0	0	0	0	0
Noise	$	0	0	0	0	0	0	0	0	0	0
Other Mileage-Based External Costs	$	0	0	0	0	0	0	0	0	0	0
Other Trip-Based External Costs	$	0	0	0	0	0	0	0	0	0	0
Change in Public Agencies Costs (Efficiency Induced)	$	0	0	0	0	0	0	0	0	0	0
Other Calculated Benefits	$	0	0	0	0	0	0	0	0	0	0
User Defined Additional Benefits	$	0	0	0	0	0	0	0	0	0	0
Total Annual Benefits	$	**566,865**	**850,298**	**963,671**	**1,077,044**	**1,133,730**	**1,190,417**	**1,417,163**	**1,700,595**	**2,267,460**	**6,802,380**
Annual Costs											
Average Annual Private Sector Cost	$	0	0	0	0	0	0	0	0	0	0
Average Annual Public Sector Cost	$	213,238	213,238	213,238	213,238	213,238	213,238	213,238	213,238	213,238	213,238
Total Annual Cost	$	**213,238**	**213,238**	**213,238**	**213,238**	**213,238**	**213,238**	**213,238**	**213,238**	**213,238**	**213,238**
Benefit/Cost Comparison											
Net Benefit (Annual Benefit - Annual Cost)	$	**353,627**	**637,059**	**750,432**	**863,805**	**920,492**	**977,178**	**1,203,924**	**1,487,357**	**2,054,222**	**6,589,142**
B/C Ratio (Annual Benefit/Annual Cost)		**2.66**	**3.99**	**4.52**	**5.05**	**5.32**	**5.58**	**6.65**	**7.98**	**10.63**	**31.90**

B.5 Telephone Multimodal Traveler Information System

Benefits and Costs		V/C Ratios									
		0.50	0.75	0.85	0.95	1.00	1.05	1.25	1.50	2.00	6.00
Annual Benefits											
Change in User Mobility	$	6	86	293	886	289,896	2,394	13,689	84,667	2,048,175	14,921,719
Change In User Travel Time											
In-Vehicle Travel Time	$	0	0	0	0	0	0	0	0	0	0
Out-of-Vehicle Travel Time	$	0	0	0	0	0	0	0	0	0	0
Travel Time Reliability	$	0	0	0	0	0	0	0	0	0	0
Change in Costs Paid by Users											
Fuel Costs	$	0	0	0	0	0	0	0	0	0	0
Non-fuel Operating Costs	$	0	0	0	0	0	0	0	0	0	0
Accident Costs (Internal Only)	$	0	0	0	0	0	0	0	0	0	0
Change in External Costs	$	0	0	0	0	0	0	0	0	0	0
Accident Costs (External Only)	$	0	0	0	0	0	0	0	0	0	0
Emissions											
HC/ROG	$	0	0	0	0	0	0	0	0	0	0
NOx	$	0	0	0	0	0	0	0	0	0	0
CO	$	0	0	0	0	0	0	0	0	0	0
PM10	$	0	0	0	0	0	0	0	0	0	0
CO2	$	0	0	0	0	0	0	0	0	0	0
Global Warming	$	0	0	0	0	0	0	0	0	0	0
Noise	$	0	0	0	0	0	0	0	0	0	0
Other Mileage-Based External Costs	$	0	0	0	0	0	0	0	0	0	0
Other Trip-Based External Costs	$	0	0	0	0	0	0	0	0	0	0
Change in Public Agencies Costs (Efficiency Induced)	$	0	0	0	0	0	0	0	0	0	0
Other Calculated Benefits	$	0	0	0	0	0	0	0	0	0	0
User Defined Additional Benefits	$	0	0	0	0	0	0	0	0	0	0
Total Annual Benefits	$	**6**	**86**	**293**	**886**	**289,896**	**2,394**	**13,689**	**84,667**	**2,048,175**	**14,921,719**
Annual Costs											
Average Annual Private Sector Cost	$	305,821	305,821	305,821	305,821	305,821	305,821	305,821	305,821	305,821	305,821
Average Annual Public Sector Cost	$	219,276	219,276	219,276	219,276	219,276	219,276	219,276	219,276	219,276	219,276
Total Annual Cost	$	**525,097**	**525,097**	**525,097**	**525,097**	**525,097**	**525,097**	**525,097**	**525,097**	**525,097**	**525,097**
Benefit/Cost Comparison											
Net Benefit (Annual Benefit - Annual Cost)	$	**-525,091**	**-525,011**	**-524,804**	**-524,212**	**-235,201**	**-522,703**	**-511,408**	**-440,431**	**1,523,078**	**14,396,621**
B/C Ratio (Annual Benefit/Annual Cost)		**0.00**	**0.00**	**0.00**	**0.00**	**0.55**	**0.00**	**0.03**	**0.16**	**3.90**	**28.42**

B.6 Internet/Web Multimodal Traveler Information Systems

Benefits and Costs		V/C Ratios									
		0.50	0.75	0.85	0.95	1.00	1.05	1.25	1.50	2.00	6.00
Annual Benefits											
Change in User Mobility	$	40	574	1,955	5,905	1,932,642	15,963	91,263	564,446	13,654,504	99,478,121
Change In User Travel Time											
In-Vehicle Travel Time	$	0	0	0	0	0	0	0	0	0	0
Out-of-Vehicle Travel Time	$	0	0	0	0	0	0	0	0	0	0
Travel Time Reliability	$	0	0	0	0	0	0	0	0	0	0
Change in Costs Paid by Users											
Fuel Costs	$	0	0	0	0	0	0	0	0	0	0
Non-fuel Operating Costs	$	0	0	0	0	0	0	0	0	0	0
Accident Costs (Internal Only)	$	0	0	0	0	0	0	0	0	0	0
Change in External Costs	$	0	0	0	0	0	0	0	0	0	0
Accident Costs (External Only)	$	0	0	0	0	0	0	0	0	0	0
Emissions											
HC/ROG	$	0	0	0	0	0	0	0	0	0	0
NOx	$	0	0	0	0	0	0	0	0	0	0
CO	$	0	0	0	0	0	0	0	0	0	0
PM10	$	0	0	0	0	0	0	0	0	0	0
CO2	$	0	0	0	0	0	0	0	0	0	0
Global Warming	$	0	0	0	0	0	0	0	0	0	0
Noise	$	0	0	0	0	0	0	0	0	0	0
Other Mileage-Based External Costs	$	0	0	0	0	0	0	0	0	0	0
Other Trip-Based External Costs	$	0	0	0	0	0	0	0	0	0	0
Change in Public Agencies Costs (Efficiency Induced)	$	0	0	0	0	0	0	0	0	0	0
Other Calculated Benefits	$	0	0	0	0	0	0	0	0	0	0
User Defined Additional Benefits	$	0	0	0	0	0	0	0	0	0	0
Total Annual Benefits	$	**40**	**574**	**1,955**	**5,905**	**1,932,642**	**15,963**	**91,263**	**564,446**	**13,654,504**	**99,478,121**
Annual Costs											
Average Annual Private Sector Cost	$	305,821	305,821	305,821	305,821	305,821	305,821	305,821	305,821	305,821	305,821
Average Annual Public Sector Cost	$	219,276	219,276	219,276	219,276	219,276	219,276	219,276	219,276	219,276	219,276
Total Annual Cost	$	**525,097**	**525,097**	**525,097**	**525,097**	**525,097**	**525,097**	**525,097**	**525,097**	**525,097**	**525,097**
Benefit/Cost Comparison											
Net Benefit (Annual Benefit - Annual Cost)	$	**-525,057**	**-524,523**	**-523,142**	**-519,192**	**1,407,544**	**-509,135**	**-433,835**	**39,349**	**13,129,406**	**98,953,024**
B/C Ratio (Annual Benefit/Annual Cost)		**0.00**	**0.00**	**0.00**	**0.01**	**3.68**	**0.03**	**0.17**	**1.07**	**26.00**	**189.45**