Applying Analysis Tools in Planning for Operations

Case Study #1 – Operations Strategy Impact Reference and Deployment Guidance

U.S. Department of Transportation
Federal Highway Administration

Notice

This document is disseminated under the sponsorship of the U.S. Department of Transportation in the interest of information exchange. The U.S. Government assumes no liability for the use of the information contained in this document. This report does not constitute a standard, specification, or regulation.

The U.S. Government does not endorse products or manufacturers. Trademarks or manufacturers' names may appear in this report only because they are considered essential to the objective of the document.

Quality Assurance Statement

The Federal Highway Administration (FHWA) provides high-quality information to serve Government, industry, and the public in a manner that promotes public understanding. Standards and policies are used to ensure and maximize the quality, objectivity, utility, and integrity of its information. FHWA periodically reviews quality issues and adjusts its programs and processes to ensure continuous quality improvement.

1. Report No.
FHWA-HOP-10-002

2. Government Accession No.

3. Recipient's Catalog No.

4. Title and Subtitle
Applying Analysis Tools in Planning for Operations:
Case Study #1– Operations Strategy Impact Reference and Deployment Guidance

5. Report Date
September 2009

6. Performing Organization Code

7. Author(s)
Douglas Sallman, Krista Jeannotte, Dorothy Morallos, and Shriram Ramaratnam, Cambridge Systematics; Jim Bunch, Cheryl Lowrance, and Greg Hatcher, Noblis

8. Performing Organization Report No.

9. Performing Organization Name and Address

Cambridge Systematics, Inc.	Noblis
555 12th Street, Suite 1600	600 Maryland Ave., Suite 755
Oakland, CA 94607	Washington, DC 20024

10. Work Unit No.

11. Contract or Grant No.
DTFH61-05-C-00036

12. Sponsoring Agency Name and Address
Department of Transportation
Federal Highway Administration
U.S. Department of Transportation
1200 New Jersey Avenue, SE
Washington, DC 20590

13. Type of Report and Period Covered
Brochure
November 2005 – December 2009

14. Sponsoring Agency Code

15. Supplementary Notes
FHWA COTR: Wayne Berman, Office of Operations; John Halkias, Office of Operations; and Richard Backlund, Office of Operations

16. Abstract

More and more, transportation system operators are seeing the benefits of strengthening links between planning and operations. A critical element in improving transportation decision-making and the effectiveness of transportation systems related to operations and planning is through the use of analysis tools and methods. This brochure is one in a series of five intended to improve the way existing analysis tools are used to advance operational strategies in the planning process. The specific objective of developing this informational brochure series was to provide reference and resource materials that will help planners and operations professionals to use existing transportation planning and operations analysis tools and methods in a more systematic way to better analyze, evaluate, and report the benefits of needed investments in transportation operations. This particular case study focused on compiling information on various operations strategies in order to promote a greater understanding of the impacts including:

- **High-level summaries of the likely impacts** of operational strategies on performance measures.
- **Guidance on specific thresholds or rules-of-thumb** that have been developed to help practitioners identify conditions that warrant deployment of particular operations strategies.

The guidance provided in this case study is intended to bridge a common knowledge gap faced by many deploying agencies and aims to answer the questions: "what situations are most conducive to operational strategy deployments" and "what are the likely impacts of the strategies under consideration."

17. Key Words
analysis tools, planning for operations, transportation operations, performance measures, operations impacts, deployment guidance

18. Distribution Statement
No restrictions. This document is available to the public through the National Technical Information Service, Springfield, VA 22161.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No of Pages	22. Price
		24	na

SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
(Revised March 2003)

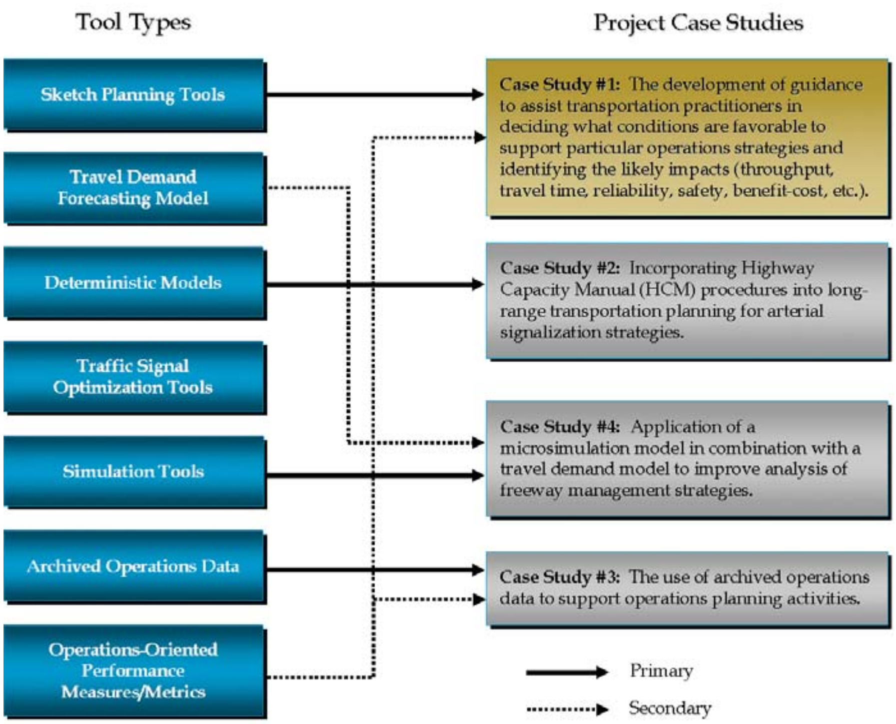
Applying Analysis Tools in Planning for Operations

Case Study #1 – Operations Strategy Impact Reference and Deployment Guidance

More and more, transportation system operators are seeing the benefits of strengthening links between planning and operations. A critical element in improving transportation decision-making and the effectiveness of transportation systems related to operations and planning is through the use of analysis tools and methods. This brochure is one in a series of five intended to improve the way existing analysis tools are used to advance operational strategies in the planning process. The specific objective of developing this informational brochure series was to provide reference and resource materials that will help planners and operations professionals to use existing transportation planning and operations analysis tools and methods in a more systematic way to better analyze, evaluate, and report the benefits of needed investments in transportation operations.

The series of brochures includes an overview brochure and four case studies that provide practitioners with information on the feasibility of these practices and guidance on how they might implement similar processes in their own regions. The particular case studies were developed to illuminate how existing tools for operations could be

Figure 1. Analytical Methods/Tools and Related Case Studies Developed Under this Project



utilized in innovative ways or combined with the capabilities of other tools to support operations planning.[1] The types of tools considered when selecting the case studies included:

- Sketch planning tools;
- Travel demand forecasting models;
- Deterministic models;
- Traffic signal optimization tools;
- Simulation tools;
- Archived operations data;
- Operations-oriented performance measures/metrics; and
- Combinations of these tools and methods.

Additional information on these existing tool types is presented in the overview brochure to this series.

In selecting the case studies to highlight in this brochure series, a number of innovative analysis practices and tool applications were considered. Ultimately, four different case studies were selected from among many worthy candidates. Each of these case studies represents an innovative use of one or more of the tool types listed above. Figure 1 presents the topics of the case studies and maps them to the related tool. Although individual case studies were not developed for each tool category, this should not be considered as a measure of indictment of the ability of any tool type to be used in innovative ways to support operations planning – there simply weren't project resources to identify and document all of the innovative practices being used. Likewise, the selection of a particular case study representing a specific tool should not be construed as the only manner in which to apply the particular tool. Instead, the case studies represent a sampling of the many innovative ways planners and operations personnel are applying these tools currently.

Case Study Introduction

This particular case study focused on compiling information on various operations strategies into an easily accessible format in order to promote a greater understanding of the strategy impacts. As previously shown in Figure 1, this case study is most reflective of "sketch planning tools". The information compiled and organized focused on the following two separate areas:

- **High-level summaries of the likely impacts of operational strategies on various performance measures**. These impacts were compiled from observed impacts of previous deployments, previously conducted simulation analyses, and the suggested impacts of several existing analysis tools (e.g., the FHWA's ITS Deployment Analysis System software).

- **Guidance on specific thresholds or rules-of-thumb** that have been developed to help practitioners identify conditions that warrant deployment of particular operations strategies.

The guidance provided in this study is intended to bridge a common

1 The use of the term "Tools" in this context is meant not only to include physical software and devoted analytical applications, but is also intended to encompass more basic analysis methods and procedures as well.

knowledge gap faced by many deploying agencies and aims to answer the questions: "what situations are most conducive to operational strategy deployments" and "what are the likely impacts of the strategies under consideration." By providing this information, this study is intended to aid planners and operational personnel in conducting preliminary analysis and screening of the need for operations strategies and in comparing the relative impacts of various strategies.

This specific case study was unique among the four conducted under this project in that it did not involve the direct participation of a particular state, regional, or local agency. Instead, this case study was led by Cambridge Systematics with support from Noblis, Inc., which conducted literature searches and research of the impacts and deployment guidance.

Case Study Objectives

A significant effort has been made by Federal, state, and local transportation agencies in quantifying and documenting the impacts and benefits associated with the deployment of various operations strategies. Many of these impact studies have been compiled in national, cross-cutting database repositories such as the U.S. DOT *ITS Benefits Database* (http://www.itsbenefits.its.dot.gov/), and other libraries maintained by agencies and research institutions. These impact studies have also served as the basis for developing recommended impact ranges for different strategies used in several operations analysis tools developed by Federal, state, and regional agencies. While these resources provide extremely useful and detailed information to practitioners, the amount of documentation and quantity of information can be overwhelming, thus limiting practitioners from quickly obtaining a high-level understanding of the range of impacts associated with particular strategies. Simple questions, such as "What is the average impact on safety of adding ramp metering?" can not be easily answered without scanning multiple documents.

In addition to the information on the likely benefits of operations strategies, some agencies have begun to develop guidelines for identifying conditions where operations strategies are warranted. The development of these guidelines is still in its infancy and these often take the form of suggested thresholds or rules-of-thumb regarding deployment conditions that are favorable to particular strategies. Over time it is expected that this deployment guidance will become more common and more detailed as the thresholds are vetted against real-world conditions.

The purpose of this case study was to assemble this impact data and deployment guidance into a spreadsheet format that was readily accessible and could easily be customized by practitioners. Two separate spreadsheets were developed:

1. Impacts Summary – This summarizes the likely impacts of various operations strategies, and

2. Deployment Guidelines – This summarizes the deployment guidance that has been developed to date by various agencies.

Each spreadsheet was developed in a simple format that may be freely modified by individual practitioners to add new data as it is discovered, or to serve as a repository for their own customized impact ranges or deployment guidelines. The spreadsheets are available for download at the following link http://www.plan4operations.dot.gov/casestudies/analysis.htm.

The ultimate objective of developing these spreadsheets was to provide a valuable reference source for this information in order to improve access to the data by planners and operational staff, and provide this in a format that could be easily used and updated by these individuals.

How Can This Information Be Used?

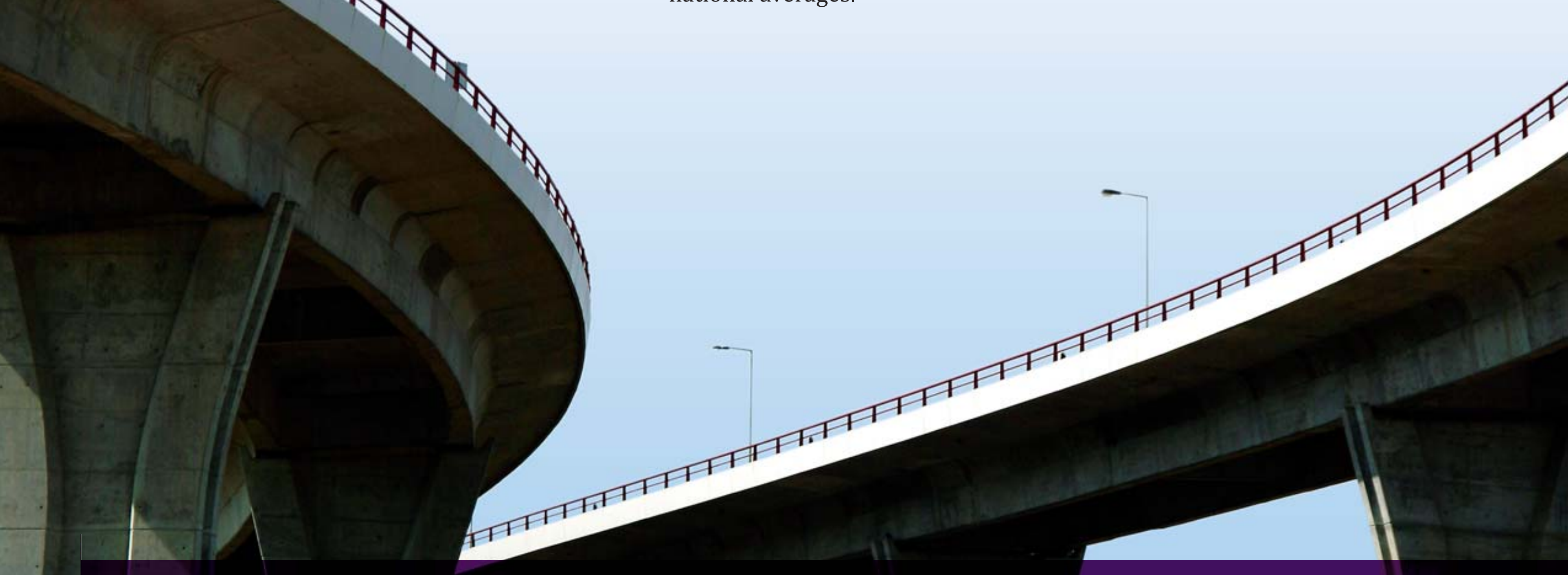
The summary information presented in the Impact Summary provides a valuable reference source for information on the order of magnitude impacts observed in other regions that have deployed particular operations strategies. This data is provided in a format that can be easily used and updated by individual practitioners to develop their own impact repositories.

To illustrate how this data and the Impact Summary can be used by practitioners to improve their planning for operations, several hypothetical applications are discussed below that show how the tool could have been applied in several previously conducted studies.

Example 1 – OKI ITS Benefits Study

In the early 2000s, the Ohio-Kentucky-Indiana (OKI) Regional Council of Governments undertook a major study to estimate the benefits of the current and future planned ITS deployments in the Cincinnati region. The region decided to conduct the analysis using the FHWA ITS Deployment Analysis System (IDAS) software. The IDAS tool estimates impacts of ITS deployments using default impact rates for different strategies based on national averages of impacts observed in other regions.

Prior to implementing the analysis, OKI wanted to assess the appropriateness of the default rates based on national averages for application in the Cincinnati region (i.e., to determine if the national averages were reflective of the conditions in Cincinnati). To accomplish this, a comprehensive literature review was undertaken to find particular studies that had been conducted in regions of similar size, geography, and climate. Findings from these studies were then compared with the default national averages to assess if particular impacts should be adjusted in the analysis. Studies that were found from more similar regions (e.g., Columbus, Nashville, St. Louis) were given more weight in this assessment while studies of impacts from widely differing regions (e.g., Los Angeles) were given less weight. The result of this activity was adjusted impact factors for a wide range of ITS deployments that OKI felt were more representative of the Cincinnati region than the default national averages.



Had the Impacts Summary spreadsheet been available at the time, this research and adjustment process could have been greatly streamlined. The researchers could have first consulted the spreadsheet to identify similar regions where impact findings were available. The impacts from these regions could have been quickly compared with the findings from other regions to assess whether there were discernable differences in impacts based on these regional characteristics, and any difference could have been investigated by utilizing the reference notations in the spreadsheet to obtain the full study documentation for studies that were particularly interesting. Use of the Impact Summary spreadsheet in this way would have eliminated weeks of time and effort from this example application.

Example 2 – Florida DOT ITS Benefits Repository

The Florida DOT (FDOT) recently conducted the development of an ITS Benefits Repository. This effort was undertaken to identify and document standardized estimates of impacts that could then be used similarly in all ITS planning studies statewide. This will ensure a more level, apples-to-apples comparison of ITS project funding requests received from different regions of the State.

The Florida DOT effort utilized the ITS benefits library in the FHWA's IDAS tool, which is set up similarly to the Impact Summary, but not in as a user friendly format. The information regarding impacts observed in other regions was compared with averages as well as the engineering judgment of FDOT staff regarding impacts of particular strategies. Once a standard impact value had been agreed upon, it was documented back into a spreadsheet format for archiving. The final spreadsheet was then distributed to all ITS planners and operations personnel in the State.

Other regions could conduct a similar exercise utilizing the Impact Summary worksheet. This would provide access to a greater amount of information than is currently available in the IDAS tool, and wouldn't require the purchase of any software. The Impact Summary spreadsheet could be easily modified by any agency to serve as an archive of their own standardized impacts, simply by adding a "our preferred value" column to any strategies the agency wants to document. The spreadsheet format also aids in distribution of the customized repository or any updates.

Case Study Procedures

This section briefly summarizes the procedures followed in developing the guidance for practitioners. Subsequent sections provide greater detail on how practitioners can best use the developed guidance. The following steps were used in developing this guidance:

Develop Format

The study team first reviewed the format of some of the existing resources providing information on the observed or potential benefits of various operations strategies. Resources reviewed included the U.S. DOT *ITS Benefits Database* and the FHWA's ITS Deployment Analysis (IDAS) tool.

Based on the need to develop a simple and accessible reference, a spreadsheet format was selected. The study team decided to categorize similar strategies (e.g., signal coordination) on individual worksheets within the spreadsheet and to differentiate variations of the strategies (e.g., pre-set timing versus traffic actuated signal coordination) in the various rows of the worksheet. Columns in the worksheet were used to categorize various performance measures impacted by the particular strategies. For consistency, all the worksheets in the spreadsheet were formatted similarly so that the performance measure column headings are the same on all sheets, regardless of whether or not there were observed impact data available for the particular strategy. Both the Impacts Summary and the Deployment Guidelines spreadsheets were developed using this format; however, the Deployment Guidelines spreadsheet does not include the performance measures categorization.

Identify Strategies and Performance Measures

Next, the research team identified the strategies and categories of strategies to be included in the spreadsheets and developed a list of performance measures that could be impacted by the various strategies. The IDAS tool provided the initial basis for identifying and categorizing the various operations strategies. The strategy categorization used in IDAS was initially based on the ITS National Architecture's Market Packages; however, many of the Market Packages were further disaggregated to identify specific strategies that were more consistent with the way that practitioners typically deployed them. Over 60 individual strategies are identified in IDAS, grouped into 12 major categories as shown in Table 1. All of the IDAS identified strategies, with the exception of the "Generic Deployments" which are specific to the IDAS tool, were used to develop the preliminary list of strategies for this project.

Table 1. Operations Strategies in IDAS

Arterial Traffic Management Systems
- Isolated Traffic Actuated Signals
- Preset Corridor Signal Coordination
- Actuated Corridor Signal Coordination
- Central Control Signal Coordination
- Emergency Vehicle Signal Priority
- Transit Vehicle Signal Priority

Freeway Management Systems
- Pre-set Ramp Metering
- Traffic Actuated Ramp Metering
- Centrally Controlled Ramp Metering

Advanced Public Transit Systems
- Fixed Route Transit–Automated Scheduling System
- Fixed Route Transit–Automatic Vehicle Location
- Fixed Route Transit–Combination Automated Scheduling System and Automatic Vehicle Location
- Fixed Route Transit–Security Systems
- Paratransit–Automated Scheduling System
- Paratransit–Automatic Vehicle Location
- Paratransit–Automated Scheduling System and Automatic Vehicle Location

Incident Management Systems
- Incident Detection/Verification
- Incident Response/Management
- Incident Detection/Verification/Response/Management combined

Electronic Payment Systems
- Electronic Transit Fare Payment
- Basic Electronic Toll Collection

Railroad Grade Crossing Monitors

Emergency Management Services
- Emergency Vehicle Control Service
- Emergency Vehicle AVL
- In-Vehicle Mayday System

Regional Multimodal Traveler Information Systems
- Highway Advisory Radio
- Freeway Dynamic Message Sign
- Transit Dynamic Message Sign
- Telephone-Based Traveler Information System
- Web/Internet-Based Traveler Information System

Regional Multimodal Traveler Information Systems (continued)
- Kiosk with Multimodal Traveler Information
- Kiosk with Transit-only Traveler Information Handheld Personal Device–Traveler Information Only
- Handheld Personal Device–Traveler Information with Route Guidance
- In-Vehicle–Traveler Information Only
- In-Vehicle–Traveler Information with Route Guidance

Commercial Vehicle Operations
- Electronic Screening
- Weigh-in-Motion
- Electronic Clearance–Credentials
- Electronic Clearance–Safety Inspection
- Electronic Screening/Clearance combined
- Safety Information Exchange
- On-board Safety Monitoring
- Electronic Roadside Safety Inspection
- Hazardous Materials Incident Response

Advanced Vehicle Control and Safety Systems
- Motorist Warning–Ramp Rollover
- Motorist Warning–Downhill Speed
- Longitudinal Collision Avoidance
- Lateral Collision Avoidance
- Intersection Collision Avoidance
- Vision Enhancement for Crashes
- Safety Readiness

Supporting Deployments
- Traffic Management Center
- Transit Management Center
- Emergency Management Center
- Traffic Surveillance–CCTV
- Traffic Surveillance–Loop Detector System
- Traffic Surveillance–Probe System
- Basic Vehicle Communication
- Roadway Loop Detector
- Information Service Provider Center

Generic Deployments
- Link based
- Zone based

Additionally, several new operations strategies not currently available in IDAS were identified to supplement the list based on feedback from practitioners. These strategies include the following:

- Congestion Pricing:
  - High-Occupancy Toll (HOT) lanes,
  - Variable Tolls, and
  - Cordon Pricing.
- Weather Applications:
  - Ice Removal,
  - Weather Detection, and
  - Weather Information.
- Work Zone Management.

Once the various strategies were identified, a list of performance measure categories was developed. These performance measure categories were based on impact categories listed in the ITS JPO's ITS Benefits Database and in the IDAS software. Merging the performance measure categories in these two resources resulted in the following impact categories:

- Travel time and speed;
- Throughput;
- Mode shift;
- Time-of-day (temporal) shift;
- Route shift;
- Forgone trip;
- Safety;
- Customer satisfaction;
- Emissions;
- Energy;
- Costs (e.g., benefit/cost analysis results);
- Agency efficiency; and
- Other impacts.

Conduct Research

Research was then conducted to identify studies that could be used to populate the cells of the spreadsheets. For the Impacts Summary, data was first compiled from the internal IDAS benefits library and the *ITS Benefits Database*. This data was updated through searches of more recently conducted impact studies and through additional research. This additional research was particularly useful in compiling impact information for some strategies that had not been previously included in IDAS or the ITS Benefits Database, such as Congestion Pricing and Work Zone Management. For consideration in the Impacts Summary the identified data minimally must include the following:

1. Location of the study (if applicable);

2. Identification of strategy deployed;

3. Identification of impact (e.g., travel times were reduced by five percent after the signal coordination was deployed); and

4. Reference to more detailed documentation on the deployment and the impact analysis to allow users to further investigate interesting findings.

The identification of the impact in the spreadsheet is generally terse, for example the following entry summarizes one regions observed safety impacts of ramp metering: "Minneapolis St. Paul – Average number of peak period accidents decreased by 24 percent". These entries were kept brief because the goal of this Impacts Summary was to provide a quick reference guide for practitioners, not to provide a detailed assessment of each impact study. Therefore, the research team did not attempt to compile data at the comprehensive level of detail of the ITS Benefits Database or other similar sources.

For the Deployment Guidelines spreadsheet, research was conducted to identify state or local agencies that have developed guidelines or thresholds for identifying problem locations or conditions that are appropriate for deployment of various operations strategies. This research included contacting a number of state DOTs known to be investigating these types of guidelines. Information regarding guidelines, thresholds, or warrants for determining the potential for operations strategy deployment proved much more difficult to compile than the impact data. The development of these types of guidelines is still in its infancy and there are very few agencies that currently have any formalized and documented guidance; however, a greater number of agencies reported that these types of guidelines were currently under development or at least under consideration, so it is hoped that more data on these guidelines will be available in the near future. Guideline information that was identified was compiled along with any supporting documentation, when available.

Organize Materials

The compiled data were then used to populate the appropriate spreadsheet cells. For the Impact Summary worksheet, identified impacts were mapped to the appropriate category (worksheet), strategy (row), and performance measure (column). To further assist the user, strategies with many entries for a specific performance measure were further organized to disaggregate the impacts identified in domestic locations from those observed in international deployments. Additionally, those impacts estimated through the use of modeling or simulation studies were segregated from empirical results observed in "before-and-after" studies.

To provide additional guidance to the user, the default impact values identified in the IDAS analysis tool were also entered into the spreadsheet for appropriate strategies. These IDAS default values from the tool are based on an average of impact values observed in nationwide studies and provide users with a suggested value to use as a starting point in their own investigations. These default impact values from IDAS are provided in the spreadsheet for a similar purpose–to provide an average value to serve as a starting point for practitioners to initiate their investigating of strategy impacts. The same caveats that apply to these default values in IDAS also apply to the spreadsheet including, the user is strongly encouraged to view these national average values in light of the impacts experienced by individual jurisdictions and make adjustments to more closely fit their own regional conditions and environment. All IDAS default values identified in the spreadsheet are specifically denoted as such, as shown in Figure 2, which presents a sample view of the Impacts Summary spreadsheet.

Figure 2. Sample View of Impact Summary Structure

ITS ELEMENT Freeway Traffic Management System			Travel Time and Speed Impact	Throughput Impact
Ramp Metering	*Pre-set Timing*	*National studies/statistics*	**National** - 13% to 48% reduction in travel time	**National** - 17% to 25% increase in volume
			National - 16% to 62% improvement in speed, 48% reduction in travel time	
			National - 5% to 20% time savings	
		U.S. state, regional, local studies/statistics	**Austin, TX** - Travel time decreased by 37.5%	**California** (I-680 and I-405 simulation models) - 15% ramp capacity reduction at metered ramps, 14% capacity increase on freeway mainline
			Dallas, TX - 7.6% to 55% increase in speed	**Phoenix, AZ** - 15% increase in volume
			Dallas, TX (North Central Expwy) - 15% increase in speed, 15% decrease in delay	**Phoenix, AZ** - 3.6% reduction in vehicle stops, 25% for SB direction during PM peak
			Detroit, MI - Speeds increased by 8%	**Portland, OR** - 25% increase in volume
			Detroit, MI - Travel time decreased by 7.4%	**Seattle, WA** - Increase capacity at rush hour by 10% to 100%
			Houston, TX - 29% increase in speed	**Seattle, WA (I-5 in 1980s)** - 62% to 86% increase in volume
			Phoenix, AZ - 5% to 10% increase in speed	**Seattle, WA (SR-520 in 1986)** - 6.5% increase in volume
			Portland, OR - 39% reduction in travel time, 60% improvement in speed	
			Portland, OR - Speeds increased from 16 to 41 mph NB and 40 to 43 mph SB (156% and 7.5% increase, respectively)	
			Portland, OR - Travel time decreased by 7.4%	
			Seattle, WA - Travel time decreased by 47.7% to 52.3%, speed increased by 20%	
		FHWA ITS Deployment Analysis System (IDAS) software tool impacts	No Data Available	**IDAS** - Suggests an impact equaling a 9.5% capacity increase at freeway links affected by ramp metering
				IDAS - Suggests an impact equaling a 33% capacity reduction at affected freeway ramps
		Simulation Results	No Data Available	No Data Available
		International and Misc.	**England** - Ramp delays added 1.5 minutes to average travel time	**England** - Bottleneck capacity increased by 3.2%, resulting in 20 minute reduction in peak period
			Netherlands - 5kmh to 30kmh improvement in speed, 3% to 10% reduction in travel time, and up to 20% reduction in delay	**Handle** - 8% to 22% increase in traffic
				Netherlands - up to 5% increase in bottleneck capacity, but up to 50% reduction in on-ramp volume

For cells where no suitable impact data were identified, an entry of "No Data Available" was made.

Additionally, for all data entered, a reference is provided to the source document where the data was obtained. For ease of use, the reference columns are hidden when the spreadsheet is first opened, but this data may be easily viewed by the user if they are interested in investigating the specifics regarding any particular data entry.

For the Deployment Guidelines spreadsheet, all compiled guidelines and thresholds were mapped to the appropriate worksheet and row for the particular strategy. Given the general lack of data for this subject, the identified guidelines are provided in a single column with any source information provided in an adjacent column, as shown in Figure 3. No attempt was made to further disaggregate these guidelines according to particular conditions or the threshold performance measures used, although the spreadsheet format provides for this possibility in the future if more information becomes available.

Figure 3. Sample View of Deployment Guidelines Structure

Freeway Traffic Management System		Document Name/ Study/Specifics	Deployment	Comment 1
Ramp Metering	*General*	Ramp Metering Study Sources: (1) 2030 Statewide Transportation Plan; Intelligent Transportation Systems Technical Report; February 2005; Colorado DOT http://www.dot.state.co.us/StateWidePlanning/PlansStudies/files_final2030update_jdc/2030%20Plan%20Technical%20Reports/ITS%20Technical%20Report.pdf and (2) Town Meeting document of the Town of Superior, Colorado which includes a section on Warranting Ramp Metering; page 70 of 75. http://www.townofsuperior.com/pdf/Final_TB_4.10.06_for_website.pdf	• The designer should consult the "Methodology" section in the Ramp Metering Feasibility Study.	*Design Guidelines for Including Intelligent Transportation Systems on Project*s http://www.cotrip.org/its/ITS Guidelines Web New Format 2-05/ITS GUIDELINES Fund 1-05.doc
	General	Ramp Meter Guidance from *Caltrans Transportation Management System Master Plan; financial plan report* http://www.dot.ca.gov/hq/traffops/sysmgtpl/reports/TMS%20Master%20Plan%20Financial%20Plan.pdf	Urban/suburban – • Ramp Meters should be used where forecasted volume (forecasted volumes are generally obtained from regional travel demand models) is greater than 1,800 vehicles per hour at the rightmost freeway lane plus the on-ramp; • Ramp Meters should be used at areas with significant merging problems; • Priority should be given to already congested locations, whenever possible in coordination with regional and local jurisdictions.	
	General	Mn DOT Study http://www.cotrip.org/cotrip_quarterly/4-2/news3.htm	• A MN/DOT study concluded that it is typical for travelers to perceive ramp metering wait times to be about double what they are in reality.	*Design Guidelines for Including Intelligent Transportation Systems on Projects http://www.cotrip.org/its/ITS Guidelines Web New Format 2-05/ITS GUIDELINES Fund 1-05.doc*
	Pre-set Timing	Ramp Control Guidance Guidance in Source: *Understanding the Benefits and Costs of Intelligent Transportation Systems; A toolkit approach; version 1.0* ; February 2005 Department for Transport, United Kingdom	<u>Use:</u> Ramp control is only useful if the seedpoint of congestion is at the merge or if the merge close is to the seedpoint of congestion. <u>Existing Infrastructure/Conditions Requirements</u>: (1) Existing on-ramp must be long enough to allow traffic to accelerate from the traffic signals to an appropriate speed prior to merging. (2) Ramp metering may not be appropriate where lanes on the on-ramp are divided by a ghost island for each lane with behave discreetly. (3) Need to consider existing road networks ability to cope with vehicles queuing back--ramp control systems can incorporate detection at the start of the on-ramp to prevent waiting traffic from interfering with the local highway network.	

Develop User Guidance

The final step in developing the Impact Summary and Deployment Guidelines resources was to develop instructions and user guidance for their application. In order to provide a simple resource that could be easily distributed as a single file, the instructions for use were incorporated as a separate worksheet in both resources. This user guidance is also provided in Appendix B of this report.

Data in the Spreadsheets

Table 2 provides a quick-look summary of the data contained in the Impact Summary spreadsheet. This table provides a cross reference of those strategies and performance measures where data was available at the time of publication of this document.

Table 3 provides a further synthesis of the data contained in the Impacts Summary spreadsheet by highlighting general ranges of impacts noted in the individual data points.[2] Note that not all the data points

2 The individual data points that were used in estimating the general ranges presented in Table 3 are presented in the Impacts Summary spreadsheet. These individual data points also identify the region in which the impact was observed and provide a reference for this information. The ranges presented in Table 3 are only intended as a general overview of the more detailed data contained in the spreadsheet tool and in many cases are not inclusive of outliers observed in the collected data.

Table 2. Quick-Look Reference to “Impact Summary” Data

STRATEGY	Speed & Time	Throughput	Mode Change	TOD Change	Route Change	Foregone Trip	Safety	Customer Satisfact.	Emissions	Energy	Cost	Efficiency	Other
ATMS Signal Coordination													
Traffic Actuated Isolated	❍	❍							❍				
Preset Timing Corridor	❍	❍					❍		❍	❍	❍	❍	❍
Traffic Actuated Corridor	❍	❍					❍	❍	❍	❍			❍
Central Control Corridor	❍	❍							❍	❍	❍		❍
ATMS Signal Priority													
Transit Vehicle	❍	❍					❍		❍			❍	
Emergency Vehicle	❍						❍					❍	
Freeway Management Systems													
Ramp Metering Pre-Set Timing	❍	❍					❍			❍	❍		
Ramp Metering–Traffic Actuated	❍	❍					❍	❍	❍	❍	❍		
Ramp Metering–Central Control	❍	❍					❍						
Advanced Public Transportation Systems													
Fixed Route–Automated Schedule	❍										❍		
Fixed Route–AVL	❍										❍	❍	❍
Fixed Route–Security Systems							❍	❍					
Paratransit–Automated Schedule	❍							❍					
Paratransit–AVL							❍				❍		
Incident Management Systems													
Detection/Verification	❍	❍					❍		❍		❍	❍	
Response/Management	❍						❍	❍	❍	❍	❍	❍	
Combination Detection & Response	❍	❍					❍	❍			❍	❍	
Electronic Payment Collection													
Transit Fare Payment								❍			❍		
Basic Toll Collection	❍	❍		❍				❍	❍	❍	❍	❍	❍
Railroad Grade Crossing													
Grade Crossing Monitor	❍						❍	❍					❍
Emergency Management Services													
Emergency Vehicle Control	❍						❍	❍				❍	
Emergency Vehicle AVL							❍	❍				❍	
In-vehicle Mayday								❍					❍
Multimodal Traveler Information													
Highway Advisory Radio	❍				❍			❍					
Highway Dynamic Message Sign	❍	❍			❍			❍					
Transit Dynamic Message Sign	❍							❍					
Telephone–511			❍	❍	❍			❍			❍	❍	❍
Web/Internet	❍	❍					❍	❍	❍	❍			❍
Transit/Multimodal Kiosk	❍							❍					❍
Handheld Personal Device	❍	❍		❍	❍		❍	❍	❍	❍	❍		❍
In-Vehicle Guidance	❍	❍			❍		❍	❍	❍	❍	❍		❍
Commercial Vehicle Operations													
Electronic Screening	❍										❍		
Weigh-in-Motion											❍		
Electronic Clearance	❍							❍		❍	❍		
Safety Inspection							❍				❍	❍	
Hazmat Incident Response											❍	❍	
Congestion Pricing													
HOT Lanes	❍	❍	❍	❍			❍	❍	❍		❍	❍	❍
Variable Tolls	❍	❍	❍	❍			❍	❍	❍		❍		❍
Cordon Pricing	❍		❍	❍		❍	❍	❍	❍	❍	❍		❍
Weather Applications													
Ice Removal	❍						❍				❍		
Snow Removal											❍		
Weather Detection	❍						❍						❍
Work Zone Management													
Smart Work Zones	❍				❍		❍	❍			❍		❍

Table 3. High-level Synthesis of Impact Summary Spreadsheet Data

STRATEGY	Sample Synthesis of Impacts (Ranges)
ATMS Signal Coordination	• Majority of available data focuses on travel time, speed, and delay impacts. — Speed increases typically ranged from approximately 6 to 20 percent. — Travel time decreases typically ranged from approximately 8 to 25 percent. — Delay decreases typically ranged from approximately 15 to 40 percent. • Limited studies show overall crash risk reduction of approximately 2 to 10 percent.
ATMS Signal Priority	• Majority of available data focuses on transit travel times in relation to transit signal priority systems. — Transit travel time decreases range from 5 to 33 percent. • Limited information available on impacts to autos and cross street traffic.
Freeway Management Systems–Ramp Metering	• Majority of available data focuses on speed, throughput and safety. — Speed increases typically ranged from approximately 6 to 20 percent. — Throughput increases typically ranged from approximately 5 to 20 percent. — Crash risk decreases typically ranged from 10 to 50 percent. • Ramp metering systems benefit/cost ratio typically ranged from approximately 4:1 to 15:1.
Advanced Public Transportation Systems	• Majority of available data focuses on travel time, on-time performance and agency costs/efficiency. — Travel time decreases typically ranged from approximately 7 to 15 percent. — On-time performance improvements typically ranged from 12 to 30 percent. — National synthesis studies suggest decreases in annual agency operating costs of 5 percent and capital costs of 1 percent.
Incident Management Systems	• Majority of available data focuses on delay and agency efficiency impacts. — Delay decreases typically ranged from approximately 5 to 50 percent. — Although significant data is available for other measures, synthesis is difficult due to differences in the definition of "incidents" and the multiple performance metrics used in the individual studies including: » Incident notification time, » Incident duration, » Clearance time, » Response time, and » Blockage clearance time.
Electronic Payment Collection	• Majority of available data focuses on throughput and agency cost/efficiency; however, due to variations in performance metrics, synthesis of general findings is not possible.
Railroad Grade Crossing	• National synthesis studies suggest a decreases of approximately 40 percent of accidents at crossing locations.
Emergency Management Services	• Majority of available data focuses on customer satisfaction impacts related to crash notification services.
Multi-modal Traveler Information	• Majority of available data focuses on travel time and customer satisfaction impacts. — Travel time decreases typically ranged from approximately 5 to 15 percent (differences in metrics provide ambiguity to this estimated range). • Customer satisfaction impacts can not be effectively synthesized due to variations in performance metrics.
Commercial Vehicle Operations	• Majority of available data focuses on agency cost/efficiency; however, due to variations in performance metrics, synthesis of general findings is not possible.

for all strategies and impact categories (as identified in Table 2) are presented in this table. Publication logistics only allow a brief summary of the wealth of information in the actual spreadsheets. This data also represents a snapshot in time of the available data on the impacts of these operations strategies. New deployments and evaluation efforts are constantly being completed that provide additional data points for these impacts. The spreadsheet provides the opportunity for practitioners to update the impact information with new data as it is discovered; however, the summary information in this static publication is not anticipated to reflect any future updates to the spreadsheet.

Case Study Outcomes

This case study resulted in the development of two separate resources: 1) Impacts Summary – summarizing the likely impacts of various operations strategies, and 2) Deployment Guidelines – summarizing deployment guidance that has been developed to date. Each data set was developed in a simple spreadsheet format that may be freely modified by individual practitioners to add new data as it is discovered, or to serve as a repository for their own customized impact ranges or deployment guidelines.

The Impacts Summary contains a high-level identification of the impacts associated with various operations strategies disaggregated by performance measures impacted. The impacts identified in the resource represent observed impacts from before-and-after studies of previous deployments in other U.S. and international locations, results from simulation and modeling studies, and the recommended default impact values from the FHWA's IDAS tool. The resource is intended to provide a quick guide to the overall range of impacts associated with various strategies; however, references to the source documentation is provided to allow the user to conduct further, more detailed investigation of any of the values.

Recent changes to the U.S.DOT *ITS Benefits Database*, implemented in parallel with the development of this Impacts Summary, have replicated some of the quick reference capabilities provided by the spreadsheet – providing users the much needed ability to more quickly view summaries of impact findings. The Internet-based format of the *ITS Benefits Database* provides advantages to the user in that it is continually updated and can provide direct links to the data source documentation. These changes to the *ITS Benefits Database* do not, however, eliminate the need for a resource like the Impact Summary. This Impact Summary provides advantages to potential users, including the following:

- High-level summary of the impact data;
- Inclusion of the IDAS default impact estimates;
- Impacts for additional strategies (e.g., congestion pricing);
- Data can be viewed without Internet access; and
- Resource can be customized by the user to serve as a repository for his/her own impact data.

The Deployment Guidelines spreadsheet likewise provides a valuable, quick-check resource for investigating deployment guidance and rules-of-thumb in use by other agencies. The usefulness of this resource is currently restricted, however, due to the limited amount of data that is currently available. The open format of this resource does provide the opportunity to update the repository in the future in the event that

more information and guidelines become available. Many agencies contacted as part of the research effort indicated that they currently were considering or actively developing these types of guidelines.

The two resources developed as part of this case study effort represent high-level summaries of the currently available information. More importantly, however, the resources provide a basic framework for presenting the information that may be adopted, modified, and updated by individual agencies to serve as customized repositories for this type of information in order to better support their own planning for operations efforts.

Appendix A – Spreadsheet Instructions

This appendix contains the instructions for using the Impact Summary [DRAFT Impact Summary v1.xls] and Deployment Guidelines [DRAFT Deployment Guidelines v1.xls] resources. These instructions are also provided on the INTRODUCTION sheet of the respective spreadsheets.

Impact Summary

This spreadsheet was developed as a case study conducted as part of the FHWA project "Improving the Application of Existing Methods to Advance Transportation Operations." This Impacts Summary spreadsheet is intended to provide users with a high-level, quick reference of the impacts associated with various operations strategies. Many of the impact values presented in this resource were summarized from studies compiled in national, cross-cutting database repositories such as the U.S. DOT *ITS Benefits Database* [http://www.itsbenefits.its.dot.gov/], and other libraries maintained by agencies and research institutions, as well as from several operations analysis tools such as the FHWA ITS Deployment Analysis System (IDAS) tool [http://idas.camsys.com/]. This resource is not intended to replace these other resources. Instead, the information in this spreadsheet is intended to provide a high-level summary of available impact measures and help guide users in investigating these other data sources. The spreadsheet format of the resource also allows users to add their own data to create a customized repository.

The Impacts Summary is organized as a series of 17 individual worksheets, each representing a general category of operations strategies, including the following:

- ATMS – Signal Coordination;
- ATMS – Signal Priority;
- Freeway Management Systems (e.g., ramp metering);
- Advanced Public Transit Systems;
- Incident Management Systems;
- Electronic Payment Collection Systems;
- Railroad Grade Crossing Systems;
- Emergency Management Services;
- Regional Multimodal Traveler Information;
- Commercial Vehicle Operations;
- Supporting Deployments (e.g., Traffic Management Centers, Surveillance Systems);
- Advanced Vehicle Control and Safety Systems;
- System Integration (i.e., impacts associated with combinations of system types);
- Congestion Pricing;
- Parking Systems and Technologies;
- Weather Applications; and
- Work Zone Management.

Within each strategy category (each worksheet) there may be multiple individual strategies presented. These strategies are identified down the left-hand side of each worksheet and can be viewed by scrolling down through the sheet.

For each individual strategy, impacts are identified and mapped to a number of performance measure categories, including the following:

- Travel time and speed;
- Throughput;
- Mode shift;
- Time-of-day (temporal) shift;
- Route shift;
- Forgone trip;
- Safety;
- Customer satisfaction;
- Emissions;
- Energy;
- Costs (e.g., benefit/cost analysis results);
- Agency efficiency; and
- Other impacts.

The performance measures are represented by the columns in the sheet. Within the cells representing a specific strategy (rows) and performance measure category (columns) there may be multiple impact findings noted, based on the number of data points available. In cases where there are many impact data points identified, these are generally arranged as:

- National – Representing impact findings from national synthesis studies. These are often presented as a range or an average value.
- U.S. State, Regional, and Local – Representing findings obtained through various domestic evaluations.
- FHWA ITS Deployment Analysis System (IDAS) Software Tool Impact – Representing the default impact recommended in the IDAS tool. These IDAS default values are based on an average of impact values observed in nationwide studies and provide users with a suggested value to use as a starting point in their own investigations.
- Simulation Results – Representing findings from simulation or modeling studies.
- International and Miscellaneous – Representing findings from evaluations in international locations.

In situations where no relevant data were identified for a particular strategy and performance measure, a statement of "No Data Available" was entered in the cell.

Although not shown in the default spreadsheet, references to the source data for each entry are provided. This material is located in the two columns immediately to the right of each entry in a performance measure column. By default, these columns are initially hidden. The user can unhide these columns to view this supplemental data. For example, if the user would like to learn more information regarding an entry in the Travel Time & Speed Impact column (typically column "D"), the user should unhide the two columns immediately to the right of the performance measure column (columns "E and F" in this example). A sample view of the references is shown in the figure below.

Figure 4. Example Screen Showing Unhidden Reference Columns

ITS ELEMENT Freeway Traffic Management System			Travel Time and Speed Impact	Travel Time and Speed Comment 1
Ramp Metering	*Pre-set Timing*	*National studies/statistics*	**National** - 13% to 48% reduction in travel time	from Transportation Planning and ITS: Putting the Pieces Together - FHWA, 1998
			National - 16% to 62% improvement in speed, 48% reduction in travel time	from ITS Benefits: 2001 Update - Mitretek
			National - 5% to 20% time savings	from ITS Benefits: 2001 Update - Mitretek and Ramp Metering: A Review of the Literature - Arnold
		U.S. state, regional, local studies/statistics	**Austin, TX** - Travel time decreased by 37.5%	from ITS Benefits: Continuing Successes and Operational Test Results and ITS Benefits: 2001 Update - Mitretek
			Dallas, TX - 7.6% to 55% increase in speed	from Overview of Ramp Metering Subsystem for Phoenix Freeway Management System - ITE
			Dallas, TX (North Central Expwy) - 15% increase in speed, 15% decrease in delay	from The 2nd National Symposium on ITMS - TRB
			Detroit, MI - Speeds increased by 8%	from PATH's Learning from the Evaluation and Analysis of Performance web site, 1998 - California PATH and Caltrans
			Detroit, MI - Travel time decreased by 7.4%	from ITS Benefits: Continuing Successes and Operational Test Results - Mitretek
			Houston, TX - 29% increase in speed	from ITS Benefits: Review of Evaluation and Reported Benefits - TTI, 1998 and Twin Cities Ramp Meter Evaluation - Cambridge Systematics, 2000
			Phoenix, AZ - 5% to 10% increase in speed	from Ramp Metering in Minnesota - TTI and Twin Cities Ramp Meter Evaluation - Cambridge Systematics
			Portland, OR - 39% reduction in travel time, 60% improvement in speed	from ITS Benefits: 2001 Update - Mitretek
			Portland, OR - Speeds increased from 16 to 41 mph NB and 40 to 43 mph SB (156% and 7.5% increase, respectively)	from PATH's Learning from the Evaluation and Analysis of Performance web site, 1998 - California PATH and Caltrans
			Portland, OR - Travel time decreased by 7.4%	from ITS Benefits: Continuing Successes and Operational Test Results - Mitretek
			Seattle, WA - Travel time decreased by 47.7% to 52.3%, speed increased by 20%	from ITS Benefits: Continuing Successes and Operational Test Results and ITS Benefits: 2001 Update - Mitretek
		FHWA ITS Deployment Analysis System (IDAS) software tool impacts	No Data Available	
		Simulation Results	No Data Available	
		International and Misc.	**England** - Ramp delays added 1.5 minutes to average travel time	from PATH's Learning from the Evaluation and Analysis of Performance web site, 1998 - California PATH and Caltrans
			Netherlands - 5kmh to 30kmh improvement in speed, 3% to 10% reduction in travel time, and up to 20% reduction in delay	from Evaluation of ITS in Netherlands - Taale, 2002

Deployment Guidelines

This spreadsheet was developed as a case study conducted as part of the FHWA project "Improving the Application of Existing Methods to Advance Transportation Operations." This Deployment Guidelines spreadsheet is intended to provide users with a high-level, quick reference of specific thresholds or rules-of-thumb that have been developed by other agencies to help practitioners identify conditions that warrant deployment of particular operations strategies. The spreadsheet format of the resource also allows users to add their own data to create a customized repository.

To populate this Deployment Guidelines spreadsheet, research was conducted to identify state or local agencies that have developed guidelines or thresholds for identifying locations or conditions that are appropriate for deployment of various operations strategies. This research included contacting a number of state DOTs known to be investigating these types of guidelines. Currently (2008), there is still very limited information regarding guidelines, thresholds or warrants for determining the potential for operations strategy deployment. The development of these types of guidelines is still in its infancy and there are very few agencies that currently have any formalized and documented guidance; however, a greater number of agencies reported that these types of guidelines were currently under development or at least under consideration. It is hoped that more data for these types of guidelines will be available in the near future.

The Deployment Guidelines spreadsheet is organized as a series of 12 individual worksheets, each representing a general category of operations strategies, including the following:

- ATMS – Signal Coordination;
- ATMS – Signal Priority;
- Freeway Management Systems (e.g., ramp metering);
- Incident Management Systems;
- Electronic Payment Collection Systems;
- Regional Multimodal Traveler Information;
- Commercial Vehicle Operations;
- Supporting Deployments (e.g., Traffic Management Centers, Surveillance Systems);
- Advanced Vehicle Control and Safety Systems;
- Parking Systems and Technologies;
- Weather Applications; and
- Work Zone Management.

Within each strategy category (each worksheet) there may be multiple individual strategies presented. These strategies are identified down the left-hand side of each worksheet and can be viewed by scrolling down through the sheet.

For each individual strategy, identified guidelines are presented in the Deployment Guidance column. Within the cells representing a specific strategy (rows) there may be multiple guidelines noted, based on the number of data points available. In most cases, however, there are limited or no guidelines currently available. Empty cells are provided as a placeholder for any future guidelines that may be identified.

References to the original source documentation are provided in the Document Name/Study/Specifics column, and the location of the agency developing the guidelines is presented in the Location column.

Federal Highway Administration
U.S. Department of Transportation
1200 New Jersey Avenue SE
Washington, DC 20590
www.ops.fhwa.dot.gov

Publication # FHWA-HOP-10-002

U.S. Department of Transportation
Federal Highway Administration