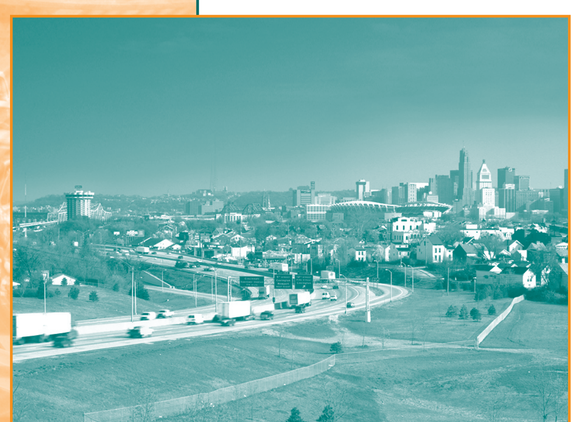
Benefits and Costs of Full Operations and ITS Deployment



A 2003 Simulation for Cincinnati

Varying Weather and Work Zone Conditions

Table of Contents

Figures

Tables

Cover Photo: Cincinnati Skyline. Photo Credit: ARTIMIS.

Preface

People who live in urban areas nationwide report that traffic congestion is one of their greatest quality-of-life concerns. When the demand for travel in a region exceeds the available capacity of the transportation system, residents suffer from excessive travel times, increased crash risks, diminished air quality, and other negative impacts. State and local transportation agencies have found it difficult to increase the transportation system supply rapidly enough to keep pace with the growing demand. Traditional approaches such as adding highway lanes, building new roads, or providing new transit lines are often too costly to be considered as reasonable solutions, particularly in the more densely populated areas of major cities. Transportation agencies are further challenged by the time required to design and construct these traditional infrastructure improvements.

In response to this dilemma, transportation agencies have increasingly turned to improved operational strategies and Intelligent Transportation Systems (ITS) in order to squeeze more operational efficiency out of the existing transportation system. Examples of these operations and ITS strategies include synchronizing the timing of traffic signals to smooth traffic flow, providing incident response vehicles such as freeway service patrols to quickly clear traffic incidents and breakdowns, automatically tracking and dispatching transit buses to improve their on-time performance, and providing meaningful traveler information to the public to allow travelers to better plan their trips. ITS America, the professional organization founded to facilitate the successful deployment of such systems, defines ITS as follows:

"Intelligent transportation systems encompass a broad range of wireless and wireline communications-based information, control and electronics technologies. When integrated into the transportation system infrastructure, and in vehicles themselves, these technologies help monitor and manage traffic flow, reduce congestion, provide alternate routes to travelers, enhance productivity, and save lives, time, and money."[1]

Information technology has contributed to efficiency gains in a wide range of industries, and ITS produces similar results for transportation. ITS solutions can be implemented more quickly and less expensively in comparison to traditional infrastructure improvements, and nationwide deployments of ITS have been shown to produce significant benefits. By themselves, these operations and ITS strategies will not eradicate congestion; however, they are essential components to a well-balanced, well-operating transportation network.

Furthermore, these individual operations and ITS improvements can be tied together to achieve even greater benefit than they can alone. Recognizing that the whole is often greater than the sum of its parts, the United States Department of Transportation (U.S. DOT) and numerous local agencies have launched initiatives to encourage deployment and integration of these systems in order to maximize their potential benefits.

The goal of full deployment and complete integration of ITS, however, has yet to be

[1] ITS America website: www.itsa.org.

realized in any metropolitan area. Financial constraints, along with technical and institutional barriers, have held up achievement of this goal. Operations and ITS implementation have typically advanced incrementally within communities, targeting the highest priorities first while deferring enhancements until additional resources are available. This piecemeal approach has hindered or sometimes prevented the integration of the individual deployments, excluding regions from experiencing the full potential of benefits from a coordinated and complementary system.

To date, the analysis and evaluation of operations and ITS deployments have followed a similar path—often focusing on the benefits of a single ITS technology used in a single location. As a result of this narrow focus, very little information exists that exemplifies the benefits of increased deployment and integration of operations and ITS strategies.

As a result, the Federal Highway Administration (FHWA) initiated a study to explore the benefits and costs of fully deploying operational strategies and integrating ITS in metropolitan areas. The goal of this effort is to provide transportation professionals and decision makers with a better understanding of the potential benefits of implementing the full suite of available operations and ITS strategies in a metropolitan area.

The U.S. DOT and FHWA selected Tucson, Cincinnati, and Seattle for case studies representing small, medium, and large metropolitan areas, respectively. Scenarios were identified comprising complete operations and ITS deployment at an appropriate, logical scale for each area. These scenarios were then evaluated to estimate the regionwide benefits and costs.

Beyond the difference in the size of the three metropolitan areas, some additional variations in the analysis approach affected the relative benefits estimated in each case study area. Benefits were estimated in the Tucson example based on forecasts of traffic in the year 2025, while the benefits for Cincinnati and Seattle were based on more current (2003) traffic conditions. The Cincinnati study also includes the additional analysis of impacts during inclement weather conditions and construction activity, as well as the added benefits of weather and work zone mitigation strategies—strategies that are not included in the deployments for Tucson or Seattle.

This report presents the findings of the Cincinnati, Ohio, scenario. The findings of the Seattle scenario are presented in *Benefits and Costs of Full Operations and ITS Deployment: A 2003 Simulation for Seattle* (FHWA-JPO-04-033, EDL# 13977). The findings of the Tucson scenario are presented in *Benefits and Costs of Full Operations and ITS Deployment: A 2025 Forecast for Tucson* (FHWA-JPO-04-032, EDL# 13978).

Evaluation Approach

The analysis compares the Full Operations and ITS Deployment Scenario to one that contains no operations and ITS deployment whatsoever.

How Were Operations and ITS Strategies Selected?

The first step in estimating the potential impacts of full operations and ITS deployment in Cincinnati was the identification of the logical suite of ITS improvements that would constitute "full deployment." This process was started by conducting an inventory of all current and planned operations and ITS deployments in the Cincinnati region. The deployments in this inventory then served as the building blocks for the full deployment scenario. These existing elements were then enhanced and expanded by identifying additional improvements to fill gaps, upgrade the existing systems with more advanced technologies, and then integrate the diverse systems. The result was the establishment of the Full Operations and ITS Deployment Scenario, defined as the maximum amount of locally desirable operations and ITS—at the highest range of technical and institutional sophistication—that can be deployed without regard to funding constraints.

Several additional guidelines were used in identifying the appropriate amount of operations and ITS to include in the full deployment scenario in order to avoid making overly optimistic assumptions about benefits. For example, the Full Operations and ITS Deployment Scenario includes only those strategies that are funded or significantly subsidized by the public sector. Private sector strategies, such as in-vehicle navigation or safety systems in personal automobiles, or freight management systems used by commercial trucking firms, were not considered. Although the benefits of these systems are not included in this analysis, they are expected to offer significant benefits.

In addition, the Full Operations and ITS Deployment Scenario did not include technologies or approaches that have not currently progressed past development and testing, due to a general lack of industry consensus on their potential costs, benefits, and market penetration. New operations and ITS strategies are emerging constantly due to the ever-changing nature of technology; however, those improvements evaluated in this study include only well-established systems that are currently in use throughout the nation.

How Were the Benefits Estimated?

The analysis of the benefits and costs for the Full Operations and ITS Deployment Scenario was conducted using the ITS Deployment Analysis System (IDAS). The IDAS tool is designed to estimate the specific benefits and costs of ITS deployments based on observed, real-world costs and benefits. This analysis tool was used to estimate benefits, including changes in travel time, travel time reliability, number and severity of crashes, vehicle emissions, fuel use, and other important measures.

The analysis compares the Full Operations and ITS Deployment Scenario to one that contains no operations and ITS deployment whatsoever. This "all-or-nothing" approach was used to compare the complete costs and benefits of operations and ITS in Cincinnati for the current year (2003).

This approach further allows the findings to be applicable to other regions that may be at different stages of operations and ITS deployment.

These deployment scenarios were analyzed under a variety of possible conditions that might be present during an average year in Cincinnati. These varying conditions were tested to identify the different levels of impacts that may occur during peak commute hours, inclement weather, or road construction activity. Different conditions tested during the analysis included:

- Variations in the time of day—The impacts of operations and ITS improvements were analyzed separately during the morning commute period, the mid-day period, the afternoon commute period, and the nighttime period.

- Variations in the weather—The impacts of the operations and ITS improvements were evaluated during clear weather, rain, and ice/snow.

- Presence of construction activity—Conditions representing road maintenance activities during a typical road construction season were estimated as well as traffic conditions during the off-season for construction.

All the probable combinations of these conditions were identified and evaluated, resulting in the identification of the impacts caused by operations and ITS strategies in each of these conditions. The annual benefits of the operations and ITS strategies in Cincinnati were then estimated by multiplying the impacts observed under the various conditions by the likelihood each of the conditions would occur during a typical year. These annualized benefits were then compared with the annual costs. A Technical Appendix accompanying this report provides additional detail on the methodology used in estimating the benefits and costs.

Cincinnati's Full Operations and ITS Deployment Scenario

An inventory of all the existing operations and ITS deployments, as well as planned improvements over the next 25 years, was conducted as the first step in identifying the Full Operations and ITS Deployment Scenario. This inventory was identified through consultations with local agencies the regional planning of operations and ITS, including the Ohio-Kentucky-Indiana (OKI) Regional Council of Governments, the Ohio Department of Transportation (ODOT), and the Kentucky Transportation Cabinet (KYTC). Through these and other agencies' efforts, the Cincinnati region has implemented a diverse and robust set of operations and ITS initiatives, many of which are coordinated as the Advanced Regional Traffic Interactive Management and Information System (ARTIMIS) program. ARTIMIS includes incident, congestion, and freeway management, and traveler information services for the Cincinnati and Northern Kentucky region. Many other individual strategies have been deployed as well, and the region maintains aggressive plans for geographic expansion and enhancement in the future.

Planned operations and ITS improvements identified in the region's long-range plans were brought forward to the current year and added to the inventory of existing strategies to provide a rational baseline for building the Full Operations and ITS Deployment Scenario. This baseline was then analyzed to identify supplemental strategies, expanded geographic coverage, and upgrades to technology that would serve to fully deploy and integrate the strategies throughout the region. This suite of identified strategies formed the region's Full Operations and ITS Deployment Scenario.

Table 1 presents the strategies selected and the number of deployment locations for Cincinnati. The proportional coverage on the system is also presented to portray the ITS deployment density level relative to the entire system.

Table 1. Strategies Included in the Cincinnati Full Operations and ITS Deployment Scenario

Strategy	Deployment	Coverage
Arterial Traffic Management Systems		
Central Control Signal Coordination	1,700 intersections	100% of major and minor arterials
Emergency Vehicle Signal Preemption	1,850 intersections 1,000 emergency vehicles	100% of intersections 100% of emergency vehicles
Transit Vehicle Signal Priority	40 intersections 30 transit vehicles	5% of urban intersections 5% of fixed-route transit vehicles
Highway Advisory Radio	35 transceivers	100% of major arterial corridors
Dynamic Message Signs	20 locations	100% of major arterial corridors
Freeway Management Systems		
Central Control Ramp Metering	83 on-ramps	35% of on-ramps
Highway Advisory Radio	813 transceivers	70% of freeway miles
Dynamic Message Signs	65 locations	100% of urban freeway miles
Transit Management Systems		
Fixed Route Automated Scheduling and Automatic Vehicle Location	700 transit vehicles	100% fixed-route transit vehicles
Fixed Route Security Systems	700 transit vehicles 20 transit stations	100% fixed-route transit vehicles 100% of major transit transfer stations and park-and-ride locations
Incident Management System		
Incident Detection, Verification, Response, and Management	32 freeway service patrol vehicles	100% of freeway and expressway miles
Emergency Management Systems		
Emergency Vehicle Control Service	1,000 emergency vehicles	100% of emergency vehicles
Emergency Vehicle AVL	1,000 emergency vehicles	100% of emergency vehicles
Telemedicine	100 ambulances	100% ambulances
Electronic Payment Systems		
Electronic Transit Fare Payment	700 transit vehicles	100% of fixed-route transit vehicles
Traveler Information		
Telephone- and Web-Based Traveler Information System	Regionwide	40% market penetration
Kiosk-Based Traveler Information	10 kiosks	100% of major arterial at-grade rail crossings

Table 1. Strategies Included in the Tucson Full Operations and ITS Deployment Scenario (Cont'd from page 7)

Strategy	Deployment	Coverage
Crash Prevention and Safety		
Railroad Crossing Monitoring Systems	40 rail crossings	10% of major arterial at-grade rail crossings
Commercial Vehicle Operations		
Weigh-in-Motion and Safety Information Exchange	4 check stations	100% of checkstations
Combination Screening and Clearance—Credentials and Safety	4 check stations 60,000 equipped commercial vehicles	40% market penetration
Weather Mitigation Strategies		
Road Weather Information Systems	10 remote weather stations	100% of region
Advanced Traveler Information Systems	One interface	100% of region
Work Zone Mitigation Strategies		
Work Zone Highway Advisory Radio	6 locations	High priority locations
Work Zone Dynamic Message Signs	6 locations	High priority locations
Work Zone Information Dissemination (Phone and Internet)	One interface	100% of region
Work Zone Closed Circuit Cameras for Incident Management	12 locations	High priority locations
Lane Merging Applications	8 locations	100% of major work zones
Alternative Route Management	30 intersections	Routes paralleling work zone locations
Alternative Work Hours/ Contracting Techniques	Regionwide policies	100% of major work zones
Supporting Deployments		
Traffic Management Center	One	100% of region
Traffic Management Center	One	100% of region
Emergency Management	One	100% of region
Information Service Provider Center	One	100% of region
Traffic Surveillance - Closed Circuit Television	1,100 locations	100% of freeway, expressway, and urban arterial miles
Traffic Surveillance - Loop Detectors	2,245 locations	100% of freeway, expressway, and urban arterial miles

Benefits of Full Operations and ITS Deployment

What Would Be the Benefits?

The performance of the Cincinnati transportation system in the year 2003 was analyzed for two deployment scenarios—No Operations and ITS Deployment, and the Full Operations and ITS Deployment Scenario. The results from the two scenarios were then compared to identify the incremental change due to the inclusion of operational improvements and ITS deployment.

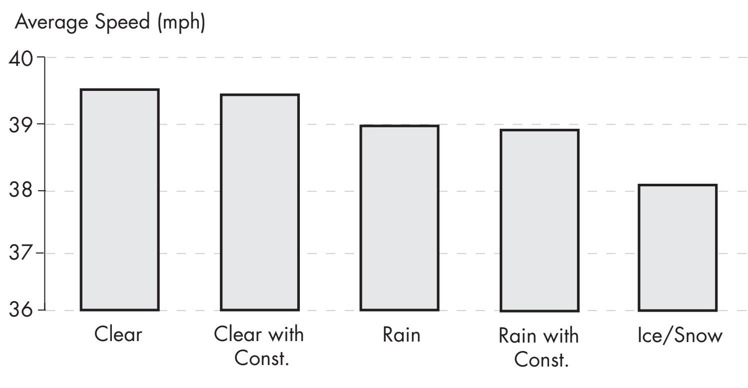
These two deployment scenarios were also analyzed during 20 different traffic and environmental conditions that might occur in an average year. These conditions include variations in the time of day, weather conditions, and the presence of road construction activity, as well as all probable combinations of these conditions. These varying conditions were analyzed separately because these factors have been shown to significantly affect the performance of the transportation system. Figure 1 demonstrates the impact these conditions were predicted to have on average daily speed in the region for those scenarios with no operations or ITS strategies. As the figure shows, the average regionwide speeds were greatest during clear weather when no construction activity was present. Slightly slower average speeds were expected on clear days during the construction season due to the bottlenecks created by the construction lane closures. Days with rain, and days with rain during the construction season were predicted to have even slower average speeds, and days with snow and ice were estimated to have the slowest speeds of all the possible conditions.

The Full Operations and ITS Deployment Scenario was analyzed in each of these varying weather and construction conditions, as well as by time of day, in order to identify differences in the possible impacts occurring under these different conditions. This analysis of the Full Operations and ITS Deployment Scenario showed positive impacts for all performance measures studied, including:

- Decreased travel times
- Increased vehicle speeds
- Decreased delay
- Decreased number and severity of crashes
- Decreased environmental impacts (reduced emissions and fuel use).

Positive impacts of operations and ITS strategies were typically greater when travel conditions were at their worst.

Figure 1. Impact of Weather and Construction on Average Speed in Scenarios with No Operations or ITS Strategies



The operations and ITS strategies were more effective at reducing travel times during more congested commute periods and during periods of inclement weather and construction activity.

Further, the full deployment of operations and ITS strategies was estimated to have a positive impact in all the varying weather and construction conditions evaluated; however, these impacts were typically greater when travel conditions were at their worst. The following sections discuss specific impacts in greater detail.

Decreased Travel Times

The full implementation of operations and ITS strategies in the Cincinnati region was estimated to significantly decrease personal travel time. Over the course of a year, more than 15.1 million hours of travel time were reduced in the region, or 4 percent of the total travel time. This impact amounts to nearly eight hours saved per resident in the region annually. The analysis also revealed that the operations and ITS strategies were more effective at reducing travel times during more congested commute periods and during periods of inclement weather or construction activity. For example, travel times in the morning commute periods were reduced by an average of 6.7 percent, and this reduction ranged as high as 8.7 percent when snow conditions occurred during the morning commute period. Less congested periods were observed to have positive, but less significant impacts. For example, travel times during the nighttime period in clear weather were reduced by less than 1 percent.

Increased Vehicle Speeds

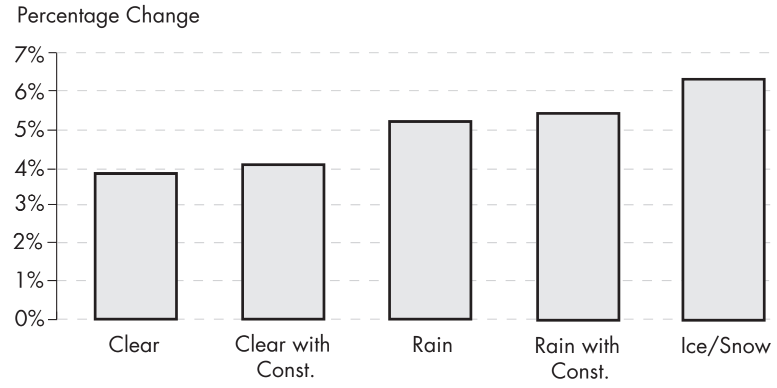
Vehicle speeds during all conditions increased by an average of 4.7 percent as a result of the operations and ITS deployments. The increases in regionwide vehicle speeds varied according to the weather and construction conditions, and were generally higher during more congested periods, as shown in Figure 2. Vehicle speed changes observed on individual roadways were even greater than the regionwide average, and the majority of the speed increase was observed on major facilities, including freeways, expressways, and major arterials that served as a focus of a number of the ITS and operations improvements. Speed increases observed on more minor local streets, which received fewer improvements, and during less congested non-commute hours were generally less significant.

The speed increases observed for selected segments of major roadways were even more significant. This phenomenon was particularly evident for those roadways used to represent construction zones during the construction season. Vehicle speed increases on selected roadways in these construction zones were as much as 15 percent higher as a result of the operations and ITS strategies. Although the operations and ITS strategies did not fully restore the average speeds to the levels observed during clear weather without construction, the deployments were shown to be successful in mitigating much of the negative impacts on speed caused by inclement weather and construction activity.

Decreased Delay

The impact of the ITS and operations strategies on improving vehicle speeds and travel times resulted in significantly reduced delay in the region. This delay reduction was particularly evident during the congested, delay-prone commute hours, during inclement weather conditions, and during the construction season. Overall, delay was reduced in the region by 17.7 percent, or an average of more than 12 million hours annually. This reduction

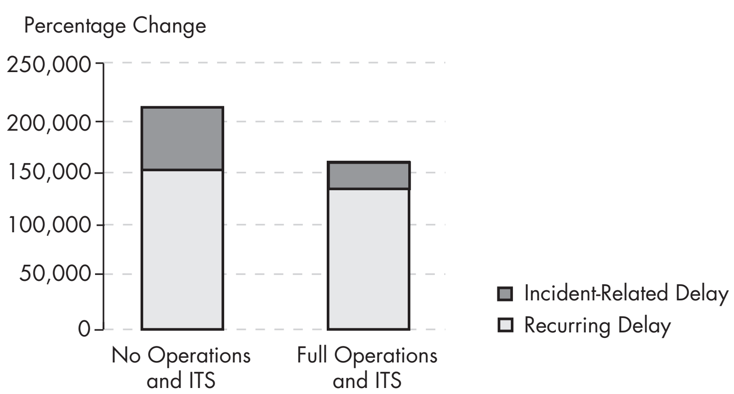
Figure 2. Impact of Operations and ITS Strategies on Average Speed During Various Weather and Construction Conditions



included a decrease in the delay due to everyday, recurring congestion as well as a decrease in the delay caused by traffic incidents. Overall, operations and ITS strategies reduced the amount of delay caused by everyday, recurring congestion for roadway users by 11.7 percent in the Cincinnati region. Consistent with the observed speed changes, the reductions in delay were greatest on primary roadways that received the greatest concentration of ITS and operations deployments. Table 2 shows how the reductions in delay varied according to the type of roadway.

In addition to the impacts on delay related to everyday congestion, many operations and ITS strategies are intended to specifically reduce incident-related delay. These strategies diminish incident-related delay by either decreasing the number of crashes occurring on the network, or minimizing the time required to respond and clear incidents once they do occur. In the Cincinnati region, the full deployment of operations and ITS resulted in a dramatic reduction of incident-related delay, amounting to an average of nearly 31,400 hours saved per day. This reduction, which was only estimated on the freeways, represents a decrease of nearly 56 percent of the total freeway incident-related delay. Figure 3 shows the reduction in hours of everyday recurring delay compared with the reduction in hours of incident-related delay on the freeways.

Figure 3. Reduction in Hours of Delay Due to Operations and ITS Deployments



The reduction in incident-related delay was most significant during the more congested periods representing peak commute periods, inclement weather conditions, or construction activity. For example, the operations and ITS strategies were estimated to reduce incident-related delay by more than 18,300 hours in the average afternoon commute period, but only approximately two hours were estimated to be saved during an average nighttime period.

Decreased Number and Severity of Crashes

The operations and ITS deployments resulted in the avoidance of more than four crashes per day in the Cincinnati region, representing an average reduction of more than 3 percent. Additionally, the deployment of incident and emergency management systems, which minimize the response time to crashes, led to a reduction in the severity of crashes as well. Overall, fatal crashes decreased by nearly 9 percent, while injury and property damage crashes were reduced by approximately 3 percent. This safety improvement resulted in the average annual avoidance of more than 12 fatal crashes, 420 injury crashes, and 570 property damage crashes per year in the Cincinnati region.

Freeways in particular were observed to benefit from the deployment of operations and ITS strategies. The number of crashes occurring on freeways was reduced by more than 9 percent.

Decreased Environmental Impacts

Vehicle pollutants and fuel use were estimated to be reduced in the Cincinnati region as a result of the operational and ITS improvements. The full deployment of these strategies resulted in a reduction for all emissions analyzed, including average reductions of 22 percent of carbon monoxide emissions, 18 percent of hydrocarbon emissions, and 25 percent of nitrous oxides emissions.

Fuel use in the region was decreased by nearly 24 percent. This reduction represents a savings of nearly 790,000 gallons per day. Over the period of an average year, this equals approximately 100 gallons saved per resident in the Cincinnati region.

Table 2. Comparison of Recurring Delay Reduction for Various Roadways

Facility Type	Hours of Delay with No Operations and ITS	Hours of Delay with Full Operations and ITS	Percentage Change
Freeway	30,136	25,673	14.8%
Major Arterial	31,744	25,772	18.8%
Rest of Network	90,772	83,301	8.2%
Total	***152,602***	***134,746***	***11.7%***

What Would Be the Value of the Benefits?

The monetary value of the benefits of Full Operations and ITS Deployment was estimated by applying a dollar value to each of the impacts. For example, the estimated number of gallons of fuel saved in any given period was multiplied by the cost of a single gallon of fuel to estimate the fuel-reduction benefit. Similar computations were completed for the other benefit measures. The benefit values from the various periods of the day were then added to estimate the daily benefit. Comparisons of the benefit values for days with different weather and construction conditions revealed that the operations and ITS strategies provided greater benefits on those days with inclement weather or construction conditions, as shown in Table 3.

The annual benefit was calculated by multiplying the benefits from each period by the likely number of times those conditions represented by the period would occur in a typical year. When the impacts of the operations and ITS deployments were annualized and dollar values applied, the benefits total more than $1.16 billion per year for the Cincinnati region as presented in Table 4, along with the percentage of the value of each benefit compared to the total.

A further comparison of the proportion of the benefits that were accrued in each time period revealed that the majority of benefits for the operations and ITS strategies occurred during the peak afternoon (34 percent) and morning (33 percent) commute periods, as shown in Figure 4. This impact occurs despite the fact that these peak commute periods are shorter in duration than the non-commute periods.

Table 3. Daily Value of Benefits Estimated for Various Weather and Construction Conditions (In $ Thousands in 2003 dollars)

Weather Conditions	Construction Season	Daily Benefit
Clear	No	$4,499
Clear	Yes	$4,510
Rain	No	$4,778
Rain	Yes	$4,813
Ice/Snow	No	$5,056

Figure 4. Proportion of Benefits in Cincinnati, by Time of Day

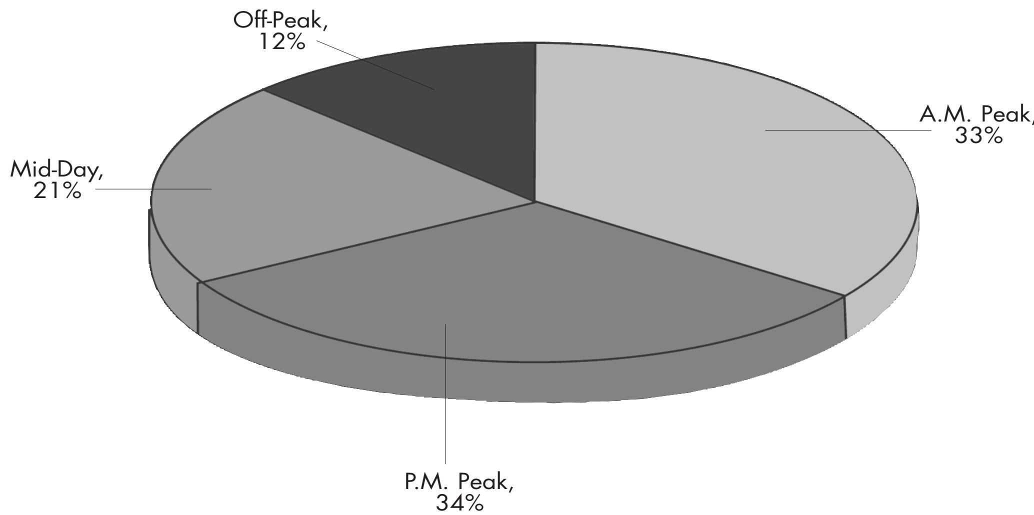


Table 4. Annual Benefits of Operations and ITS Deployment in Cincinnati (In $ Millions in 2003 dollars)

Benefit	Value	Percent of Total
Reduction in travel time (Mobility)	$267	23%
Reduction in incident delay (Reliability)	$305	26%
Reduction in crashes (Safety)	$85	7%
Reduction in emissions (Environment)	$140	12%
Reduction in fuel consumption (Energy)	$293	25%
Increase in public agency efficiency (Productivity)	$4	1%
Other[2]	$67	6%
Total benefits	***$1,160***	***100%***

2 Other estimated benefits include reduced noise, decreased non-fuel operating costs, and additional safety benefits associated with decreased emergency vehicle response time.

Costs of Full Operations and ITS Deployment

The average life-cycle costs of the resources necessary to implement, operate, and maintain the operations and ITS in Cincinnati were estimated to be $98.2 million annually. Table 5 presents the costs for the Full Operations and ITS Deployment Scenario.

Although the strategies included in this analysis were primarily funded by the public sector, a portion of the costs was projected to be paid for by the private sector. These private sector costs include the equipment needed on commercial trucks to enable the use of automated screening and clearance deployments at check stations. The considerable number of commercial trucks assumed to be equipped in the full deployment scenario (60,000) influenced the substantial estimated cost for this equipment.

Supporting deployments presented in Table 5 represent the backbone infrastructure necessary to operate and manage the deployed strategies. These include items such as traffic management centers, traffic surveillance cameras, and communication systems.

How Do the Costs and Benefits Compare?

A comparison of the estimated annual benefits and costs shows the investment in operations and ITS in the Cincinnati region to be cost-efficient. The benefits of the deployment outweigh the costs by a

Table 5. Annual Cost of Operations and ITS Deployments in Cincinnati (In $ Millions in 2003 dollars)

Deployment	Cost	Percentage of Total Costs
Arterial management systems	$7.6	7.7%
Freeway management systems	$4.3	4.4%
Transit management systems	$3.5	3.6%
Incident management systems	$6.4	6.6%
Emergency management systems	$1.8	1.8%
Electronic payment systems	$2.4	2.4%
Traveler information	$2.2	2.2%
Crash prevention and safety	$1.4	1.4%
Commercial vehicle operations	$23.1	23.5%
Supporting deployments	$45.4	46.2%
Weather and work zone mitigation strategies	$0.9	1.0%
Total costs	***$98.2***	***100.0%***
Private sector costs	*$22.4*	*22.8%*
Public sector costs	*$75.8*	*77.2%*

The benefits of the deployment outweigh the costs by a ration of 11.8 to 1.

ratio of 11.8 to 1, as shown in Table 6. This ratio indicates that each dollar spent on operations and ITS in the Cincinnati region would return $11.80 in benefits, including decreased travel time, improved safety, and reductions in vehicle emissions and fuel consumption.

The benefits estimated for the full deployment of operations and ITS in Cincinnati were overwhelmingly positive when compared with the costs. The conservative treatment of several factors related to the analysis suggests that future benefits of operations and ITS may be even greater. These assumptions include:

- The analysis only considered those operations and ITS deployments that are funded or significantly subsidized by the public sector. Many additional private sector ITS initiatives are currently deployed or planned, but were not considered in this analysis. These private sector deployments, such as in-vehicle navigation and safety systems, and commercial vehicle tracking and dispatching, would likely provide benefits beyond those presented in this report.

- The analysis used currently observed equipment costs as the basis for estimating the expenditures necessary to deploy and operate the strategies. The level of deployment considered for many strategies is beyond what has been deployed in any region to date; however, there may be significant economies-of-scale cost savings that would reduce the incremental cost of the deployments, if they were deployed at this scale. This impact was not considered in this analysis since there is currently little consensus on the precise savings that might be achieved. This assumption may result in the overestimation of costs associated with full deployment.

Table 6. Comparison of Annual Benefits and Costs in Cincinnati (In $ Millions in 2003 dollars)

Average annual benefits	$1,160
Average annual costs	$98.2
Benefit–cost ratio	11.8

Summary

This analysis examined the potential benefits and costs of fully deploying and integrating operations and ITS strategies in the Cincinnati region. A Full Operations and ITS Deployment Scenario was identified representing the maximum amount of locally desirable operations and ITS. This Full Deployment Scenario was compared to a scenario without any operations and ITS deployments in order to identify the incremental changes in impacts that might be possible in the year 2003. The results showed the investment in operations and ITS to be cost-efficient—returning $11.80 in benefits for every dollar invested.

The impacts and benefits identified for Cincinnati were tested in a variety of time periods and under various weather and construction conditions that may occur in a typical year. In all time periods and all conditions, the operations and ITS strategies were shown to have a positive impact in reducing many of the negative impacts related to congestion: delay, crashes, and environmental impacts. These operations and ITS strategies were estimated to provide significantly greater benefits during periods of increased congestion, occurring during peak periods of the day, or resulting from inclement weather or construction activities.

The full deployment of operations and ITS in Cincinnati was projected to produce benefits that were overwhelmingly positive when compared with the costs. The conservative treatment of several factors related to the analysis suggests that future benefits of operations and ITS may be even greater.

For More Information

Additional information on the operations and ITS strategies discussed in this report can be obtained through the FHWA's Office of Operations www.ops.fhwa.gov, and through the U.S. Department of Transportation's ITS Joint Program Office, www.its.dot.gov. For additional information on the individual benefits and costs of the ITS deployments presented in this report, please visit the ITS Joint Program Office's ITS Benefits and Costs Database at: www.benefitcost.its.dot.gov. More information on the IDAS analysis tool used in this evaluation may be found at: www.idas.camsys.com. Please visit the ITS Deployment Tracking website, www.itsdeployment.its.dot.gov, for more information on the current and historical levels of operations and ITS deployment in U.S. metropolitan areas.

Technical Appendix

Background

This Technical Appendix provides a general overview of the methodology used in the study of the potential benefits of fully deploying operations and ITS strategies. This study was initiated by the U.S. DOT to explore the benefits and costs of fully deploying and integrating ITS and operations strategies in metropolitan areas. Three test sites—Tucson, Arizona; Cincinnati, Ohio; and Seattle, Washington—were selected to represent small, medium, and large metropolitan areas, respectively. Hypothetical deployment scenarios were developed to represent the full logical deployment of operations and ITS strategies in each area. These scenarios were then evaluated to identify the likely benefits and costs of the deployments. The goal of this study was to provide transportation professionals and decision makers with an increased understanding of the potential benefits possible through the full deployment of ITS and operations strategies.

The findings from these three case studies are summarized in individual reports. This appendix provides additional detail on the similar approach used in all three regions to estimate the likely benefits and costs of full operations and ITS deployment.

Methodology Overview

The goal of this analysis was to estimate the likely benefits and costs resulting from the full deployment and integration of ITS and operations strategies in a region. For the purpose of this study, "full deployment" is defined as the maximum amount of locally desirable ITS and transportation operations strategies—at the highest range of technical and institutional sophistication—that can be deployed without regard to funding constraints. Consistent with this goal and definition, full operations and ITS deployment scenarios were identified for the three case study regions.

The analysis methodology used in this study was developed to identify the incremental benefits and costs of the strategies contained in the full operations and ITS deployment scenario. To identify these incremental impacts, it was necessary to estimate what travel conditions would be in the full operations and ITS deployment scenario, as compared with a scenario that did not contain any operations and ITS deployments. This "all-or-nothing" approach was used to isolate the full costs and benefits of the operations and ITS deployments.

The FHWA's ITS Deployment Analysis System software was used in conjunction with the locally validated travel demand models for the three case study regions to predict the traffic conditions that would be likely in the two deployment scenarios—the No Operations and ITS Deployment Scenario and the Full Operations and ITS Deployment Scenario. An overview of the IDAS tool analysis process is provided in a subsequent section.

This analysis approach resulted in numerous regional performance measures being estimated for the two scenarios, such as the person hours of travel, roadway speeds, the number of crashes, and the gallons of fuel used, among others. To identify the incremental impact resulting from the deployment of ITS, the performance measures from the Full Operations and ITS Deployment Scenario were subtracted from the identical performance measures for the No Operations and ITS Deployment

Scenario. The difference between the performance measures of the two scenarios represented the incremental impact caused by ITS during the day or time period represented by the model data. The annual impact was determined by multiplying the daily incremental impact by the number of days per year.

For example, the Tucson case study used a single daily model in the analysis. To estimate the impact on any particular performance measure, such as the number of fatality crashes, the following approach was used:

- *Annual Benefit = (Number of Fatality Crashes Occurring in the No Operations and ITS Deployment Scenario – Number of Fatality Crashes Occurring in the Full Operations and ITS Deployment Scenario) * Number of Days Per Year*

For those models having multiple time periods represented within a day, separate No Operations and ITS Deployment and Full Operations and ITS Deployment Scenarios were developed for each time period. The performance measure for the No Operations and ITS Deployment and the Full Operations and ITS Deployment Scenarios were then compared within each time period to identify the incremental impact. The incremental impacts from all the available time periods summed up the daily impact.[A-1] This summed figure was then multiplied by the number of days per year to annualize the benefit. An example of this approach for annualizing the results for models with multiple time-of-day analysis is shown below:

$$\text{Annual Benefit} = \sum \begin{bmatrix} \text{AMNo} - \text{AMFull} \\ \text{MDNo} - \text{MDFull} \\ \text{PMNo} - \text{PMFull} \\ \text{OPNo} - \text{OPFull} \end{bmatrix} * \text{Number of Days Per Year}$$

Where:

- *AMNo = performance measure from the AM Peak Period – No Operations and ITS Deployment Scenario*
- *AMFull = performance measure from the AM Peak Period – Full Operations and ITS Deployment Scenario*
- *MDNo = performance measure from the Mid-day Period – No Operations and ITS Deployment Scenario*
- *MDFull = performance measure from the Mid-day Period – Full Operations and ITS Deployment Scenario*
- *PMNo = performance measure from the PM Peak Period – No Operations and ITS Deployment Scenario*
- *PMFull = performance measure from the PM Peak Period – Full Operations and ITS Deployment Scenario*
- *OPNo = performance measure from the Off-Peak Period – No Operations and ITS Deployment Scenario*
- *OPFull = performance measure from the Off-Peak Period – Full Operations and ITS Deployment Scenario*

[A-1] The summing of the performance measures across all time periods was performed for all cumulative impacts. Non-cumulative performance measures, such as vehicle speeds, were not summed. Instead, these performance measures were calculated from the cumulative performance measures. For example, the estimate of daily speed was determined by summing the vehicle miles traveled (VMT) for all periods and dividing by summed vehicle hours traveled (VHT) for all periods.

The value of the annual benefit was then determined by applying the appropriate benefit values from the IDAS tool to the incremental change in the performance measures. The values from all the various performance measures were summed to determine the total annual benefit of all operations and ITS strategies included in the Full Operations and ITS Deployment Scenario. This benefit value was compared with the annual cost of the strategies to present the benefit/cost ratio for the included strategies.

IDAS Overview

What is IDAS?

The IDAS software was developed by the FHWA as a tool focused on analyzing the specific impacts of ITS. IDAS operates as a post-processor to travel demand models used by metropolitan planning organizations and by state departments of transportation for transportation-planning purposes. IDAS is intended to mimic and build upon the results of these tools, and shares many of the same analysis techniques and processes. Although a sketch-planning tool, IDAS implements the modal split and traffic assignment steps associated with a traditional planning model. These steps are key to estimating the changes in modal, route, and temporal decisions of travelers resulting from ITS technologies.

IDAS was developed as a tool specifically focused on analyzing the specific impacts of ITS. IDAS was also designed to serve as a repository of information on the impacts of various types of ITS deployments and of the costs associated with various types of ITS equipment. The default ITS impacts and costs used in the IDAS tool are based on the observed experiences of deploying agencies, as maintained in the U.S. DOT's ITS Benefits and Costs Database, www.benefitcost.its.dot.gov. By offering these capabilities, IDAS provides the ability to critically analyze and compare different ITS deployment strategies, prioritize the deployments, and compare the benefits of the ITS deployments with other improvements to better integrate ITS with traditional planning processes.

How Does IDAS Work?

The IDAS tool works by importing the results from travel demand models in order to recreate the validated regional network structure and travel demand within IDAS. The data are imported into IDAS using a special internal input/output interface, which is capable of reading and interpreting ASCII text data files. These input data files are created from data generated by the regional travel demand models. The data exchanged between the travel demand model and IDAS include network data regarding the characteristics of transportation facilities in the region and travel demand data, including the number of trips and mode share of travel between different zone pairs in the model. Depending on the needs of the analysis and the format of the available data, the user is typically required to perform some data conversion prior to import into IDAS. Once the data are imported, they are stored in a database accessible by the IDAS software and may be viewed in a graphical output by the user.

Once the data input is complete, IDAS is capable of operating independently of the travel demand model. The IDAS user is then able to create analysis alternatives by selecting ITS components from a menu of more than 60 ITS improvements, and placing these on the desired location on the network. The user then provides additional information regarding their deployment, such as the implementation date and proposed operational strategies.

Once the analysis alternative has been created, the IDAS software then modifies the network or travel characteristics to represent the likely impacts of the ITS deployments placed on the network by the user. These modifications are based on real-world impacts observed in other regions following their deployment of similar ITS components, and may include changes in link capacities or speeds, zone-to-zone travel times, crash or emissions rates, or other impacts specific to the ITS component. The specific default impacts associated with each of the various ITS deployments are described in *Appendix B – IDAS Default Values* of the *IDAS User's Manual* available on the IDAS software website idas.camsys.com.

The IDAS model then uses analysis techniques similar to the travel demand models to analyze the impacts created by the modifications to the alternative network and travel characteristics. A traffic assignment routine is used to estimate the changes in travel patterns caused by the modifications, and a mode shift routine is used to estimate any travel mode changes. The results of this analysis are revised link volumes and speeds and mode shares. IDAS conducts the same analysis procedures on the unmodified, baseline network (without ITS deployments) as well as the modified alternative network (with ITS deployments). These two scenarios are then compared to identify the incremental impact resulting from the ITS deployment.

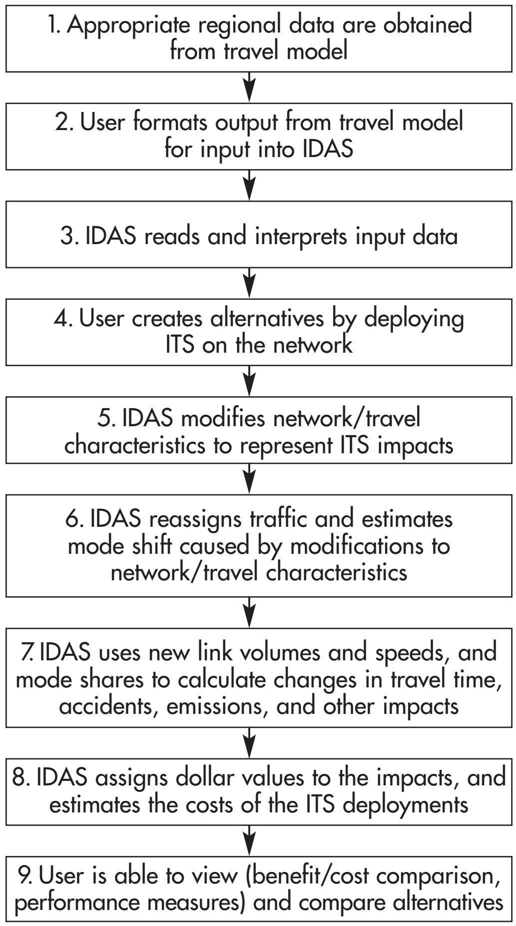
The changes in link volumes and speeds and mode shares are then used by IDAS in another series of analysis to calculate changes in the travel time, the number of crashes, the amount of emissions and other impacts. Dollar values are then applied by IDAS to these impacts to provide an estimate of the benefits of the ITS components deployed in the alternative.

In a separate process, the costs of the ITS deployments are also estimated by IDAS. The costs of the ITS deployments are calculated by identifying the inventory of equipment necessary to deploy and operate each improvement, based on the suggested equipment packages in the ITS National Architecture. IDAS then applies unit costs (capital and operations and maintenance [O&M] costs) to each piece of equipment in the inventory and annualizes the capital costs based on the anticipated useful life of the equipment.[A-2] The costs of all equipment included in the inventory for a particular deployment alternative are summed and compared with the benefits in the form of a benefit/cost ratio. These outputs are summarized and displayed to the user in several formats. The complete IDAS analysis process is summarized in Figure A-1.

Additional information regarding the structure of IDAS and its processes is presented in the *IDAS User's Manual*, which is distributed electronically with the

[A-2] IDAS equipment unit costs are periodically updated to represent the latest costs reflected in the U.S. DOT's ITS Benefits and Costs Database: www.benefitcost.its.dot.gov

Figure A-1. IDAS Analysis Process



IDAS software, or is available on the IDAS website at idas.camsys.com.

Use of IDAS in Analyzing the Impacts of Full Operations and ITS Deployment

Except where noted, the analysis of the impacts of full operations and ITS deployment used the default IDAS procedures, parameters, and impacts. These parameters and impact values were held constant in the three case study regions in order to produce comparable results.

The following exceptions to the standard IDAS methodology were made in the analysis:

- Estimation of Costs – A separate cost estimation spreadsheet tool was developed outside the IDAS software to calculate the cost of the operations and ITS deployments. This spreadsheet tool applied the same methodology and used the identical equipment unit costs as the IDAS software. This external spreadsheet method was used to improve the ease of use for the analysts, and better account for particular ITS equipment not currently represented in the IDAS software.

- Estimation of the Impacts of Advanced Traveler Information Systems (ATIS) – A blanket assumption of the overall effectiveness of all ATIS deployments was made, rather than make individual assumptions regarding the likely market penetration and effectiveness of each individual component. It was assumed that the various deployed ATIS components (pre-trip and in-route systems) were successful in reaching 40 percent of travelers. Of those travelers receiving the information, 25 percent were able to save 6.3 percent of their travel time. This impact assumption was based on a comparison of the various IDAS impact assumption values for the individual ATIS components.

- Estimation of Benefit/Cost – An external spreadsheet tool was developed to compare the benefits and costs for the full deployment scenario. This separate spreadsheet was needed in order to aggregate the results from multiple IDAS runs representing different time periods (A.M., P.M., etc.). IDAS currently only has the ability to compare benefits and costs for a single time period. This spreadsheet compiled the results from multiple time-period scenarios into combined daily and annual results.

- Estimation of the Impacts of Weather and Work Zone Mitigation Strategies – Weather and work zone mitigation strategies are not currently available as deployments within the IDAS software. Special analysis techniques were developed, using capabilities within the IDAS software, to analyze the impacts of these specific strategies. These techniques are described in a subsequent section.

- Estimation of the Incident-Related Delay on Freeway Facilities – The IDAS software contains a default methodology and parameters for estimating the incident related delay for freeway facilities. Although previous IDAS studies conducted by numerous agencies have served to vet these impacts as reasonable representations for individual deployments, this study includees combinations and intensities of deployment that exceed any that have been tested using this methodology. It was the opinion of an expert panel that reviewed the preliminary results that the initial estimates of the cumulative impact to incident related delay overstated the potential reduction. In order to ensure a conservative estimation of benefits, a sensitivity analysis was performed to identify the default impact parameters used in IDAS that were most likely to result in an overestimation of benefits. These parameters were modified and the model analysis was re-run to produce the more reserved final results.

Model Networks and Adjustments

Network and travel demand data from the regional travel demand models formed the basis of the analysis. These models varied from region to region in their size and complexity. Additionally, some adjustments were necessary to modify the available travel demand model data to match the specific needs of the desired analysis. This section summarizes the models used in the three regions and describes the necessary modifications to generate the baseline data needed for the analysis.

Tucson

The model data available for the Tucson region represented daily travel conditions in the year 2025. This model was developed and maintained by the Pima Association of Governments (PAG). The Tucson model was the smallest of the models used in the analysis, representing a daily total of approximately 5.4 million person trips traveling between 870 possible origins and destinations. Three vehicle modes were represented in the model, including: Auto, Light Truck, and Heavy Truck. Two public transit modes were represented; however, both represented bus travel. The transit modes were differentiated by the form of access to the transit stop: Transit Walk Access and Transit Drive Access.

No significant modifications were required to prepare the Tucson model data for use in the analysis. Minor reformatting of the data was performed to prepare the data for input into the IDAS software tool.

Cincinnati

The Cincinnati region model, obtained from the Ohio-Kentucky-Indiana Regional Council of Governments (OKI), was the most complex of the three regional models used in the analysis. The model had recently undergone a significant update, which resulted in the merging of the regional travel demand models representing the Cincinnati and Dayton, Ohio, regions. Models were specifically developed for this analysis representing travel demand for the year 2003. These models were developed to represent four separate time periods: A.M. Peak Period (2.5 hours), Mid-day Peak Period (6.5 hours), P.M. Peak Period (3.5 hours), and Off-Peak Period (11.5 hours). The combined travel demand in these four periods represented approximately 9.3 million daily person trips traveling between 2,999 possible origins and destinations. Approximately 69 percent of this travel occurs in the Cincinnati region.

Adding to the complexity of the Cincinnati model was the disaggregation of travel into 11 possible modes, including five vehicle modes: Single Occupancy Vehicle, High Occupancy Vehicle (two people), High Occupancy Vehicle (three or more people), Single-Unit Truck, and Multiple-Unit Truck. Six separate bus transit modes were also available, segmented by the type of bus service and access mode, including: Local Bus Walk Access, Local Bus Park & Ride, Local Bus Kiss & Ride, Express Bus Walk Access, Express Bus Park & Ride, and Express Bus Kiss & Ride.

Several significant modifications were made to the existing Cincinnati models to prepare the data for use in this analysis. The first modification was the development of models representing travel in the year 2003. No specific existing models were available representing this year. Travel demand from models representing the year 2000 and 2010 were interpolated to develop travel demand trip tables for each of the analysis periods representing the year 2003. The model networks from the 2000 models were used since these models already contained roadway improvements that were expected to be completed by 2003.

A second modification was required to allow the analysis to focus only on the impacts in the Cincinnati region. The recent model update had merged the previous models from the Cincinnati and Dayton regions into a single model; however, the focus of this analysis was only on the Cincinnati region. A special data flag was added to the network link data to identify in which region each roadway was located. This enhancement allowed performance measures to be extracted from only those portions of the network located in the Cincinnati (OKI) region.

Other minor modifications were required to reformat the data for input into the IDAS software. Additional modifications were also required to perform a separate analysis of the impacts of weather and work zone mitigation strategies in the Cincinnati region. These specific modifications are discussed in a subsequent section.

Seattle

The Seattle regional models used in the analysis represented travel demand in the year 2003 for three separate time periods: A.M. Peak Period, P.M. Peak Period, and the Off-Peak Period. These models were based on the Puget Sound

Regional Council (PSRC) travel demand models. These models represented a combined daily travel demand of approximately 10.8 million person trips traveling between 850 possible origins and destinations. Five separate travel modes were used in the analysis including: Single Occupancy Vehicle, High Occupancy Vehicle, Truck, Transit (bus and rail), and Ferry.

Several modifications were made to the existing PSRC models to generate data suitable to the analysis of full operations and ITS deployment. The first modification was the development of specific models representing travel conditions in the year 2003. Travel demand data from existing year 2000 and 2005 models were interpolated to develop these interim year models.

A second modification to the Seattle model networks was required to allow the analysis of ramp metering strategies. On-ramp facilities are not represented in the current Seattle models. Instead, these interchanges are coded similar to surface street intersections and allow traffic to move directly from arterial roadways to freeway facilities. The IDAS software typically requires that ramp facilities be coded in the network to allow the analysis of ramp metering strategies. When ramp meters are deployed, additional impedance is added to the ramp facilities to simulate the impact of the ramp signal on traffic entering the freeway. Since the ramp facilities were not available in the Seattle model network, modifications were required to properly represent this impact. Turning movement restrictions, available for use in the IDAS software, were specially modified to represent the additional impedance caused by ramp metering strategies in the absence of ramp facilities.

A final modification to the Seattle models was required to properly represent automobile carrying ferries in the IDAS analysis. Some reformatting of the model data was necessary to properly account for this specific travel mode that is prevalent in the Puget Sound region.

Additional Analysis for Estimating the Impacts of Weather and Work Zones

Analysis Scenarios

Additional analysis was conducted in Cincinnati to identify the impacts, benefits, and costs that could be expected with the addition of specialized operations and ITS strategies intended to counter the effects of inclement weather and help mitigate the negative impacts occurring as a result of road construction and maintenance.

Additional scenarios were needed to analyze these strategies because the baseline networks obtained from the travel demand model assume no inclement weather or road construction activity. The analysis scenarios that were developed differed by four separate variables: the presence of roadwork, weather conditions, deployment intensity, and time of day. These variables were defined as follows:

- Presence of Roadwork — Two separate roadwork scenarios were evaluated, including a network with a representative sample of construction activity and a network without road construction/reconstruction activity. The impact of roadwork activity was represented by reducing facility capacities through the construction zones, as described in a subsequent section.

- Weather Conditions — Three separate weather conditions were evaluated: clear, rain, and ice/snow. The network representing clear conditions was identical to the baseline network obtained from the travel demand model. The impacts of the rain and ice/snow conditions were represented by decreasing capacities throughout the network, as described in a subsequent section.

- Deployment Intensity — Several different deployment intensities were evaluated. These include a No Operations and ITS Deployment Scenario, which did not contain any ITS or operational improvements, and a Full Operations and ITS Deployment Scenario, which contained the full compliment of operations and ITS deployments. Note that for those scenarios that contained the negative impacts of inclement weather or construction activity conditions, the deployment scenario was enhanced by adding either weather or work zone mitigation strategies, or both, as appropriate to the conditions included in the scenario. These specific mitigation strategies were not included in the scenarios that did not contain either the inclement weather or construction activity. For example, the impacts of work zone mitigation strategies were only analyzed in those scenarios with roadwork conditions.

- Time of Day — Models representing four separate time periods were available for the Cincinnati region, including A.M. Peak Period, P.M. Peak Period, Mid-day Period, and Off-Peak.

An analysis approach was developed by creating a matrix of all the potential combinations of these variables and then discarding illogical combinations. For example, no scenarios analyzing conditions representing roadwork activity during ice/snow conditions were evaluated since little construction activity is anticipated in the winter months. To accommodate these variables in the analysis, 40 separate scenarios were developed and analyzed. Table A-1 presents these scenarios.

The following sections describe how the various impacts of weather and construction activity were simulated on the network to create these scenarios.

Simulation of Weather Impacts

Three different weather situations were considered in this analysis—clear, rain, and snow. Clear weather scenarios were represented using the baseline roadway network from the TDM. Scenarios representing rain and snow weather conditions were represented by reducing the capacity of network roadways to simulate the negative impact of the inclement weather. Weather impacts on capacity represented a weighted average of suggested capacity reductions from the *Highway Capacity Manual 2000* [A-3] and the FHWA's Operations website www.ops.fhwa.dot.gov. The capacity reductions are shown in Table A-2.

Simulation of Construction Activity Impacts

The negative impacts of construction activity were simulated on the model networks by first identifying a set of construction projects that would be representative of a typical construction season. These were identified by reviewing major regional construction projects from the previous three years and selecting a set of projects representative of a typical construction season. Eight projects were selected: four lane-addition projects,

Table A-1. Cincinnati Analysis Scenarios

Weather	Construction Activity?	Scenarios with No Operation and ITS	Scenarios with Full Operation and ITS
Clear	No	A.M. Peak Mid-day P.M. Peak Off-Peak	A.M. Peak Mid-day P.M. Peak Off-Peak
	Yes	A.M. Peak Mid-day P.M. Peak Off-Peak	A.M. Peak Mid-day P.M. Peak Off-Peak
Rain	No	A.M. Peak Mid-day P.M. Peak Off-Peak	A.M. Peak Mid-day P.M. Peak Off-Peak
	Yes	A.M. Peak Mid-day P.M. Peak Off-Peak	A.M. Peak Mid-day P.M. Peak Off-Peak
Ice / Snow	No	A.M. Peak Mid-day P.M. Peak Off-Peak	A.M. Peak Mid-day P.M. Peak Off-Peak

Table A-2. Capacity Reductions Used to Represent Inclement Weather Conditions

Weather Conditions	Freeway Reduction	Arterial Reduction
Clear	None	None
Rain	-6%	-6%
Ice / Snow	-10%	-12%

[A-3] Transportation Research Board (2000). *Highway Capacity Manual*, Washington D.C.

two reconstruction projects, and two resurfacing projects. The construction schedules for these projects were also evaluated to estimate the typical number of days within a year in which construction activity was estimated to occur.

The construction projects were then coded into those scenarios meant to analyze work zone projects. Since the representative construction activities represent real projects, they were coded in the actual network locations they occurred. The negative impacts of the construction activities were simulated by reducing the baseline capacities for those roadway links identified as being within the construction zone. This reduction was conducted on an individual link-by-link basis, based on the initial number of roadway lanes, the number of lanes closed during construction, and the type of construction activity. The capacity reduction for each individual link included in the work zone was calculated by first subtracting out the number of lanes anticipated to be closed as a result of the construction activity. The capacities of the remaining lanes were then reduced based on the recommended capacity reduction factor from the highway capacity manual (based on the number of lanes in normal conditions and the type of construction activity). These capacity adjustments, for the lanes remaining open for the various projects, ranged from 75 percent of the original capacity for a two-lane facility undergoing resurfacing to 93 percent of the original capacity for a 3+ lane facility undergoing the addition of new lanes.

Additional Weather and Work Zone Mitigation Strategies

Additional weather and work zone mitigation strategies were deployed and analyzed in the appropriate Full Operations and ITS Deployment Scenarios containing the negative impacts of inclement weather and/or construction activity. These operations and ITS strategies are not currently included as available components for analysis within the IDAS tool. The software does have the capability, however, to deploy and analyze "generic," user-defined components. For these generic deployments, the user is provided the opportunity to specify the impacts of the components. The components are then analyzed identically to all other existing deployments in the scenario, providing the opportunity to analyze the impacts of the user-defined components side-by-side with existing IDAS components to capture the full synergistic impacts of all components. This capability was used to simulate the weather and work zone improvements on the network.

The impacts used in the analysis to represent weather and work zone mitigation strategies were based on the observed impacts from these types of deployments, where available, or the impact of similar operations and ITS components already available within IDAS. The impacts associated with the various weather and work zone mitigation strategies are presented in Table A-3.

Table A-3. Impacts of Weather and Work Zone Mitigation Strategies

Strategy	Analysis Impact
Weather	
Weather ATIS/Road Weather Information Systems (RWIS)	ATIS information reaches 40 percent of regional travelers. Of those travelers receiving the information, 25 percent were able to save 6.3 percent of their travel time. (Based on existing IDAS ATIS methodology)
Work Zones	
Work Zone ATIS	ATIS information reaches an additional 10 percent of travelers using the work zone corridors. Of those travelers receiving the information, 25 percent were able to save 6.3 percent of their travel time. (Based on existing IDAS ATIS methodology)
Work Zone Incident Detection	15 percent reduction in incident duration in work zones.15 percent reduction in fuel use rate and emissions rates in work zone. (Based on existing IDAS methodology and information from similar work zone deployment in Albuquerque, NM)
Lane Merging Applications	5 percent restoration of facility capacity in work zone. (Based on information from Midwest Smart Work Zone Initiative)
Alternative Route Management	10 percent increase in facility capacity for selected parallel arterial corridors serving as diversion routes. (Based on existing IDAS methodology for traffic signal coordination)
Alternative Work Hours	Reduction in the number of days (annually) with construction activity occuring in the peak hours, offset by lesser increase in the number of days with construction occurring in the nighttime period. (Based on information from Midwest Smart Work Zone Initiative)

Estimating the Annual Impact of the Full ITS Deployment Scenario in Cincinnati

Each of the 40 individual scenarios were analyzed separately to estimate the likely traffic conditions that would occur for each given time-of-day period with similar weather, construction activity and operations, and ITS deployment intensity. The results of the individual scenarios were then annualized by applying a weight to each scenario representing how many days a year that scenario would be anticipated to occur in a typical year.

The applied weights were developed by reviewing historical weather patterns and construction schedules. Historical weather data from the National Weather Service revealed that rain would be expected to occur on 17 percent of days annually, and measurable ice/snow precipitation occurs on an average of 18 days per year. A similar review of the construction schedules of the representative projects included in the typical construction season indicated that construction activity would be expected to occur on 53 percent of the days annually. The analysis further assumed that 45 percent of the rain days would occur during the construction season.

The number of days in a year was assumed to be 250, representing the number of weekdays in a year, not including significant holidays. The historical rates of occurrence for the various weather and construction activities were then applied to identify weights (in number of days per year) for the No Operations and ITS Deployment Scenarios. The weights for the Full Operations and ITS Deployment Scenarios were determined similarly, with the following exception. The weight representing number of days with construction activity in the peak periods was reduced to reflect the impact of alternative work scheduling strategies. The construction season for the off-peak scenarios was then extended to reflect the additional work shifted to the nighttime periods.

These identified weights were applied to each scenario and the resulting performance measures were summed for the No Operations and ITS Deployment and the Full Operations and ITS Deployment Scenario. The summed results were then compared to identify the annual incremental benefits of the Operations and ITS strategies. Table A-4 presents the annualization rates that were applied in the analysis for each possible scenario, and shows how the proportion of days included in the annualization changes between the No Operations and ITS Deployment and Full Operations and ITS Deployment Scenarios. For the peak periods (AM, Mid-Day, and PM) the proportion of days with road construction is reduced between the No Operations and ITS Deployment and Full Operations and ITS Deployment Scenarios to represent the impacts of alternative work hours. This table also shows the impact of shifting some of these roadwork activities to the off-peak periods.

Table A-4. Annualization Weights for Cincinnati

	Peak Periods (Includes AM, Mid-Day, and PM Peak Periods)				Off-Peak Periods			
	No Ops and ITS		Full Ops and ITS		No Ops and ITS		Full Ops and ITS	
Scenario	Days	%	Days	%	Days	%	Days	%
Clear	49	20%	66	26%	49	20%	32	13%
Rain	21	8%	24	10%	21	8%	18	7%
Ice/Snow	46	18%	46	18%	46	18%	46	18%
Clear with Roadwork	113	45%	96	38%	113	45%	130	52%
Rain with Roadwork	21	8%	18	7%	21	8%	24	10%
TOTAL	**250**	**100%**	**250**	**100%**	**250**	**100%**	**250**	**100%**

Study Caveats

As documented in this appendix, the analysis of the three case study regions were conducted using similar, but not identical approaches and assumptions. Therefore, comparisons of major trends across the three regions are generally valid. Caution should be applied in any detailed cross-cutting analysis of specific impacts, however, due to model and approach differences that may have skewed results. The differences in the analysis approaches may make it difficult to discern if variations observed between the three regions are valid, or are a product of the analysis methodology. Some of the significant variations in the models and approaches which have the potential to impact results are documented below.

Tucson

The analysis of impacts in the Tucson region employed model data representing average daily travel in the year 2025. This region was the only one to use a future forecast of travel demand. The use of this future demand may result in the inflation of benefits, relative to other regions, since travel demand and related congestion is presumably greater than in the current year. The Tucson region was also the only region where a single daily forecast was used in the analysis. This unique characteristic may have the impact of decreased benefits relative to the other areas because the daily traffic model does not capture the impacts of increased congestion during the peak hours. The Tucson model was also not adjusted to specifically analyze variations in weather conditions or construction activity, as was performed in Cincinnati.

Cincinnati

The analysis of impacts in the Cincinnati region used model data representing travel conditions in 2003 for four separate periods—A.M. Peak Period, Mid-day Peak Period, P.M. Peak Period, and Off-Peak Period—with the sum of these periods equal to a single day. Further, additional models were constructed from these base models to represent traffic conditions during different combinations of weather conditions and road maintenance activity typifying a normal construction season. These additional models resulted in the analysis of ITS impacts during 20 unique traffic conditions, greatly adding sensitivity to the analysis compared to the other regions. Because the analysis produced increased benefit estimates for those alternatives representing inclement weather or construction activity, it is likely that the overall benefits estimated for Cincinnati are greater relative to the other areas. The analysis in Tucson and Seattle were not conducted with this sensitivity to weather conditions or construction activity, and would not have captured these additional benefits.

Seattle

The Seattle regional models used in the analysis represented travel demand in the year 2003 for three separate time periods: A.M. Peak Period, P.M. Peak Period, and the Off-Peak Period. The results from the Seattle analysis are, therefore, sensitive to the variations in impacts caused by peak period congestion. The Seattle models were not adjusted, however, to specifically analyze variations in weather conditions or construction activity, as was performed in Cincinnati.

In addition to the model differences noted above, other factors and parameters internal to the individual region's models may also affect the estimated impacts. Model characteristics such as the length of peak periods, volume-delay functions, and mode choice sensitivity may also promote differences in the analysis results.

Additional Caveats

Impacts of the operations and ITS deployments on incident-related delay were estimated in all three case study regions. The use of incident-related delay, non-recurring congestion, or travel time reliability as a measure of system performance is an emerging practice. As yet, there is often little consensus on the specific definitions of the performance measures used or the analysis methodologies applied in different studies. In this study, "incident-related delay" is estimated only for freeway facilities and represents the expected amount of delay occurring as a result of traffic incidents (crashes, stalls, and breakdowns). This performance measure is synonymous with the "travel time reliability" impact within the IDAS analysis methodology. Current incident data availability limits the appli- cation of this analysis methodology to only freeway facilities and does not currently allow for the estimation of incident-related delay for other surface roadways.

Other caveats, specific to the individual case study regions, are documented within the individual reports.

ITS Web Resources

ITS Joint Program Office:
http://www.its.dot.gov

ITS Cooperative Deployment Network:
http://www.nawgits.com/icdn

ITS Electronic Document Library (EDL):
http://www.its.dot.gov/itsweb/welcome.htm

ITS Professional Capacity Building Program:
http://www.pcb.its.dot.gov

Intelligent
Transportation
Systems

U.S. Department of Transportation
400 7th Street, SW
Washington, DC 20590

FHWA-JPO-04-031 May 2005 EDL #13979