FINAL REPORT

An Analysis of the Worst Commuting Days in Washington, DC (June 1, 2000 to May 31, 2001)

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ABSTRACT

Previous research using the Heuristic On-Line Web Linked Arrival Time Estimator (HOWLATE) methodology showed that the user benefits associated with pre-trip route choice and trip timing are highly concentrated for congested PM peak trips. One implication of this finding is that pre-trip traveler information benefits increase with increasing congestion. This report explores how much benefit pre-trip traveler information provides on some of the worst commuting days, seen over a year, in Washington, DC. It analyzes the impacts on a commuter who does not utilize traveler information services, and examines what would have happened to his commute if he had made use of a notification-based pre-trip traveler information service on those days. The worst days were determined as those that had high travel times, travel disutility cost, travel-expenditure, late and early schedule delays, and poor on-time reliability and just-in-time reliability. When possible, contributing factors that made the days the worst with respect to a particular measure were identified from data on incidents, weather and high-demand. The study showed that the worst days varied by the measure of effectiveness chosen to rank them. High-demand was the main contributing factor for high travel time and travel expenditure, while incidents played a major role in increased travel disutility cost and late schedule delays, and poor on-time reliability and just-in-time reliability. The impacts on the worst days were significant for a commuter who did not rely on traveler information; typically late trips doubled and travel disutility cost jumped by 30%. The benefits of pre-trip traveler information were high on the worst days; lateness risk was cut by more than half and travel disutility cost was reduced by more than 20%. With respect to just-in-time reliability and early schedule delay, a commuter who made use of pre-trip traveler information fared better on the worst days than a commuter who did not use traveler information service on a typical day of the year. On the worst days, users who made use of pre-trip traveler information changed routes or trip start time or both on more than 60% of the trips.

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EXECUTIVE SUMMARY

INTRODUCTION

Previous research using the Heuristic On-Line Web Linked Arrival Time Estimator (HOWLATE) methodology showed that the impacts of pre-trip traveler information were found to be highly concentrated with the highest benefits occurring for congested PM peak trips, implying that pre-trip traveler information benefits increase with increasing congestion. The question that remains to be answered is if traveler information helps when traffic conditions are bad, then how much benefit is accrued on the worst days? But what constitutes a worst day? What are the contributing factors that make a day *the worst*? This report tries to address these questions using the HOWLATE methodology. It analyzes the impacts on some of the worst days in Washington, DC on a commuter who does not utilize traveler information, and examines what would have happened to his commute had he made use of a notification-based pre-trip traveler information service on those days. The worst days are determined as those that have high travel times, travel disutility cost, travel-expenditure, late and early schedule delays, and poor on-time reliability and just-in-time reliability. In this study ten worst days are determined for each of these performance measures.

APPROACH

The analysis was conducted using data archived over the period from March 1, 2000 to May 31, 2001 and the HOWLATE methodology. HOWLATE reconstructs hypothetical pairs of driving trials or simulated yoked trials between a pair of habitual commuters, one who does not make use of ATIS, and the other who uses pre-trip ATIS, using archived travel times. In simulated yoked trials two subjects are yoked or paired together to conduct identical trips, i.e., they have the same origin, destination, and target arrival time, and their trips are simulated or synthesized. For purposes of this report, ATIS is defined as a notification-based route choice and departure time selection service (*defined in detail in §2.4*). Real-time travel time data was archived from the SmarTraveler traveler information web site (www.SmarTraveler.com) every 5 minutes from 6:30 AM to 6:30 PM for each day. The HOWLATE simulation includes training and evaluation periods. During training, the two commuters establish their habitual routes and determine the trip start time that enables them to arrive at their destination at their desired arrival time. During evaluation, simulated yoked trials are conducted between the two commuters who have familiarized themselves with the route and trip start times, and the effect of pre-trip ATIS is assessed for target arrival times at 15-minute intervals between 6:30 AM and 6:30 PM. The training period for this study was from March 1, 2000 to May 31, 2000, and composed of 33 weekdays. The evaluation period was from June 1, 2000 to May 31, 2001, and composed of 178 weekdays. Of the 319 potential days (*weekends excluded*) for archiving data, only 211 days were used in this study. A total of 108 days were excluded from consideration due to gaps in the data archive. If on any day data on a facility was not archived for duration of more than 20 minutes, that day was not used. The absence in archiving was due to the following factors: the SmarTraveler site was down, Internet connectivity for the Mitretek site was down, or SmarTraveler modified significantly the format and/or content of the web pages causing problems with the automated download process. Simulated yoked trials between the non-ATIS and the ATIS users were conducted using 5 random number seeds for each day in the evaluation period for the Washington, DC HOWLATE network.

Ten worst days were determined for the seven measures of travel times, travel disutility cost, travel-expenditure, late and early schedule delays, on-time reliability and just-in-time reliability, by sorting for that MOE for the non-ATIS user for the AM and PM peak periods (*178 x 2 peak periods*). Of the 356 peak periods, 42 of these were the worst with respect to at least one performance measure. The contributing factors that made the days the worst with respect to the MOE examined were a combination of incidents, weather and high-demand. The weather data were obtained from the Hourly Automated Surface Observing System (ASOS) stations at the three regional airports of Washington Reagan National, Dulles International, and Baltimore-Washington International. The incident data were obtained from the Virginia Department of Transportation Smart Traffic Center at Arlington, VA, and the Maryland Traffic Management Center. However, it should be noted that incident data was available only for December 15, 2000, December 19, 2000 and the period from March 01, 2001 to May 31, 2001. For the remaining worst days, whenever severe weather and high-demand were not identified as contributing factors, it was assumed that there was an incident (*Please see §3 for more details.*). The hypotheses of the study were as follows:

1. *The worst days will differ by the performance measure chosen to rank them.*
2. *ATIS impacts will be higher than average on the worst days.*

KEY FINDINGS

1. *The worst days vary by the measure of effectiveness chosen to rank them.*

   A commuter faced some of the worst travel disutility cost, early schedule delay and just-in-time reliability on the same day; a non-ATIS user had the worst travel disutility cost, early schedule delay and just-in-time reliability on six days. Three of the worst travel time days were also the worst days with respect to on-time reliability and travel expenditure. On February 16, 2001, which had a combination of high-demand and rain, a commuter had the worst travel time, on-time reliability, travel disutility cost, late schedule delay, and travel expenditure.

2. *Contributing factors vary by the measure of effectiveness chosen.*

   Incidents played a major role in increased travel disutility cost (*60%*) and late schedule delays (*60%*), and poor on-time reliability (*80%*) and just-in-time reliability (*80%*), while high-demand was the main contributing factor for high travel time (*60%*) and travel expenditure (*60%*).

3. *Impacts on the worst days are significant for a commuter who relies solely on past experience.*

   Late trips typically doubled or tripled, while on the worst days with respect to on-time reliability it increased 5 times. Travel disutility cost typically jumped by 30%, and on the worst days with respect to travel disutility cost, early schedule delay or just-in-time reliability it increased by more than half. Average delay doubled, as was observed for the worst days with respect to travel time, on-time reliability, or travel expenditure. Late schedule delay increased, and on the worst days with respect to late schedule delay or travel expenditure it doubled.

4. *Benefits of pre-trip traveler information services are higher than average on the worst days.*

   With ATIS, lateness risk was cut by more than half, travel disutility cost was reduced by more than 20%, just-in-time reliability increased by more than 20%, and early schedule delay reduced by more than 15%. The ten worst days with respect to on-time reliability were also the top ten days with most benefit from ATIS. For some measures (*travel time, on-time reliability, and early schedule delay*), the worst day was also the day with most benefit from pre-trip ATIS. On the ten worst days with respect to all seven measures, a commuter who made use of ATIS fared better than a non-ATIS commuter on a typical day of the year, with respect to just-in-time reliability and early schedule delay (*There were reductions of nearly 20%.*).

5. *On the worst days, ATIS users changed routes or trip start time or both on more than 2/3rd of the trips to arrive at their destination just-in-time.*

   ATIS users changed their time of departure 6-7 times more frequently than routes. When departing earlier than the habitual departure time, pre-trip ATIS users left more than 5 to 7 minutes early, and when departing later, they left late by more than 6 minutes.

CONCLUSIONS AND FUTURE WORK

The analyses of the worst days showed that the effect on a commuter who does not use ATIS is high. However, use of pre-trip traveler information service can help mitigate the adverse effect on trip predictability, travel disutility cost, lateness risk, and late and early schedule delays. The results presented were for the entire Washington, DC network. An extension to the study will be to examine the effect of traveler information services on some of the worst days on some specific corridors that are already congested, such as I-66.

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1. INTRODUCTION

The Heuristic On-line Web-Linked Arrival Time Estimator (HOWLATE) is an analytical method developed by Mitretek Systems, Inc. to evaluate the benefits of Advanced Traveler Information Services (ATIS). The HOWLATE methodology has been applied to evaluate the benefits of ATIS, delivered pre-trip and en route to the Washington, DC and Minneapolis/St. Paul metropolitan areas (*1, 2*). The HOWLATE studies concur with previous field experiments in that ATIS users experience minimal reduction in in-vehicle travel time. The results showed that although ATIS users had only marginal reduction in in-vehicle travel time compared to travel times experienced by commuters who rely only on past experience, they benefited from an improvement in on-time reliability, and a reduction in Small's travel disutility cost, which is the value of travel time and on-time reliability (*3*). Small's dollar-valued benefit of reductions in travel disutility is calculated from the reductions in the frequency and magnitude of early or late arrivals as well as in-vehicle travel time. It can be construed as the value paid for obtaining traveler information service (*$3-$5 per month*; *4*). In our study, the traveler information service that was modeled uses data collected and disseminated by SmarTraveler to suggest changes in trip timing and route choice. In Washington, DC, 40% of the trips were able to accumulate an average annual benefit in excess of the typical charge for traffic alert services, compared with 20% of the trips in the Minneapolis/St. Paul metropolitan area. The analyses also showed that the impacts of ATIS were found to be highly concentrated with the highest benefits occurring for PM peak trips, which also had the highest travel times, implying that ATIS benefits increase with increasing congestion.

One question that remained to be answered was if ATIS helps when traffic conditions are bad, then how much benefit is accrued with ATIS on the worst days? But what constitutes a worst day? What are the contributing factors that make a day *the worst*? This report tries to address these questions using the HOWLATE methodology. It analyzes the impacts on some of the worst days in Washington, DC, on a commuter who does not utilize traveler information services, and examines what would have happened to his commute if he had made use of a notification-based pre-trip traveler information service on those days. The worst days are determined as those that have high travel times, travel disutility cost, travel-expenditure, late and early schedule delays, and poor on-time reliability and just-in-time reliability. In this study ten worst days were determined for each of the aforementioned performance measures. The hypotheses of the study were as follows:

1. *The worst days will differ by the performance measure chosen to rank them.*
2. *ATIS impacts will be higher than average on the worst days.*

A brief overview of the HOWLATE methodology is given in Section 2. This section also discusses the geographic area covered, and the measures of effectiveness (MOE) that were evaluated. Section 3 provides the analyses of the ten worst days with respect to each of the seven HOWLATE MOEs that were examined. Section 4 presents the behavior of a commuter who uses pre-trip traveler information on the worst days. Finally, Section 5 summarizes the key findings and future work.

2. THE HOWLATE METHODOLOGY

The HOWLATE process reconstructs trip durations and on-time performance of travelers who travel certain routes at various times of the day. The first step in the HOWLATE process is to archive travel time reports from the SmarTraveler traveler information web site (www.SmarTraveler.com). The SmarTraveler web site lists by facility, publicly available real-time travel time information as well as information on accidents, construction, and special events, for a number of cities in the United States. Next, simulated yoked trials (*the technique where hypothetical pairs of driving trials are reconstructed using archived travel times*) are conducted between a pair of habitual commuters, one who does not avail of traveler information services, and the other who uses pre-trip traveler information. The HOWLATE simulation includes training and evaluation periods. During training, the two commuters establish their habitual routes and determine the trip start time that enables them to arrive at their destination at their desired arrival time. In addition, pre-trip ATIS users also determine the error in the predicted pre-trip traveler information and the actual travel time that they experience. During evaluation, simulated yoked trials are conducted between the two commuters who have familiarized themselves with the route and trip start times, and the effect of pre-trip traveler information services is assessed. A detailed description of the training methodology is available elsewhere (*1*).

The geographic area covered under this study is presented in Section 2.1, followed by a brief discussion on the archived travel time reports and the training and evaluation periods used in the study in Sections 2.2 and 2.3, respectively. The two commuter types whose performances are evaluated are described in Section 2.4. Section 2.5 presents the definitions of the seven measures of effectiveness examined in the study.

2.1 Geographic Network

The study was conducted for the Washington, DC metropolitan area. The geographic coverage by SmarTraveler for the Washington region ranges from Laurel and Gaithersburg in Maryland, to Centreville and Dale City in Virginia. Figure 1 presents the SmarTraveler map and the corresponding HOWLATE network for the Washington, DC area.

The Washington, DC network, for which travel time reports are posted on the SmarTraveler web site, consists of 33 facilities (*18 freeways and 15 major arterials*), with a total of 711.8 directed miles. The 18 freeway facilities constitute 472.4 of the 711.8 miles, and the 15 arterial facilities constitute the remainder (*239.4 miles*). The average facility length is 10.8 miles, with the longest and shortest lengths being 25.0 and 2.6 miles, respectively.

The 33 facilities were divided into 75 links (*150 directed links*), for use in the DC HOWLATE network. The average link length for the DC HOWLATE network was 4.6 miles. The longest link was 13.5 miles while the shortest link was 1.0 mile. As SmarTraveler does not post any travel time information for the arterial facilities within the District of Columbia, an additional 18 links were modeled since these facilities were important in representing the available route choice options. A total of 55 nodes (*potential trip origin or trip destination*) were modeled in the DC HOWLATE network; thus, there were a total of 55 x 54 origin-destination pairs. A detailed description of the process used to construct the HOWLATE network is presented elsewhere (*1*).

2.2 Archived Travel Time Reports

The travel time data used for the analysis was based on an automated process developed by Mitretek Systems for archiving Internet postings made by SmarTraveler (*1*). The HOWLATE analysis was done for the period starting on March 1, 2000 and ending on May 31, 2001. Data was archived every five minutes from 6:30 AM to 6:30 PM (*145 time intervals*) for each of 33 facilities for each day. Thus, there

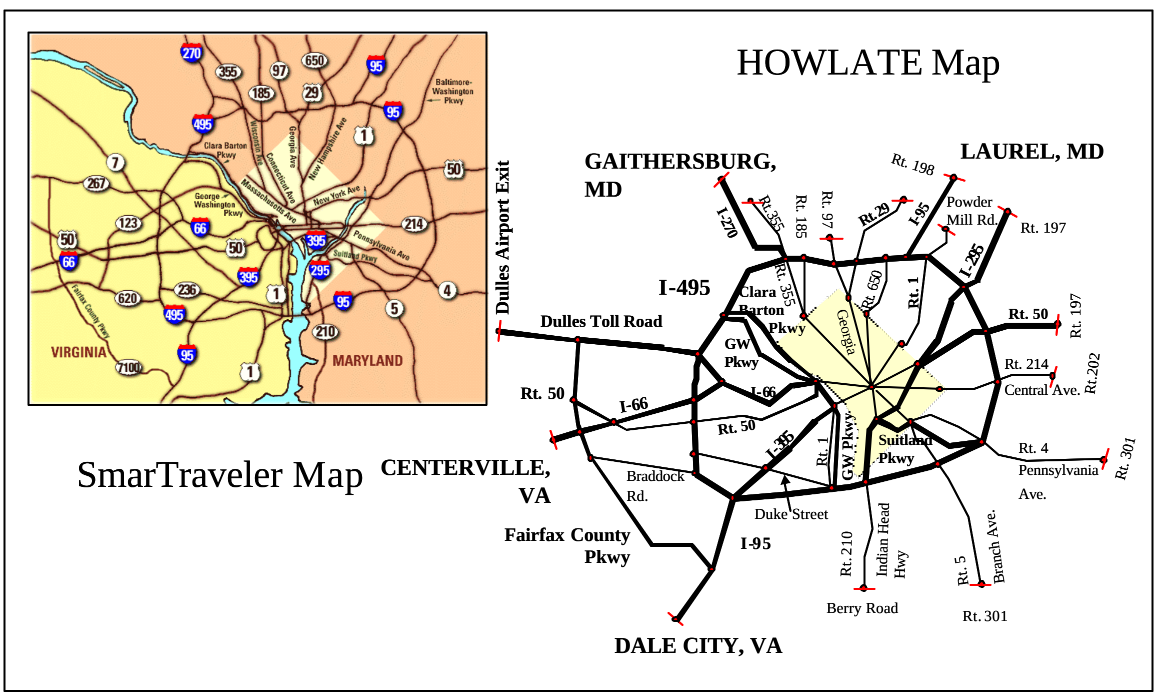

Figure 1 Washington, DC Network

were a total of 4785 (*145 x 33*) archived travel time reports for each day. The travel time for each facility was then divided among its corresponding HOWLATE network links based on the assumption of a uniform speed.

2.3 Training and Evaluation Periods

The training period for this study was from March 1, 2000 to May 31, 2000, and was composed of 33 weekdays. The evaluation period was from June 1, 2000 to May 31, 2001, and was composed of 178 weekdays. Of the 319 potential days (*weekends excluded*) for archiving data, only 211 (*66%*) days were used in this study. A total of 108 days were excluded from consideration due to gaps in the data archive. If on any day data on a facility was not archived for duration of more than 20 minutes, that day was not used. The absence in archiving was due to the following factors: the SmarTraveler site was down, Internet connectivity for the Mitretek site was down, or SmarTraveler modified significantly the format and/or content of the web pages causing problems with the automated download process. Simulated yoked trials between the non-ATIS and the ATIS users were conducted using five different random number seeds for each day in the evaluation period for 55 x 54 origin-destination pairs in the Washington, DC HOWLATE network, for target arrival times (*49 target arrival times*) at 15-minute intervals between 6:30 AM and 6:30 PM.

2.4 Commuter Types

This section presents a description of the two types of commuters whose performances were examined during the evaluation period.

2.4.1 Savvy Conservative Non-ATIS Traveler (F95)

This type of commuter is familiar with his route, and is conservative since he plans his trips to arrive on-time 95% of the time. Thus this type of non-ATIS commuter chooses a trip start time that allows him to arrive on time at his or her destination 95 percent of the time, and consequently will often arrive early, but is rarely late.

2.4.2 Savvy Pre-Trip ATIS Traveler (ASV)

This type of commuter is also familiar with his route. Prior to starting the trip, the commuter uses the current traveler information (of which he is notified by a traveler information service), and adjusts the reported travel time based on his experience of the accuracy of the ATIS, which is learned during the training period. The objective of these types of commuters is to determine the fastest route that will make them arrive at their destination just in time. The ATIS service starts checking 30 minutes before the habitual start time of the commuter, and reports the travel time information to the commuter. If the commuter thinks he will arrive at his destination more than 10 minutes before the desired arrival time, he will postpone the trip by 5 minutes. The check is performed every 5 minutes. When the commuter can no longer postpone the trip, he determines if the travel time on the fastest route is less than the travel time on the habitual route. If the travel-time-savings is 3 minutes or more (*5*), he selects the alternate fastest route; otherwise he opts for the habitual route. The postponement is done until a limit is reached, which is 30 minutes after the habitual start time. Once the route and trip start time are fixed, using the reported travel time and the prediction error, this traveler does not alter the route, even if he faces congestion on the chosen route.

It should be noted that such an ATIS service that continually checks the travel times and notifies the commuter does not currently exist. In our study, such a notification-based service was modeled using SmarTraveler data. The intent of this study was not to evaluate the accuracy of SmarTraveler data; rather it was to evaluate the impact on a commuter who makes use of an ATIS service as opposed to one who does not.

2.5 Measures of Effectiveness

Seven measures of effectiveness were defined to evaluate the benefits of the pre-trip traveler information services, and these include:

- Travel time (*TT*), defined as the difference between the actual time of arrival at the destination and the departure time.
- Small's travel disutility cost (*Small's*), defined as a measure of disutility associated with a trip by assigning a cost to the duration of travel time and how early or late one reaches one's destination is based on the research done by Small et al (*3*). The cost function is linear in in-vehicle travel time, quadratic in the magnitude of early arrivals, and linear in the magnitude of late arrival with an additional penalty for arriving late. Note that the cost of late or early arrival is not sensitive to the duration of the trip, i.e., being five minutes late has equal disutility, or cost, regardless of the fact that the trip may be five or 50 minutes long. The disutility function is defined as follows:

$$c = aT + \beta_{SDE}(SDE) + 2\ \beta_{SDE2}(SDE)^2 + ?(SDL) + ?D_L$$

T: Travel Time

SDE: Schedule delay early

SDL: Schedule delay late

D_L: Late arrival index $= \begin{cases} 1 & \text{if } SDL > 0 \\ 0 & \text{otherwise} \end{cases}$

The estimates of the parameters are:

a: $0.0564/min (linear cost of in-vehicle travel time)

$ß_{SDE}$: $-0.023/min (linear component of quadratic early cost)

$ß_{SDE2}$: $0.005/min (quadratic component of quadratic early cost)

g: $0.310/min (linear cost of late arrival)

q: $2.87 (one step penalty for arriving late)

- On-time reliability (*OTR*), defined as the percentage of trips during the evaluation period in which the traveler arrives at the destination before the target time of arrival.
- Just-in-time reliability (*JTR*), defined as the percentage of trips during the evaluation period in which the traveler arrives at the destination before the target time of arrival, and no more than 10 minutes early.
- Late schedule delay (*LSD*), defined as the difference between the actual arrival time at the destination and the target time of arrival, when the traveler arrives after the target time of arrival.
- Early schedule delay (*ESD*), defined as the difference between the actual arrival time at the destination and the target time of arrival, when the traveler arrives before the target time of arrival.
- Travel expenditure (*TExp*), defined as the difference between the target time of arrival at the destination and the departure time plus the late schedule delay, if any.

The measures of effectiveness were computed for the peak and off-peak periods for the two commuter types described in 2.4.

3. WORST DAYS ANALYSES

Prior research (*2*) using the HOWLATE methodology in the Washington, DC area has shown that commuters who made use of pre-trip traveler information services benefited by improving their trip predictability and travel disutility cost, but experienced little reduction in in-vehicle travel time. Table 1 displays the overall impacts of ATIS in DC. Over the year, a commuter in Washington, DC, who made use of traveler information services, reduced the frequency of late and early arrivals by more than 50%, reduced the travel disutility cost by 14.9%, reduced his late and early schedule delays, and increased his on-time reliability and just-in-time reliability.

Commuters typically make use of traveler information service to reduce the uncertainty of their trip, by assessing traffic congestion and incidents on their route, deciding among alternate routes, and estimating their trip duration and trip departure (*6*). Hence, although overall the use of ATIS helped in reducing travel disutility cost and frequency of late and early arrivals, it is important to see if even on some of the worst days, commuters who avail of traveler information services can continue to benefit. This report examines the effect of traveler information services on the ten worst days in Washington, DC, with respect to the measures of effectiveness described in Section 2.5.

Table 1 Overall ATIS Impacts in Washington, DC for June 2000 – May 31, 2001 (Summarized from Jung, et al, 2002[2])

MOEs	ALL DAY	PEAK
In-Vehicle Travel Time	0.3% ↓	0.01% ↓
Travel Disutility Cost	14.9% ↓	18.1% ↓
On-Time Reliability	2.4% ↑	0.2% ↑
Just-In-Time Reliability	27.1% ↑	46.1% ↑
Late Schedule Delay	5.9% ↓	0.2% ↓
Early Schedule Delay	22.1% ↓	22.5% ↓
Travel Expenditure	1.8% ↓	4.8% ↓
Frequency of Late Arrivals	52.0% ↓	2.0% ↓
Frequency of Early Arrivals	56.0% ↓	60.0% ↓

The ten worst days were determined for each of the seven measures of effectiveness, by sorting for that MOE for the non-ATIS traveler (*F95*) for the AM and PM peak periods (*178 x 2 peak periods*). Of the 356 peak periods, 42 of these were one of the ten worst with respect to the seven performance measures. Table 2 shows how the seven performance measures affected each of the 42 rush hour periods. It illustrates how poorly a day did with respect to an MOE. A black box represents the worst day (*rank 1*) with respect to the corresponding MOE, a gray box shows that the day was one of the ten worst days for that MOE, but was not the worst, and a white box implies a rank higher than 10, i.e., it was not among the ten worst days for the MOE. A commuter faced some of the worst disutility cost, early schedule delay and just-in-time reliability on the same day. Of the ten worst days with respect to disutility cost, eight were also the worst days with respect to just-in-time reliability, while seven were among the ten worst days with respect to early schedule delay. On six of the ten days, a non-ATIS commuter had the worst disutility cost, early schedule delay and just-in-time reliability, and on one of these six days, the commuter also had some of the worst late schedule delay. Three of the worst travel time days were also the worst days with respect to on-time reliability and travel expenditure. On February 16, 2001, which had a combination of high-demand and rain, a commuter had the worst travel time, on-time reliability, travel disutility cost, late schedule delay, and travel expenditure.

Table 2 Ranking of Worst Days Among the Seven Measures of Effectiveness

Day	Peak Period	TT	Small's	OTR	JTR	LSD	ESD	TExp
Jun02	PM	□	□	□	□	□	□	▒
Jun23	PM	▒	□	□	□	□	□	▒
Jul21	AM	□	□	□	□	▒	□	□
Jul25	PM	□	□	□	□	□	▒	□
Jul26	AM	□	□	▒	□	□	□	□
Aug07	PM	□	□	□	□	□	▒	□
Aug09	PM	□	□	□	▒	□	□	□
Aug11	PM	▒	□	□	□	□	□	□
Aug21	AM	□	□	□	□	▒	□	□
Aug25	PM	▒	□	□	□	□	□	□
Aug30	PM	□	▒	□	□	□	▒	□
Sep04	PM	□	▒	□	▒	□	▒	□
Sep11	PM	□	▒	□	▒	□	▒	□
Sep21	AM	□	□	■	□	▒	□	□
Oct02	PM	□	▒	□	▒	□	▒	□
Oct13	AM	□	□	□	□	▒	□	□
Oct16	PM	□	▒	□	▒	□	□	□
Oct17	PM	□	▒	□	▒	■	▒	□
Oct18	PM	□	□	□	▒	□	□	□
Oct19	AM	□	□	▒	□	□	□	□
Dec15	PM	□	□	□	□	□	□	▒
Dec19	PM	▒	□	□	□	□	□	▒
Dec21	PM	▒	□	▒	□	□	□	▒
Dec27	PM	▒	□	□	□	□	□	□
Jan03	PM	□	□	□	□	□	□	▒
Jan09	PM	□	□	□	□	▒	□	□
Jan10	AM	□	□	□	□	▒	□	□
Jan19	PM	▒	□	□	□	□	□	□
Jan23	AM	□	□	□	□	▒	□	□
Jan29	PM	□	▒	□	▒	□	□	□
Feb15	PM	□	□	□	□	□	▒	□
Feb16	PM	▒	▒	▒	□	▒	□	■
Feb19	PM	□	▒	□	■	□	▒	□
Feb27	AM	□	□	▒	□	□	□	□
Mar15	PM	▒	□	□	□	□	□	□
Mar21	PM	□	□	□	□	▒	□	□
Apr06	PM	■	□	▒	□	□	□	▒
Apr13	PM	□	□	▒	□	□	□	▒
Apr26	PM	□	□	□	□	□	□	▒
Apr26	AM	□	□	▒	□	□	□	□
May23	AM	□	□	▒	□	□	□	□
May28	PM	□	■	□	▒	□	■	□

LEGEND: ■ Worst day ▒ Ranked 2-10 □ Ranked higher than 10

TT: Travel Time
Small's: Small's Disutility Cost
OTR: On-Time Reliability
JTR: Just-in-Time Reliability
LSD: Late Schedule Delay
ESD: Early Schedule Delay
TExp: Travel Expenditure

Travel time variability is one of the major reasons for an increase in travel disutility cost, lateness risk, travel time, travel expenditure, and schedule delays. The contributing factors for travel time variability are a combination of incidents, weather and high-demand. The following sections present the contributing factors that made the ten days the worst with respect to the MOE examined, the impacts on a commuter who does not make use of traveler information services but relies only on past experience, and the effect of the use of pre-trip ATIS on the worst days. The weather data were obtained from the Hourly Automated Surface Observing System (ASOS) stations at the three regional airports of Washington Reagan National, Dulles International, and Baltimore-Washington International. The incident data were obtained from the Virginia Department of Transportation Smart Traffic Center at Arlington, VA, and the Maryland Traffic Management Center. However, it should be noted that incident data was available only for December 15, 2000, December 19, 2000 and the period from March 01, 2001 to May 31, 2001. For the remaining worst days, whenever severe weather and high-demand were ruled out as contributing factors, we were left with days where congestion was high and only incidents remained as a plausible contributing factor. On these days, we assumed that there was an incident, as no evidence existed for another reason for congested travel. As such, it is possible that we may have overestimated the number of times incidents have been identified as a contributing factor. For example, for on-time reliability eight of the ten worst days were identified as affected by incidents (Figure 5). Of these, two days had high-demand, severe weather and incidents, and the remaining six days had only incidents. Of the six days that were reported as having only incidents, four occurred outside the time periods for which we had incident records. However, since there was neither high-demand (*such as the day before Thanksgiving*) nor severe weather on these four days, it was assumed that there was an incident on these days.

3.1 Travel Time (TT)

The ten worst peak period travel times in Washington, DC were found to be in the evening-rush hour period (*6 Apr 2001, 16 Feb 2001, 23 Jun 2000, 19 Jan 2001, 21 Dec 2000, 15 Mar 2001, 25 Aug 2000, 27 Dec 2000, 11 Aug 2000, and 19 Dec 2000*).

3.1.1 Contributing Factors for the Worst Travel Time Days

Incidents, severe weather and high demand were identified as three major contributing factors in the ten worst commuting days. Weather was identified as a contributing factor in five of the ten worst commuting days, high demand in six, and incidents in three (*Note: Two of these days had no information, and hence incident was identified as the contributing factor.*). The ten days can be broken down into: three high-demand travel days, two days with a combination of high-demand and rain, one day with a combination of high-demand, rain and incident, one day each with rain and snow, and two days with incidents. The day that had a combination of high-demand, incident, and rain was the worst day (*April 6, 2001*). On this day a non-ATIS user experienced 32% higher travel time than normal. Figure 2 uses a Venn diagram to illustrate the extent to which the three factors played a role in making the ten days the worst. Thus, 30% of the days were affected only by high-demand, 20% only by severe weather, 20% only by incidents, 20% by both high-demand and weather, and 10% by demand, weather and incidents.

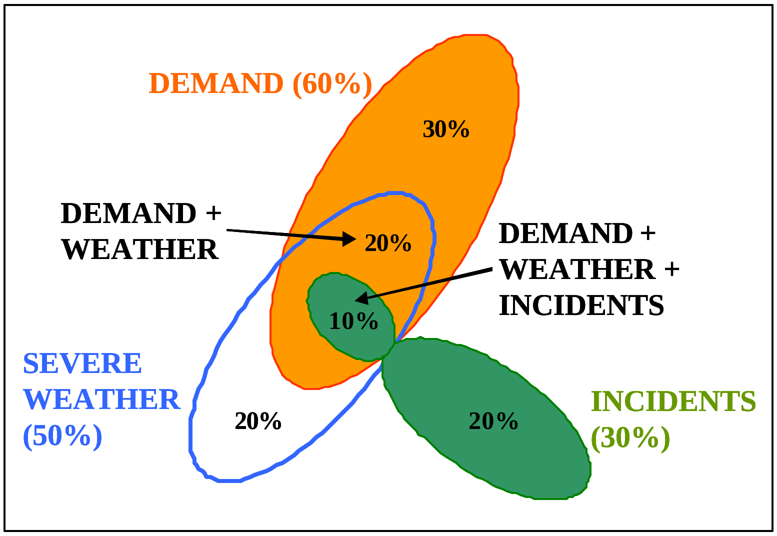

Figure 2 Contributing Factors for the 10 Worst Days in Washington, DC, with respect to Travel Time

3.1.2 Experience of a Non-ATIS User (F95) on the Worst Travel Time Days

On these ten worst days during the PM peak period, when compared to an average day of the year, a non-ATIS traveler experienced: 27.6% higher trip time than average, nearly double the average delay, triple the risk of being late than normal (*Note: Lateness risk is defined as the percentage of trips when the commuter is not on-time.*), and a reduction in just-in-time reliability by 3.6%. The average delay was computed as the increase in travel time on the worst days from the average free flow travel time. The average free flow travel time for the year was determined to be 22 min. The travel disutility cost increased by $0.70 per trip for this type of commuter. The travel expenditure increased by 17.1%, and late schedule delay by 28.6%. However, early schedule delay decreased by 4.8%. This is to be expected since as the travel time increases from the anticipated travel time, which the commuter gains knowledge of during the training period, the likelihood of the commuter arriving early diminishes, and the amount of time by which he arrives early (*namely, the early schedule delay*) decreases.

Figure 3 illustrates the impact on lateness risk experienced by a non-ATIS traveler during the PM peak period on April 6, 2001 in comparison to the normal lateness risk on a typical day. The figure shows the percentage increase in late trips for trips originating from the different shaded regions. On this day, there was a combination of incident, rain and high-demand. The incident was on I-95 near the I-95/I-395 split. The area surrounding the split is shaded red (*solid dark gray in black and white*), implying a 50-55% increase in late trips from that area. As you go farther away from the incident the effect diminishes. However, the other areas also experience an increase in the percentage of late trips due to rain and heavy demand. Overall on this day, a non-ATIS user had a lateness risk of 19.8% compared to 4.4% for the whole year.

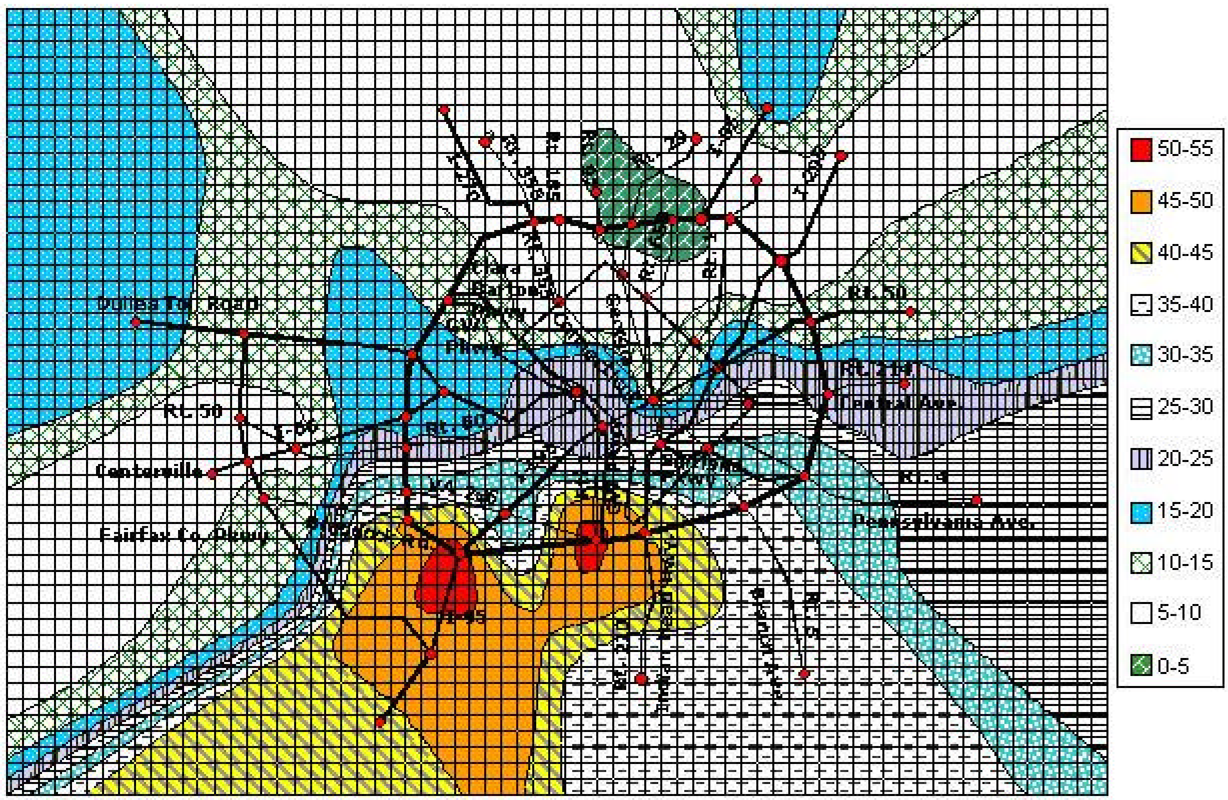

Figure 3 Percentage Increase in Lateness Risk on April 6, 2001 (Incident/High-Demand/Rain) from the Normal Lateness Risk for the Year

3.1.3 Impact of Pre-Trip ATIS on the Worst Travel Time Days

The worst day (*April 6, 2001*) was also one of the top ten days in terms of benefit from traveler information. For the evening-rush hour period for the ten worst days, users of pre-trip traveler information, when compared to their non-ATIS counterparts, experienced the following: reduction in lateness risk by half, reduction in travel disutility cost of $0.40 per trip (*decreased by 11.8%*), and an increase in just-in-time reliability by 22.7%. The early schedule delay reduced by 2.2 minutes (*15.7%*) per trip, while the late schedule delay increased by an average of 0.3 minutes (*8.3%*) per trip.

On April 6, 2001, which was the worst day, the lateness risk reduced from 19.8% to 5.8%, travel disutility cost reduced by 14.1% (*decreased by $0.50 per trip*), just-in-time reliability increased by 18.4%, early schedule delay decreased by 1.5 minutes (*decreased by 11.8%*), and late schedule delay decreased by 0.3 minutes (*decreased by 6.4%*).

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An ATIS user fared better on the ten worst days than a non-ATIS user on a typical day of the year with respect to just-in-time reliability and early schedule delay. There was an increase in just-in-time reliability by 18.3% from the average for the whole year, and a reduction of 2.9 minutes (*19.7%*) per trip from the average early schedule delay. However, with the traveler information reports, there was only a nominal reduction in travel time (*0.8%*), average delay (*1.7%*), and travel expenditure (*0.9%*). Table 3 presents the performance of a non-ATIS user (*F95*) and an ATIS user (*ASV*) on the ten worst days, and the average performance of a non-ATIS user for the whole year.

Table 3 Performance of F95 and ASV on the 10 Worst Days with respect to Travel Time

MOE	Average for the Year for F95	Performance on the Ten Worst Days	
		F95	ASV
Travel Time	31.2 min	39.8 min	39.5 min
Average Delay	9.2 min	17.8 min	17.5 min
Travel Disutility Cost per Trip	$2.7	$3.4	$3.0
On-Time Reliability (Lateness Risk)	95.6% (4.4%)	84.9% (15.1%)	93.2% (6.8%)
Just-In-Time Reliability	67.2%	64.8%	79.5%
Travel Expenditure	39.1 min	45.8 min	46.2 min
Late Schedule Delay	2.8 min	3.6 min	3.9 min
Early Schedule Delay	14.7 min	14.0 min	11.8 min

3.1.5 Key Findings for the Worst Travel Time Days

The key findings from the evaluation of the ten worst commuting days were as follows:

1. The causes for the ten worst days were a combination of incidents, severe weather and high-demand, and the worst day had a combination of all three factors. High-demand played a major role (*60%*) in making these ten days the worst with respect to travel time, followed by severe weather (*50%*) and incidents (*30%*).

2. The impacts on a non-ATIS user on the ten worst commuting days were significant. On these ten days non-ATIS users experienced an increase in travel time by a third, had double the average delay and triple the late trips than normal. Travel disutility cost increased by $0.70 per trip.

3. Impacts of ATIS were high on the 10 worst days, with the worst day having the most benefit from traveler information. Use of pre-trip traveler information service on the ten worst days reduced travel disutility cost by $0.40 per trip and lateness risk by 50% (*On the worst day it was reduced by 71%.*), and increased just-in-time reliability. The benefits to an ATIS user on the 10 worst days was higher than that for a commuter who relied only on past experience on a normal day with respect to just-in-time reliability and early schedule delay.

4. Benefits of pre-trip traveler information reports were nominal in terms of reducing travel time, average delay, and travel expenditure.

3.2 Travel Disutility Cost (Small's)

The ten worst days in Washington, DC, with the respect to travel disutility cost were found to be in the evening-rush hour period (*28 May 2001, 19 Feb 2001, 17 Oct 2000, 2 Oct 2000, 11 Sep 2000, 4 Sep 2000, 16 Feb 2001, 30 Aug 2000, 29 Jan 2001, and 16 Oct 2000*).

3.2.1 Contributing Factors for the Worst Days with respect to Disutility Cost

On these ten worst days, incidents played a major contributing role in six of the days, and weather and high demand in three each. The ten days can be broken down into: six days with incidents, one high-demand travel day, one day with rain, and two days with a combination of high-demand and rain. The greatest disutility cost was on Memorial Day (*May 28, 2001*), with an increase of $1.80 per trip from normal (*$2.70/trip*). Figure 4 shows the degree of influence of the three factors in making the ten days the worst. Thus, 10% of the days were affected only by high-demand, 10% only by severe weather, 60% only by incidents, and 20% by both high-demand and weather.

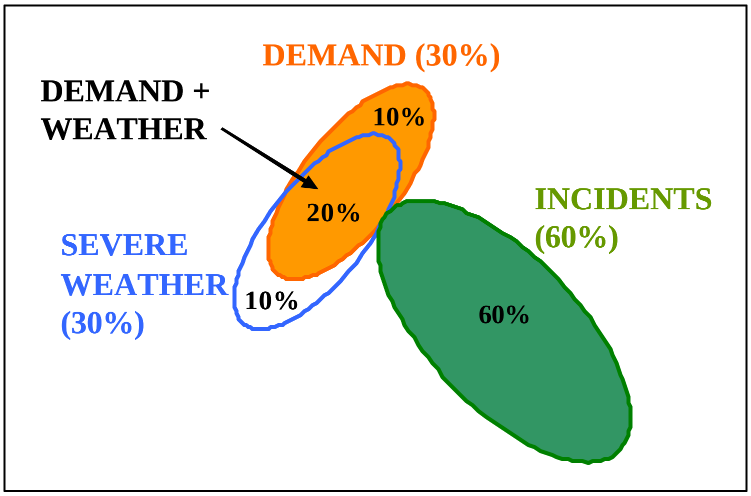

Figure 4 Contributing Factors for the 10 Worst Days in Washington, DC, with respect to Travel Disutility Cost

3.2.2 Experience of a Non-ATIS User (F95) on the Worst Days with respect to Disutility Cost

On the ten worst days during the evening rush hour period, a non-ATIS traveler, when compared to his experience on a typical day of the year, experienced: 51.9% increase in travel disutility cost (*increase of $1.40 per trip*), half the just-in-time reliability than normal, 14.3% increase in late schedule delay, 22.4% increase in early schedule delay, and 16.1% increase in travel expenditure. The increase in travel time was nominal (*2.6%*). Although travel time is a factor of disutility cost, the non-ATIS user had some of the worst disutility cost on these ten days due to an increase in the late and early schedule delays. It should also be pointed out that the non-ATIS commuter had higher travel expenditure (*a function of travel time and late schedule delay*) than normal, despite a nominal increase in travel time, due to a higher magnitude of late schedule delays than normal. Average delay, a derivative of travel time, increased by 0.8 minutes (*8.7%*).

3.2.3 Impact of Pre-Trip ATIS on the Worst Days with respect to Disutility Cost

Seven of the ten worst days were also the days with most benefit with ATIS. The worst day (*May 28, 2001*) was also the best day in terms of benefit from traveler information. On the ten worst days, use of pre-trip traveler information had the following benefits: reduction in disutility cost by $1.70 per trip (*decreased by 41.4%*), more than double the just-in-time reliability, 14.1% reduction in travel expenditure, and reduction of 6.2 minutes in early schedule delay (*34.4%*). The reduction in lateness risk (*0.1%*), late schedule delay (*0.1 minutes; 3.1%*), travel time (*0.8%*), and average delay (*2.0%*) were nominal.

As observed for the worst commuting days, use of ATIS on the 10 worst days with respect to disutility cost proved to be more beneficial for some measures of effectiveness when compared to a normal day without the use of ATIS. An ATIS user on the 10 worst days with respect to disutility cost had lower disutility cost (*saved $0.30 per trip*), higher just-in-time reliability (*increased by 21.6%*), and lower early schedule delays (*reduction of 2.9 minutes*) than a non-ATIS user on a typical day of the year. Table 4 presents the performance of a non-ATIS user (*F95*) and an ATIS user (*ASV*) on the ten worst days with respect to disutility cost, and the average performance of a non-ATIS user for the whole year.

Table 4 Performance of F95 and ASV on the 10 Worst Days with respect to Disutility Cost

MOE	Average for the Year for F95	Performance on the Ten Worst Days	
		F95	ASV
Travel Time	31.2 min	32.0 min	31.8 min
Average Delay	9.2 min	10.0 min	9.8 min
Travel Disutility Cost per Trip	$2.7	$4.1	$2.4
On-Time Reliability (Lateness Risk)	95.6% (4.4%)	96.7% (3.3%)	96.8% (3.2%)
Just-In-Time Reliability	67.2%	35.2%	81.7%
Travel Expenditure	39.1 min	45.4 min	39.0 min
Late Schedule Delay	2.8 min	3.2 min	3.1 min
Early Schedule Delay	14.7 min	18.0 min	11.8 min

3.2.4 Key Findings for the Worst Days with respect to Disutility Cost

The main findings from the evaluation of the ten worst days with respect to disutility cost were as follows:

1. Incidents played a key role (*60%*) in making these ten days the worst with respect to disutility cost. High-demand and severe weather, each played a role in 30% of the days.

2. On the ten worst days with respect to disutility cost, a non-ATIS user experienced higher early and late schedule delays, and travel expenditure, and a reduction in just-in-time reliability by half. Disutility cost increased by $1.40 per trip.

3. ATIS had high impacts on the ten worst days, with seven of the ten days having the most benefit from ATIS. The worst day was also the best with respect to disutility cost. With traveler information services, a commuter could have reduced his disutility cost by $1.70 per trip, and early schedule delay by more than a third, and increased his just-in-time reliability by more than double. With ATIS the performance with respect to disutility cost, just-in-time reliability, and early schedule delay was better than the normal for the whole year.

4. On the ten worst days ATIS had nominal effect in reducing disutility cost, travel time, average delay, lateness risk, and late schedule delay.

3.3 On-Time Reliability (OTR)

The ten worst days in Washington, DC, with the respect to on-time reliability were found to be both during the morning (*21 Sep 2000, 26 Apr 2001, 19 Oct 2000, 23 May 2001, 26 Jul 2000, 27 Feb 2001*), and evening rush-hour periods (*16 Feb 2001, 6 Apr 2001, 21 Dec 2000, and 13 Apr 2001*).

3.3.1 Contributing Factors for the Worst Days with respect to On-Time Reliability

80% of the ten worst days with respect to on-time reliability were affected by incidents, 40% by severe weather, and 30% by heavy demand. The ten days can be broken down into: one day with rain, one day with a combination of high-demand and rain, six days with incidents, and two days with a combination of high-demand, rain, and incidents. Figure 5 illustrates how the three factors affected the ten worst days. Thus, 10% of the days were affected only by severe weather, 60% only by incidents, 10% by both high-demand and weather, and 20% by demand, weather and incidents.

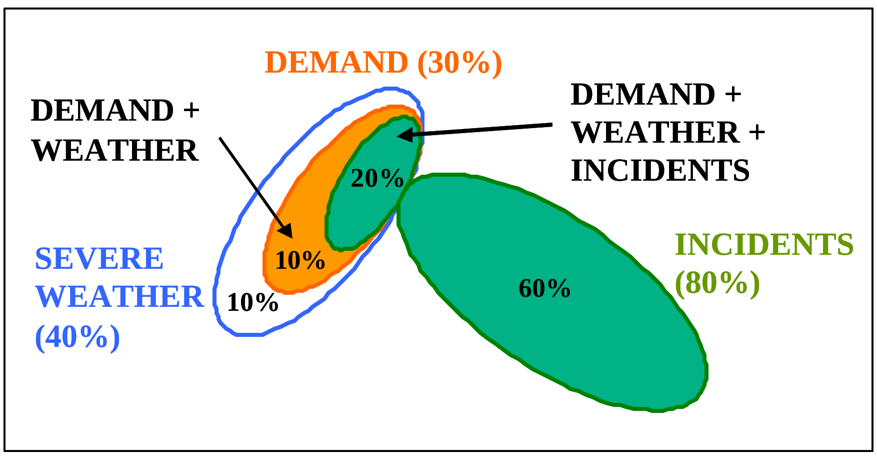

Figure 5 Contributing Factors for the 10 Worst Days in Washington, DC with respect to On-Time Reliability

3.3.2 Experience of a Non-ATIS User (F95) on the Worst Days with respect to On-Time Reliability

On the ten worst days during the rush hour period, a non-ATIS traveler, when compared to a typical day, experienced: 22.8% increase in travel time, nearly double the average delay, nearly five times the risk of being late, 29.6% increase in disutility cost (*increased by $0.80/trip*), 60.7% increase in late schedule delay, 11.5% increase in travel expenditure, and a reduction in just-in-time reliability by 5.7%. However, on these 10 worst days the early schedule delays reduced by 5.4%. This is to be expected since the ten days were days when the probability of a non-ATIS commuter arriving late at his destination was the highest. As a result, early schedule delay, a measure of how early the commuter arrives at his destination before the desired arrival time, was not high on these 10 days.

3.3.3 Impact of Pre-Trip ATIS on the Worst Days with respect to On-Time Reliability

As seen for the 10 worst commuting days, the ten worst days with respect to on-time reliability were also the days with the most benefit from ATIS. The worst day was also the day with most benefit from ATIS. If a non-ATIS user had made use of ATIS on these 10 days he would have experienced the following: more than triple the reduction in lateness risk, increase in just-in-time reliability by nearly a third, 20% reduction in disutility cost (*Value saved per trip was $0.70.*), 16.5% reduction in early schedule delay, and 8.9% reduction in late schedule delay. There were nominal reductions in travel time (*0.8%*) and average delay (*1.8%*). However, travel expenditure increased by 1 minute (*2.3%*). To minimize the lateness risk, the ATIS user left earlier than the non-ATIS user 45.6% of the time, and on those trips on an average he left 6.7 minutes earlier than the non-ATIS user (*Table 10*). Hence, despite having higher on-time reliability than the non-ATIS user, because of his early departure, and since the increases in late schedule delay and travel time for the non-ATIS user wasn't significantly higher than that for the ATIS user, the ATIS user experienced slightly higher travel expenditure.

With ATIS on the 10 worst days with respect to on-time reliability, the performance with respect to just-in-time reliability (*increased by 20.7%*), and early schedule delay (*reduced by 3.1 minutes; 21%*) was better than the normal for the whole year. This shows that the impacts of ATIS are high even on the worst days. Table 5 presents the performance of a non-ATIS user (*F95*) and an ATIS user (*ASV*) on the ten worst days, and the average performance of a non-ATIS user for the whole year.

3.3.4 Key Findings for the Worst Days with respect to On-Time Reliability

The key results from the evaluation of the ten worst days with respect to on-time reliability were as follows:

1. Incidents played a major role in 80% of the ten worst days with respect to on-time reliability, followed by severe weather (*40%*) and high-demand (*30%*).

2. The impacts on a non-ATIS user were high on the ten worst days. On these ten days a non-ATIS user experienced five times the number of late trips, double the average delay, increase in late schedule delay by more than half, and higher travel time, travel expenditure, and disutility cost. Disutility cost increased by $0.80 per trip.

3. ATIS had high impacts on the ten worst days, with these also being the days with the most benefit from ATIS. The worst day was also the best with respect to on-time reliability. Use of ATIS on the ten worst days resulted in triple the reduction in the number of late trips, increase in just-in-time reliability by nearly a third, and reduction of disutility cost, early and late schedule delays. With ATIS the performance with respect to just-in-time reliability and early schedule delay was better than the normal for the whole year.

4. With ATIS on the 10 worst days the benefits were nominal with respect to travel time, and average delay, and there was a slight increase in travel expenditure of 1 minute.

Table 5 Performance of F95 and ASV on the 10 Worst Days with respect to On-Time Reliability

MOE	Average for the Year for F95	Performance on the Ten Worst Days	
		F95	ASV
Travel Time	31.2 min	38.3 min	38.0 min
Average Delay	9.2 min	16.3 min	16.0 min
Travel Disutility Cost per Trip	$2.7	$3.5	$2.8
On-Time Reliability (Lateness Risk)	95.6% (4.4%)	79.0% (21.0%)	93.4% (6.6%)
Just-In-Time Reliability	67.2%	63.4%	81.1%
Travel Expenditure	39.1 min	43.6 min	44.6 min
Late Schedule Delay	2.8 min	4.5 min	4.1 min
Early Schedule Delay	14.7 min	13.9 min	11.6 min

3.4 Other Measures of Effectiveness

This section presents the key findings for the following performance measures: just-in-time reliability, late and early schedule delays, and travel expenditure.

3.4.1 Contributing Factors for the Worst Days (JTR, LSD, ESD, TExp)

Incident was the major contributing factor for late schedule delay (*60%*), early schedule delay (*60%*), and just-in-time reliability (*80%*), while high-demand played a major role in the ten worst days with respect to travel expenditure (*60%*). Figures 6a, 6b, 6c, and 6d show the interplay of the three factors, incident, high-demand, and weather, on the ten worst days with respect to just-in-time reliability, late and early schedule delays, and travel expenditure. Thus for just-in-time reliability (*Figure 6a*), 10% of the days were affected only by severe weather, 70% only by incidents, 10% by both high-demand and weather, and 10% by demand and incidents. For late schedule delay (*Figure 6b*), 10% of the days were affected only by high-demand, 20% only by severe weather, 60% only by incidents, and 10% by both high-demand and weather. For early schedule delay (*Figure 6c*), 10% of the days were affected only by high-demand, 20% only by severe weather, 60% only by incidents, and 10% by both high-demand and weather. For travel expenditure (*Figure 6d*), 30% of the days were affected only by high-demand, 10% only by severe weather, 30% only by incidents, 10% by both high-demand and weather, and 20% by demand, weather and incidents.

3.4.2 Experience of a Non-ATIS User (F95) on the Worst Days (JTR, LSD, ESD, TExp)

The ten worst days were found to be in the evening rush hour periods for just-in-time reliability, early schedule delays, and travel expenditure, while for late schedule delays it was found to be both during morning and evening rush hour periods. On the ten worst days with respect to just-in-time reliability and early schedule delays, a non-ATIS traveler had similar impacts to his commute. He experienced a reduction in just-in-time reliability by half, increase in disutility cost by more than half, increase in early schedule delay by more than 20%, more than 15% increase in travel expenditure, and increase in late schedule delays of more than 3%. However, on days with poor just-in-time reliability, travel time (*reduced by 0.6%*), average delay (*reduced by 2.2%*), and lateness risk (*decreased to 0.8%*) were lower than the normal for the whole year. A commuter experiences a reduction in just-in-time reliability if he reaches the destination more than 10 minutes prior to his desired arrival time. A non-ATIS user who is familiar with his route and trip start time will not be just-in-time only if the travel time on his habitual route is less than the expected travel time. This explains why on the ten worst days, a non-ATIS commuter had lower travel times and average delays than normal. Also, since the ten worst days with respect to just-in-time reliability reflect instances when the non-ATIS commuter reached his destination ahead of his desired arrival time, the probability of him being late is small. Consequently, the lateness risk is lower than normal for the year. On the ten days with the highest early schedule delays, there were small increases in travel time (*0.6%*) and average delay (*2.2%*), but lateness risk was cut by four times. A commuter experiences early schedule delays when the travel time on the habitual route is less than the expected travel time. Since these ten days had the worst early schedule delays in the year, and correspondingly lower travel times, lateness risk, a measure of whether a trip will result in a late arrival, was reduced on these ten days.

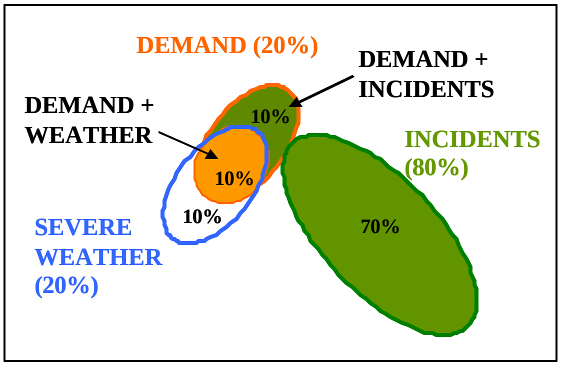

Figure 6a Contributing Factors for the 10 Worst Days with respect to JTR

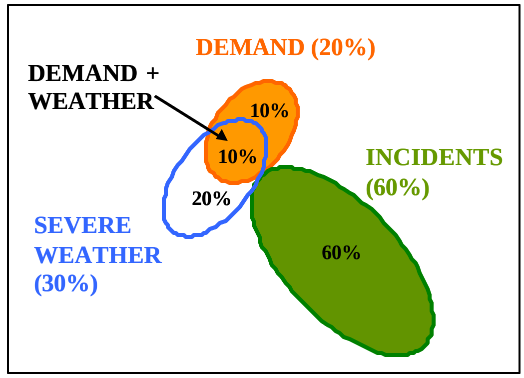

Figure 6b Contributing Factors for the 10 Worst Days with respect to LSD

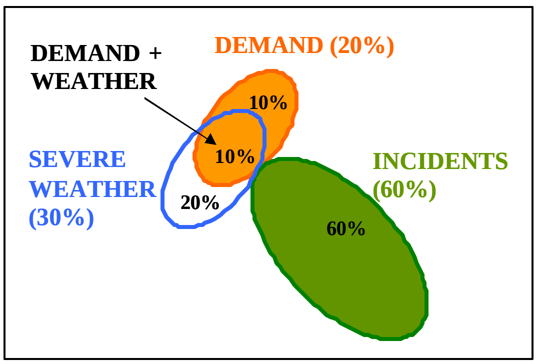

Figure 6c Contributing Factors for the 10 Worst Days with respect to ESD

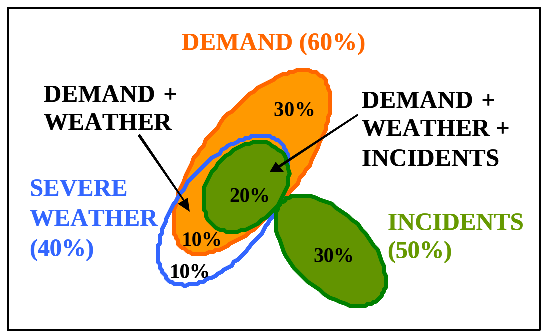

Figure 6d Contributing Factors for the 10 Worst Days with respect to TExp

High late schedule delays and travel expenditure affected a non-ATIS traveler in a similar fashion. He experienced more than double the increase in late schedule delay and lateness risk, increase in disutility cost by a third, more than 30% increase in average delay, and increases in travel time, and travel expenditure, and reduction in just-in-time reliability. The increase in early schedule delay was nominal for days with high late schedule delays, while on the worst days with respect to travel expenditure there was no change from the average for the whole year.

3.4.3 Impact of Pre-Trip ATIS on the Worst Days (JTR, LSD, ESD, TExp)

Effect of ATIS on the worst days was significant. Use of traveler information on the ten worst days had the following benefits: reduction in disutility cost by 20%, increase in just-in-time reliability by more than

37% (*double the increase for 10 worst days with respect to JTR and ESD*), decrease in early schedule delays by more than 20%, and reduction in travel expenditure. On days with the highest late schedule delays and travel expenditure, lateness risk was reduced by half. There were only nominal reductions in travel time and average delays.

An ATIS user on the 10 worst days had higher just-in-time reliability (*increased by up to 20%*), and lower early schedule delays (*reduced by 20%*) than a non-ATIS user on a typical day of the year. On days with poor just-in-time reliability and high early schedule delays, disutility cost was lower than the normal for the whole year by 14%. Tables 6-9 present the performance of a non-ATIS user (*F95*) and an ATIS user (*ASV*) on the ten worst days with respect to just-in-time reliability, late and early schedule delays, and travel expenditure, and the average performance of a non-ATIS user for the whole year.

Table 6 Performance of F95 and ASV on the 10 Worst Days with respect to Just-in-Time Reliability

MOE	Average for the Year for F95	Performance on the Ten Worst Days	
		F95	ASV
Travel Time	31.2 min	31.0 min	30.9 min
Average Delay	9.2 min	9.0 min	8.9 min
Travel Disutility Cost per Trip	$2.7	$4.1	$2.3
On-Time Reliability (Lateness Risk)	95.6% (4.4%)	99.2% (0.8%)	97.1% (2.9%)
Just-In-Time Reliability	67.2%	32.5%	83.0%
Travel Expenditure	39.1 min	45.3 min	38.2 min
Late Schedule Delay	2.8 min	2.9 min	3.2 min
Early Schedule Delay	14.7 min	18.2 min	11.6 min

Table 7 Performance of F95 and ASV on the 10 Worst Days with respect to Late Schedule Delay

MOE	Average for the Year for F95	Performance on the Ten Worst Days	
		F95	ASV
Travel Time	31.2 min	34.7 min	34.5 min
Travel Disutility Cost per Trip	$2.7	$3.4	$2.6
On-Time Reliability (Lateness Risk)	95.6% (4.4%)	90.4% (9.6%)	95.4% (4.6%)
Just-In-Time Reliability	67.2%	57.2%	81.4%
Travel Expenditure	39.1 min	43.2 min	41.5 min
Late Schedule Delay	2.8 min	6.2 min	3.8 min
Early Schedule Delay	14.7 min	14.9 min	11.7 min

Table 8 Performance of F95 and ASV on the 10 Worst Days with respect to Early Schedule Delay

MOE	Average for the Year for F95	Performance on the Ten Worst Days	
		F95	ASV
Travel Time	31.2 min	31.4 min	31.1 min
Travel Disutility Cost per Trip	$2.7	$4.1	$2.3
On-Time Reliability (Lateness Risk)	95.6% (4.4%)	98.9% (1.1%)	97.3% (2.7%)
Just-In-Time Reliability	67.2%	35.4%	82.9%
Travel Expenditure	39.1 min	45.3 min	38.3 min
Late Schedule Delay	2.8 min	3.0 min	3.1 min
Early Schedule Delay	14.7 min	18.4 min	11.7 min

Table 9 Performance of F95 and ASV on the 10 Worst Days with respect to Travel Expenditure

MOE	Average for the Year for F95	Performance on the Ten Worst Days	
		F95	ASV
Travel Time	31.2 min	39.0 min	38.7 min
Travel Disutility Cost per Trip	$2.7	$3.5	$2.9
On-Time Reliability (Lateness Risk)	95.6% (4.4%)	84.3% (15.7%)	92.9% (7.1%)
Just-In-Time Reliability	67.2%	58.1%	79.8%
Travel Expenditure	39.1 min	45.9 min	45.3 min
Late Schedule Delay	2.8 min	4.2 min	4.4 min
Early Schedule Delay	14.7 min	14.7 min	11.7 min

3.4.4 Key Findings for the Worst Days (JTR, LSD, ESD, TExp)

The key findings from the evaluation of the ten worst days with respect to just-in-time reliability, late and early schedule delays, and travel expenditure were as follows:

1. Incidents played a key role with respect to just-in-time reliability, late and early schedule delays. High-demand was the main contributing factor with respect to high travel expenditure.

2. On the ten worst days, a non-ATIS user experienced a reduction in just-in-time reliability by more than 12% (*It was cut by half on days with poor just-in-time reliability and high early schedule delays*.), increase in disutility cost by more than a third, and increases in late and early schedule delays. There was double the increase in late trips on days with high late schedule delays and triple the increase on days with high travel expenditure.

3. The benefits from ATIS on the ten worst days were significant. With use of ATIS there was a reduction in disutility cost by up to 20%, and an increase in just-in-time reliability by more than a third (*double the increase for 10 worst days with respect to JTR and ESD)*. On days with high late schedule delays and travel expenditure, lateness risk was reduced by half. With ATIS the

performance with respect to just-in-time reliability and early schedule delay was better than the normal for the whole year.

4. Pre-trip traveler information service resulted in nominal reductions in travel time, and average delay.

4. BEHAVIOR OF AN ATIS COMMUTER ON THE WORST DAYS

In the preceding sections, we saw how use of pre-trip ATIS greatly improved the performance of a commuter. An ATIS user was able to achieve this by changing his habitual behavior, either by changing his route and/or his time of departure. Table 10 displays the behavior of the ATIS user on the ten worst days with respect to each of the seven MOEs. On the ten worst days with respect to travel time, an ATIS user did not deviate from the habitual path on 32.1% of the trips, on 3.7% of the trips he took an alternate route from his habitual behavior without changing his trip start time, on 57.2% of the trips he changed his departure times without changing his route, and on 7.0% of the trips he changed both the route as well as the trip start time. On the ten days with the worst disutility cost, an ATIS user changed his trip start time on 75.5% of the trips. Of these trips he left late 83.8% of the time to minimize his early schedule delay (*Please note that on these ten days the early schedule delay was 18 minutes*.). Similar behavior was observed on the ten days with the worst just-in-time reliability and early schedule delay, as the objective on those days was to minimize the probability of early arrivals. To minimize early arrivals, on the ten days with poor just-in-time reliability a commuter left late on 68.7% of the trips, while on days with high early schedule delays he left late on 67% of the trips. On days with reduced on-time reliability, the ATIS user minimized his late arrival by changing his departure time on 65.2% of the trips, and of these trips he left early 69.9% of the time (*Conversely, he left early on a total of 45.6% of the trips*.). On an average he left early by 6.7 minutes when departing early.

On the worst days with respect to all seven performance measures, the ATIS user changed his route and/or his time of departure on nearly 70% of the trips, while on a normal day of the year, traveler information services recommended a change in the habitual behavior on 60% (*2*) of the trips. During the rush hour period on a typical day, an ATIS user left 5.3 minutes early when departing earlier than his habitual departure time. On the ten worst days, the traveler information service recommended a similar early departure of more than 5 to 7 minutes ahead of the normal departure time. During the rush hour period when departing late, an ATIS user left 7.5 minutes later than his habitual departure time on a normal day in comparison to 6 to 10 minutes on the 10 worst days with respect to the seven MOEs. On the worst days, ATIS users changed their trip departure times more often than their routes to arrive at their destination just-in-time.

Table 10 Behavior of an ATIS User on the Worst Days

Travel Choice Category	MOE Examined						
	TT	Small's	OTR	JTR	LSD	ESD	TExp
Percentage of Trips with No Changes	32.1%	23.2%	31.7%	22.9%	35.5%	23.3%	30.4%
Percentage of Trips with Only Route Changes	3.7%	1.3%	3.1%	0.7%	2.0%	0.8%	3.6%
Percentage of Trips with Only Departure Time Changes:	57.2%	66.0%	58.9%	67.4%	55.9%	66.3%	58.0%
% with Early Departures	62.5%	17.4%	71.3%	11.3%	55.2%	13.0%	52.7%
% with Late Departures	37.5%	82.6%	28.7%	88.7%	44.8%	87.0%	47.3%
Avg. Minutes Left Early (when departing early)	6.2	5.5	6.7	5.3	7.5	5.3	6.4
Avg. Minutes Left Late (when departing late)	6.8	10.3	6.6	10.5	6.2	10.6	7.4
Percentage of Trips with Both Route and Departure Time Changes:	7.0%	9.5%	6.3%	9.0%	6.6%	9.6%	8.0%
% with Early Departures	38.8%	8.0%	56.5%	2.0%	67.7%	1.8%	40.0%
% with Late Departures	61.2%	92.0%	43.5%	98.0%	32.3%	98.2%	60.0%
Avg. Minutes Left Early (when departing early)	6.2	6.0	7.1	5.5	7.5	6.1	6.5
Avg. Minutes Left Late (when departing late)	6.9	10.9	6.3	11.4	7.5	11.2	7.2
Percentage of All Trips with Route Changes	10.7%	10.8%	9.4%	9.7%	8.6%	10.4%	11.6%
Percentage of All Trips with Departure Time Changes:	64.2%	75.5%	65.2%	76.5%	62.5%	75.8%	66.0%
% with Early Departures	59.9%	16.2%	69.9%	10.2%	56.5%	11.6%	51.2%
% with Late Departures	40.1%	83.8%	30.1%	89.8%	43.5%	88.4%	48.8%
Avg. Minutes Left Early (when departing early)	6.2	5.6	6.7	5.3	7.5	5.3	6.4
Avg. Minutes Left Late (when departing late)	6.8	10.4	6.5	10.6	6.3	10.7	7.3

5. CONCLUSIONS AND FUTURE WORK

In this study the benefits of pre-trip traveler information services were examined for the Washington, DC network on some of the worst travel days using the HOWLATE methodology. The worst days were determined for seven HOWLATE performance measures. The report discussed the effect on a commuter who depends on prior experience on the worst days with respect to each MOE, and how he could have benefited through the use of traveler information services. The key findings of the analyses are presented in Section 5.1, followed by future work in Section 5.2.

5.1 Key Findings

This section presents the key findings of this study:

1. *The worst days vary by the measure of effectiveness chosen to rank them.*
   - Three out of the ten worst commuting days were also the worst days with respect to on-time reliability, while five of the worst commuting days were among the worst days with respect to travel expenditure.
   - Four of the ten worst days with respect to on-time reliability were also the worst days with respect to travel expenditure.
   - A commuter faced some of the worst disutility cost, early schedule delay and just-in-time reliability on the same day. Of the worst days with respect to disutility cost, eight were also the worst days with respect to just-in-time reliability, while seven were among the ten worst days with respect to early schedule delay. On six of the ten days, a non-ATIS commuter had the worst disutility cost, early schedule delay and just-in-time reliability, and on one of these six days, the commuter also had some of the worst late schedule delay.
   - A commuter faced high late schedule delay and on-time reliability on two days.
   - On one of the days, February 16, 2001, which had a combination of high-demand and rain, a commuter had the worst travel time, on-time reliability, disutility cost, late schedule delay, and travel expenditure.
2. *Contributing factors vary by the measure of effectiveness chosen.*
   - Incidents played a major role in increased disutility cost (*60%*) and late schedule delays (*60%*), and poor on-time reliability (*80%*) and just-in-time reliability (*80%*).
   - High-demand was the main contributing factor for high travel time (*60%*) and travel expenditure (*60%*).

3. *Impacts on the worst days are significant for a commuter who relies solely on past experience.*

- Late trips double or triple, as was seen for travel time, travel expenditure or late schedule delay. On the worst days with respect to on-time reliability it increased 5 times.
- Disutility cost typically jumps by 30%. On the worst days with respect to disutility cost, early schedule delay or just-in-time reliability it increased by more than half.
- Average delay doubles, as observed for the worst days with respect to travel time, on-time reliability, or travel expenditure.
- Late schedule delay increases. On the worst days with respect to late schedule delay or travel expenditure it doubled, and on poor on-time reliability days it increased by 60.7%.

4. *Benefits of pre-trip traveler information services are higher than average on the worst days.*

- Lateness risk is cut by more than half, as seen for the worst days with respect to travel time, late schedule delay, or travel expenditure. On days with poor on-time reliability there was triple the reduction in the number of late trips with pre-trip ATIS.
- Disutility cost is reduced with use of traveler information services. On the ten worst days with respect to disutility cost, early schedule delay, or just-in-time reliability a commuter who made use of pre-trip traveler information service had 40% lower disutility cost than a commuter did not avail of ATIS. On days with poor on-time reliability or high late schedule delays, the reduction was more than 20%.
- With ATIS, the increases in just-in-time reliability are high. On the worst days with respect to disutility cost, just-in-time reliability, or early schedule delay it increased by more than double, while on the worst days with respect to travel time, on-time reliability, late schedule delay, or travel expenditure it increased by 20 to 40%.
- Early schedule delay is reduced by more than 15%. On days with the worst early schedule delay, the reductions are as high as 40.2%.
- The ten worst days with respect to on-time reliability were also the top ten days with most benefit from ATIS. For some measures (*travel time, on-time reliability, and early schedule delay*), the worst day was also the day with most benefit from pre-trip ATIS.
- On the ten worst days with respect to all seven measures, a commuter who made use of traveler information service fared better than a commuter on a typical day of the year, who relied only on past experience, with respect to just-in-time reliability and early schedule delay (*reductions of nearly 20% for both MOEs*).

5. *On the worst days, ATIS users changed routes or trip start time or both on more than 2/3rd of the trips to arrive at their destination just-in-time.*

    - ATIS users changed their time of departure 6-7 times more frequently than routes.
    - When departing earlier than the habitual departure time, a commuter who made use of ATIS left more than 5 to 7 minutes early, and when departing later than the habitual departure time, they left late by 6 to 10 minutes.

6. *Pre-trip traveler information service resulted in nominal reductions in travel time and average delay.*

5.2 Future Work

The analyses of the worst days showed that the effect on a commuter who does not use ATIS is high. However, use of pre-trip traveler information service can help mitigate the adverse effect on trip predictability, disutility cost, lateness risk, and late and early schedule delays. The results presented were for the entire Washington, DC network. An extension to the study will be to examine the effect of traveler information services on some of the worst days on some specific corridors that are already congested, such as I-66.

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