Estimating Aggregate Regional User On-Time Reliability Benefit from Pre-Trip ATIS:

Seattle Case Study

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ABSTRACT

This study explores the on-time reliability benefits to potential users of a personalized ATIS providing real-time pre-trip roadway information for the Seattle AM peak period through the application of Heuristic On-line Web-linked Arrival Time Estimation (HOWLATE) methodology. Previous research using this technique based findings on the assumption of equal weighting of all trips within a regional network. This study weights results by regional demand patterns to generate more accurate estimates of regional user benefits. This study also estimates annual regional user benefits to ATIS users for low levels of market penetration (0% - 3%). Market penetration percentages are based on the population of travelers using roads where ATIS is available rather than the population of the region.

Based on a 6-month case study of Seattle AM peak period, regional benefit to routine users of the ATIS in the AM Peak ranges from negligible to substantial ($2.5 million annually) depending on the market penetration profile and ATIS accuracy level. Regional ATIS users' reduction in trip disutility is overestimated by 22% when regional demand is not considered because of an overrepresentation of very long trips that are likely to have high benefit from ATIS use. Findings from this case study also suggest that at high levels of reporting error, in the order of 15% to 20%, there will exist pocket populations of ATIS users that will derive significant benefits from ATIS.

KEYWORDS: Intelligent Transportation Systems, benefits, modeling, simulation, HOWLATE, Advanced Traveler Information Systems, regional demand

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1 INTRODUCTION

In 1999, at the request of the Intelligent Transportation Systems (ITS) Joint Program Office of the United States Department of Transportation (USDOT), researchers at Mitretek Systems developed a new technique for the evaluation of user impacts of Advanced Traveler Information Systems (ATIS) services based on the analysis of archived roadway travel time data, the Heuristic On-line Web-linked Arrival Time Estimation (HOWLATE) methodology. This methodology of simulated paired driver trials was documented and demonstrated using a small-scale test case (Wunderlich et al, 2001).

Mitretek then applied HOWLATE in a large scale evaluation of a prospective pre-trip notification-based ATIS in two cities over a 15-month period. The evaluation focused on the potential of ATIS to reduce trip variability and travel time in the metropolitan regions of Washington, DC, and St. Paul/Minneapolis, MN. Mitretek also demonstrated how user savings in on-time reliability and in-vehicle travel time can be translated into monetary savings (Jung et al, 2002). Two key finding from these two studies are that ATIS does benefit travelers who need to be on–time, overwhelmingly from improvements in trip reliability and minimally from improvements in in-vehicle travel time; and that benefits are highly concentrated both by time of day, by geography of trips, and by length of trips.

Thus far, reported regional estimates of ATIS user impacts have been based on an aggregation of individual trip benefit occurring at a rate of one trip from each origin to each destination. Of course, certain origin-destination (OD) trips are made by many more individuals than other OD trips. Moreover individuals making trips that derive benefit from routine ATIS use are likely to continue to use the service whereas individual making trips that do not derive benefit from routine ATIS use are likely not to continue service use. This report takes into consideration these two factors and weights HOWLATE benefits by the number of trips made by OD to derive a more accurate estimate of potential regional ATIS user impact in terms of trip reliability.

The analysis is performed for the AM peak period in the Seattle, Washington region. It is based on six months of travel time archives and on a demand planning model to derive estimates of ATIS regional benefits. The Seattle area has been selected as the region for which to conduct these analyses because of two important factors: the availability of real-time travel time archives, and the access by authors to the Seattle regional planning model with AM peak demand.

In the following Section, 1.1, we present the specific hypotheses to be addressed by this study. The subsequent two sections present the process for estimating ATIS user benefits (Section 2) and the process for estimating regional demand (Section 3). Section 4 presents the Seattle regional freeway network and describes the mapping from the freeway network where ATIS is available to the HOWLATE and the regional demand networks. Also presented in Section 4 are the characteristics of the travel time data and their implications on which trips are likely to benefit from ATIS. Section 5 describes the regional demand and identifies which OD pairs constitute the majority of trips made in the region. Section 6 details the outcomes of the experiments. Section 7 summarizes findings with regard to study hypotheses and places findings in the greater context of general ATIS benefits.

1.1 Study Hypotheses

A key goal of this study is to identify the differences in analysis outcomes between the traditional aggregation of HOWLATE results and the results weighed by the number of trips made through distinct locations in the region (called regional demand). We hypothesize that the traditional aggregation of ATIS user benefit as measured by trip disutility will be higher than results weighted by regional demand for the AM peak because of an overrepresentation of very long trips that are likely to have high benefit from ATIS use.

Another issue addressed by this study is whether significant ATIS user benefits can be derived from ATIS systems with relatively high ATIS reporting error (beyond 15%). We hypothesize that at higher levels of reporting error, there still will exist pocket populations of ATIS users that will derive significant benefits from ATIS. Moreover, these populations are likely the first adopters of ATIS. Consequently, although ATIS may prove little or no benefit at high levels of error in ATIS travel time reports under the assumption of uniform market penetration, targeted markets of ATIS users may still derive substantial aggregate annual benefit.

A third hypothesis of this study is that for commuters who routinely budget less time for their trips, ATIS may prove equally if not more useful at ensuring more frequent on-time arrivals compared to commuters who allocate greater time for the same trip. For this study, the time a commuter allocates for a trip is divided into two components: the average or normal time for commute plus additional time to account for variability in commute time. This additional time is called the travel time buffer.

The hypothesis that commuters with lower travel time buffers derive more frequent ATIS on-time arrival benefits is suggested because in circumstances of low travel time buffers, ATIS may frequently have opportunities to eliminate late arrivals. This hypothesis is examined in HOWLATE terminology by comparing ATIS user benefits among commuters with varied travel time buffers represented by differing on-time arrival thresholds. Commuters with lower on-time arrival thresholds will have lower travel time buffers and subsequently may have the opportunity for greater benefit from ATIS use.

2 ESTIMATING ATIS USER BENEFIT USING THE HOWLATE METHODOLOGY

The HOWLATE methodology brings together the necessary data for the implementation and analysis of large-scale simulated yoked studies. The simulated yoked study is an experiment wherein the trips of two drivers having the same origin, destination, desired arrival time and normal route, are repeated in simulation across many days. The simulations are based on traversals of network wherein an archive is available of travel times by link at 5-minute time interval along with an estimate of the accuracy of this archive. The archive is generated from internet-based ATIS services. The commute of one driver remains fixed while the commute of the counterpart driver varies based on information he receives from an ATIS. The objective of both of these commuters is to arrive at their destination on-time with a certain level of frequency.

HOWLATE first identifies the normal route and departure time for each set of paired drivers based on the route with the least average travel time across many days termed 'training days,' a threshold level for frequency of late arrivals, and the accuracy of the ATIS. For this experiment, the paired commuters aim for an on time arrival rate of 95% and the accuracy of the ATIS archive is assumed to be 10%. That is, ATIS travel time reports are on average accurate, but the coefficient of variance of ATIS travel time reports with respect to true travel time is 0.10.

The ATIS non-user consistently departs at the normal departure time and route while the ATIS user may vary his departure or route pre-trip based on a set of decision rules and the content of the ATIS information. In this study the ATIS user's search for information is set to start 30 minutes prior to normal trip start and the ATIS user can defer trip start as late as 30 minutes after normal trip start. ATIS user's pre-trip decision to deviate from the habitual route in HOWLATE is based on whether the alternate route saves a minimum of 3 minutes of travel. The ATIS user defers departure until the ATIS notifies him of a travel time that would result in his arrival within a few minutes of the desired arrival time.

HOWLATE then simulates commute trips of a set of paired drivers from each origin to each destination with scheduled arrival times at 15-minute intervals within the regional network for each day where complete travel time archives are available. Note that no traffic simulation software was utilized in this analysis. Instead, commutes by route and time of day are assembled from the archive of travel times. Trip departure decisions of the ATIS user are then output along with trip outcomes of the ATIS user and non-user paired counterparts. These outcomes are then aggregated across the set of simulated commute trips to generate regional averages of the effect of ATIS use. To verify that differences between ATIS user and non-users' departure decisions and trip outcomes are statistically significant, five random trials are conducted.

Additional experiments are conducted to examine the sensitivity of ATIS user benefits to ATIS reporting error as well as to different thresholds for on-time arrival frequency. Thus, for the scenario with a 95% on-time arrival commute objective, simulations are conducted at ATIS reporting error levels of 5%, 15%, and 20% in addition to the base level of 10% reporting error. Likewise, at the 10% ATIS reporting error level, simulations are conducted for on-time arrival frequencies of 90%, 80%, and 70%.

To quantify the differences in the aggregate trip choices of ATIS users we calculate the percentage of trips where ATIS users made departure time changes or route changes prior to trip start. To quantify the differences in the aggregate outcomes of ATIS users compared to their counterparts that maintain a set departure time and route we calculate average travel time, frequency of trip arrival outcome, and trip disutility. Travel time includes only the in-vehicle portion of the trip and not the information search time. Trip arrival outcomes are categorized as early, on-time, or late. Early is defined as 10 or more minutes earlier than the scheduled arrival time, while late is defined as arriving any time after the scheduled arrival time. Trip disutility is a monetary reflection of travel time calculated by assigning a cost to the duration of travel time and deviation from the scheduled arrival time. This metric is based on the work of Small et al. (1999), and is further detailed in Shah et al. (2003). A comparison of trip disutility between the paired ATIS user and non-user is used to determine whether the ATIS user benefited from the information provided by ATIS. The time cost of information acquisition is assumed to be minimal and therefore is not incorporated into the calculation of trip disutility.

The outcomes of simulated commute trips are aggregated to generate regional averages of the effect of ATIS use. To date, the aggregation process has not weighted results by the number of trips made from each origin to each destination given the complexity of identifying the regional demand that routinely uses the network of roads wherein the traveler information is available. In this study, we undertake the task of deriving regional demand and applying it in the aggregation process for assessing ATIS impact. The following section presents this process of deriving regional demand.

3 PROCESS FOR GENERATING REGIONAL TRAVEL DEMAND

In reality the number of trips made within a region from any place to any other place, termed regional demand, varies by time of day, day of week, season, and entails an evolution over time as demographics, employment and land use vary. Traditional transportation planning models approximate the regional demand and allocation among regional road infrastructure through a four-step process. In this process the region is subdivided into zones and first an estimate of the number of trips generated from each zone is calculated, followed by an estimate of which zones trips go to. These calculations are based on the socio-economic and land use characteristics within the zone. The third step is identifying the modes used in making these trips. The final step, traffic assignment, entails identifying the roads most likely used in making trips.

In a previous study (Bunch et. al. 1999), the authors applied the EMME/2 regional transportation planning model to derive an estimate of the number of trips made during the AM peak period within a 7-county region encompassing the Seattle area for the year 1997 based on the Seattle 1990 transportation demand. For this study, the trip assignment step is repeated in the EMME/2 model to derive the number of vehicle-trips made within the region that use the set of freeways identified as having ATIS coverage. We record the number of vehicle-trips made that enter from a point within the network of freeways as well as where these trips exit the same network. These trips are then aggregated and assigned to various discrete nodes within the HOWLATE network representation of the freeway network.

There are some shortcomings to this method of estimating the regional travel demand, yet we believe despite these issues, the analysis is a relatively robust representation of actual regional flow. The primary shortcoming of this model is that regional demand is based on year 1997 whereas travel times are based in years 2002 and 2003. Over the 5-year gap some of the region has undergone notable change that has likely altered the regional demand represented in the EMME/2 model employed in our analysis. Also, in conducting the trip records we do not capture the true start and end of a trip, but rather the location of where the trip entered the network of ATIS freeways and the location of where the trip exited the network of ATIS freeways. Thus the acquisition of ATIS information may be viewed in some cases as en-route rather than pre-trip as is stipulated in the HOWLATE process. The trend, of course, is toward more en-route information; thus, this issue will become less relevant in the future. In any case, what is derived is clearly more representative of actual demand than the unitary trip approach of previous HOWLATE research.

4 SEATTLE REGION TRAVEL TIME DATA

Seattle is a city of over 560,000 residents and is the largest urban center in the Puget Sound region. The city and surrounding areas serve a population of over 3.3 million. Of the employable age population (16+), approximately 75% work and earn a median individual income of $29,000. The working population overwhelmingly (95.8%) commutes to work rather than working from home. Of those commuting to work, approximately half commute to work between the hours of 6:30 am and 9:00 am. The return trip from work is far less concentrated, occurring throughout the afternoon and evening hours (www.psrc.org/datapubs/census2000/profiles/index.htm, 2003).

We concentrate on trips made where real-time travel time information is currently available via the Internet, in the counties of King and Snohomish with a population of approximately 2.26 million (http://www.psrc.org/datapubs/pubs/pophsg99.htm). These roads are highlighted in black on the left map in Figure 1. Travelers can access travel time information for various trips made on these roads through the Washington State Department of Transportation website (www.wsdot.wa.gov). The travel time information is displayed on the website as a trip from a particular location to another location, and encompasses multiple roads in many cases.

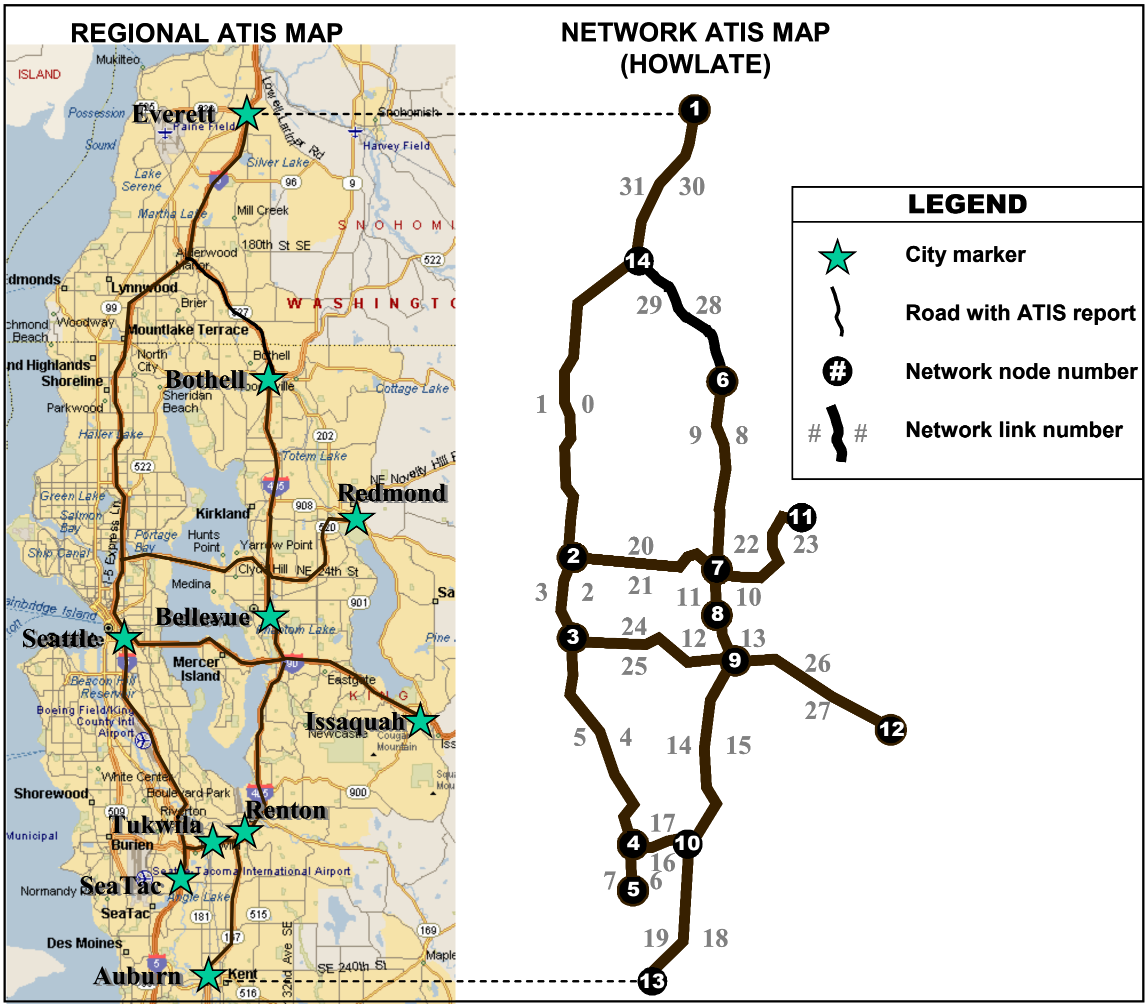

Figure 1. Regional Travel Time ATIS Map and Conversion to HOWLATE Network

A total of 10 locations are referenced in the trip profiles: Bellevue, Everett, Seattle, SeaTac Airport, Bothell, Tukwila, Auburn, Renton, Issaquah, and Redmond. Based on these 10 locations, real-time travel time information in minutes of travel are presented for a total of 12 trips (24 if accounting for directionality of trip) made using some portions of I-5, I-405, I-90, SR 527, or SR 520. The start and end points of the 12 trips are presented in Table 1 along with an estimate of trip length. These locations are presented in Figure 1 by stars. The longest trip is 23.7

miles from Everett to Seattle, while the shortest trip reported by the ATIS is 7.0 miles from Redmond to Bellevue. Potential ATIS users in this region are those who routinely travel on these roads.

Trip Commute	Route description	Trip Length (miles)
Everette to Bellevue	SR 526 in Everett at exit 189 on I-5 and the NE 8th St. exit on I-405	23.4
Everette to Seattle	SR 526 in Everett at exit 189 and the University St. exit on I-5 in downtown Seattle	23.7
SeaTac to Seattle	S. 188th St. on I-5 in SeaTac and the University St. exit on I-5 in downtown Seattle	13.0
Bothelle to Bellevue	SR522 Interchange in Bothell and the NE 8th St. exit on I-405 in downtown Bellevue	9.7
Tukwila to Bellevue	the I-5 Interchange in Tukwila and the NE 8th St. exit on I-405 in downtown Bellevue	13.5
Auburn to Renton	15th st NW in Auburn to the I-405 Interchange in Renton	9.8
Issaquah to Seattle	Issaquah's Front St. exit on I-90 and the University St. exit on I-5 in downtown Seattle	15.6
Redmond to Seattle	the Redmond Way exit on SR 520 in Redmond and the University St. exit on I-5 in downtown Seattle	14.8
Bellevue to Seattle via I-90	NE 8th St. on I-405 and the University St. exit on I-5 in downtown Seattle	10.8
Bellevue to Seattlevia SR 520	NE 8th St. on I-405 and the University St. exit on I-5 in downtown Seattle	10.3
Redmond to Bellevue	Redmond Way exit on SR 520 and the NE 8th St. exit on I-405 in downtown Bellevue	7.0
Issaquah to Bellevue	Front St. exit on SR 520 and NE 8th St. on I-405 in downtown Bellevue	9.4

Table 1. Trips where Travel Time is Reported by the Seattle ATIS

The set of 24 directed trips are converted to a set of 32 links that are connected by a set of 14 nodes in the HOWLATE network. The nodes are represented on the right side inside Figure 1 by circles. These nodes represent origin and destination points within the HOWLATE network for which ATIS user benefit is estimated. These nodes also generally align with the 10 locations for which the ATIS presents trip information.

In the following section we describe the process by which this trip-based ATIS information is archived and transformed to link-based ATIS information for use in the HOWLATE process. We then present link-based statistics related to the travel time observations used to examine ATIS user benefit.

4.1 ATIS Data Archiving

The archiving of travel time data in the Seattle region was started in June 2002 by Mitretek Systems, and is ongoing as of August 2003. The process entails automated recording of travel time across the 24 directed trips posted on the Internet and archiving this information into a database. This task is conducted for the Seattle region along with many other regions for research purposes. For Seattle, the data is recorded starting each weekday at 5:30 AM and ending that same day at 9:30 PM.

At times, due to errors either in data reporting or the software developed for the archiving process, the data archiving may have proven unsuccessful for a few or many trips, for a few minutes or many hours. This experiment is conducted using relatively complete travel time archives of 145 days between June 2002 and March 2003 where data archives have no missing data for any trip over a 10-minute period. Of these 145 days, 33 are used to calculate the normal commute characteristics, while the remaining 111 days are used to calculate the effect of ATIS use. Only travel times between 5:30 AM – 10:30 AM, are employed when conducting this experiment. This period allows for a 1-hour buffer around the 6:30 am – 9:30 am peak period wherein trips may begin or complete late a trip scheduled to arrive within the AM peak.

In dissecting the trip specific travel times, the set of 24 overlapping trips are converted to a set of 32 directed links totaling 231.8 directed miles. These 32 links are presented on the right in Figure 1 and listed numerically in Table 2. The travel time on these directed links are calculated by apportioning the trip time to particular links comprising the trip based on link length. The shortest trip is used exclusively to apportion time on a link when two or more trips reported by the website overlap in route and report travel time including that particular link. The average length of the 32 directed links is 6.5 miles and the standard deviation in length is 3.3 miles. The longest link in this network is 14.4 miles in length, while the shortest link is 1.1 miles in length. The following section describes the archive of travel time data at the link-level.

4.2 Link Travel Time Data

The normal commute patterns are set based on travel times during the training period. If travel times significantly and consistently differ in the evaluation period compared to the training period, the habitual commute plans would prove consistently less effective than trip schedules based on ATIS. In reality, if travel times did significantly and consistently differ, the commuter would likely recalibrate his trip. The benefit from ATIS therefore lies in mitigating the day-to-day variability in travel time and not necessarily a consistent increase or decrease in travel times. This section first explores any differences in the travel time between the training and evaluation periods, followed by an exploration of differences in the variation of travel time between the training and evaluation periods.

Table 2 presents the average travel time by link for the 33 days that constitute the training period as well as for the 111 days used in the ATIS for the Seattle ATIS network. The average travel time across the links is 8.1 minutes for the training period versus 8.5 minutes during the evaluation period, roughly a 5% increase in travel time. Of the 32 links, 22 have a higher average travel time for the evaluation period compared to the training period while for the other 10 links the average travel time during the training period is higher than the evaluation period. The average travel time increase is less than 0.75 minute, among those links where travel time on average increases from the training to the evaluation period. The average travel time decrease is less than 0.25 minutes among those links where travel time on average decreases from the training to the evaluation period.

The minutes increase or decrease in travel time from the training period to the evaluation period is illustrated via a color-coded network of the region in Figure 2 (left map). The greatest minutes increase in travel time from the training to the evaluation period occurs on link 8, I-405 going from Bothell to Rt. 520. This is an increase of 2.6 minutes from the training period average travel time of 12.2 minutes. The greatest minutes decrease in travel time from the training to the evaluation period occurs on link 4, I-5 going from I-405 to Downtown Seattle. This is a decrease of only 0.4 minutes from a training average travel time of 16.2 minutes.

Table 2 also presents the standard deviation in travel time by link for the 33 days that constitute the training period as well as for the 111 days used in the ATIS for the Seattle ATIS network. The average standard deviation in travel time across the links is 1.3 minutes for both the training and evaluation period. Of the 32 links, 16 have a higher average travel time standard deviation for the evaluation period compared to the training period while for the other 16 links the average travel time standard deviation during the training period is higher than the evaluation period. The average increase in travel time standard deviation is less than 0.4 minute, among those links where travel time standard deviation increases from the training to the evaluation period. The average travel time standard deviation decrease is also less than 0.4 minutes, among those links where travel time standard deviation decreases from the training to the evaluation period.

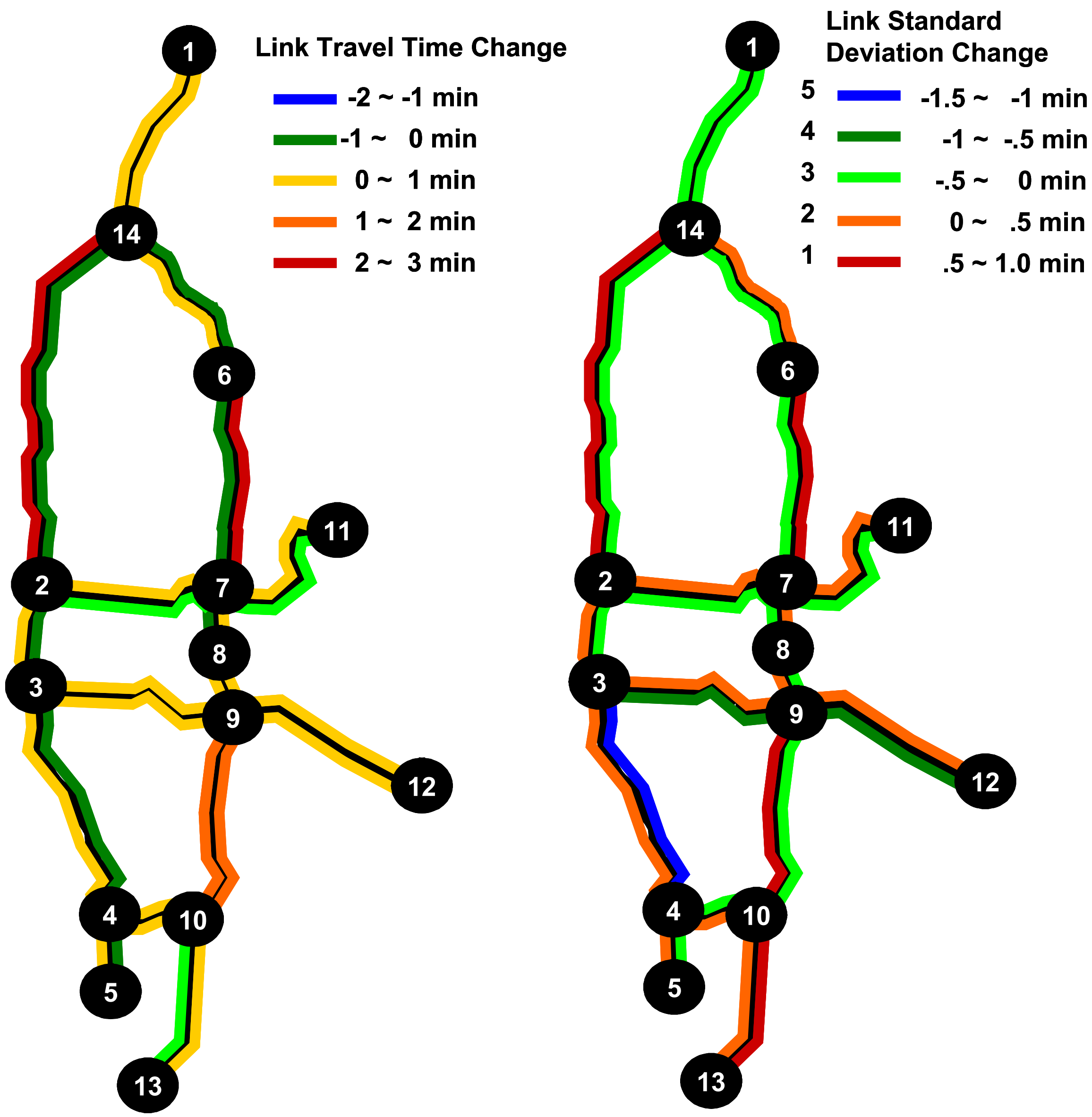

Figure 2. **Change in Travel Time and Travel Time Standard Deviation from Training to Evaluation Periods**

The difference in travel time variability from the training period to the evaluation period is illustrated via a color-coded network of the region in Figure 2 (right map).The greatest increase in travel time standard deviation from the training to the evaluation period occurs on link 8, I-405 going from Bothell to Rt. 520. This is an increase of 0.9 minutes from the training period average travel time standard deviation of 2.2 minutes. The greatest decrease in travel time standard deviation from the training to the evaluation period occurs on link 4, I-5 going from I-405 to Downtown Seattle. This is a decrease of 1.4 minutes from a training average travel time standard deviation of 4.0 minutes.

Link Number	Link Length	Average Travel Time (minutes)			Std. Deviation of Travel Time (minutes)		
		Training	Evaluation	All Days	Training	Evaluation	All Days
0	14.4	10.6	10.5	10.5	0.8	0.6	0.7
1	14.4	13.5	15.6	15.2	2.8	3.5	3.4
2	2.4	4.3	4.3	4.2	0.3	0.2	0.3
3	2.4	5.5	6.3	6.2	1.1	1.4	1.4
4	10	16.2	15.8	15.7	4.0	2.6	2.7
5	10	10.8	11.0	10.9	0.4	0.9	0.8
6	3	4.9	4.7	4.7	1.2	0.8	0.8
7	3	3.2	3.3	3.3	0.1	0.3	0.2
8	8.6	12.2	14.8	14.4	2.2	3.1	2.9
9	8.6	9.4	9.1	9.1	0.5	0.3	0.3
10	1.1	1.6	1.9	1.8	0.3	0.4	0.4
11	1.1	1.2	1.2	1.2	0.1	0.0	0.0
12	2.5	3.2	3.6	3.5	0.4	0.6	0.6
13	2.5	4.4	4.9	4.8	1.0	1.0	0.9
14	8.8	11.2	12.5	12.3	1.4	2.1	2.0
15	8.8	15.6	17.3	16.9	3.4	3.4	3.3
16	2.2	2.8	3.1	3.1	0.3	0.5	0.5
17	2.2	3.9	4.3	4.2	0.9	0.8	0.8
18	9.8	12.7	13.7	13.5	2.0	2.9	2.7
19	9.8	10.8	10.7	10.6	0.6	0.8	0.7
20	6.6	7.8	8.5	8.3	1.0	1.1	1.1
21	6.6	9.1	9.0	8.9	1.6	1.1	1.1
22	5.8	6.9	7.4	7.3	0.9	1.0	1.0
23	5.8	8.0	7.9	7.8	1.4	0.9	1.0
24	7.3	8.7	9.3	9.2	0.9	1.1	1.1
25	7.3	8.4	8.4	8.4	1.6	0.7	0.8
26	7.5	9.0	9.6	9.4	0.9	1.2	1.1
27	7.5	8.6	8.7	8.6	1.6	0.8	0.8
28	6.6	7.0	7.0	7.0	0.4	0.5	0.5
29	6.6	10.3	10.6	10.6	2.8	2.7	2.7
30	6.9	7.3	7.3	7.3	0.5	0.5	0.5
31	6.9	10.5	11.1	11.1	3.0	2.8	2.8
AVERAGE	6.5	8.1	8.5	8.4	1.3	1.3	1.3

Table 2. Link Length, and Average and Standard Deviation in Travel Time

4.3 Link Travel Time Conversion to Link Speed

Given that link travel time is a reflection of both link distance and link congestion, this section presents link travel times converted to link speeds, thereby eliminating the link distance component and focusing on link congestion. Figure 3 presents two color-coded maps of the Seattle network, one illustrating the average speed on each network link, and a second illustrating the standard deviation in average link speed from day to day within the peak period.

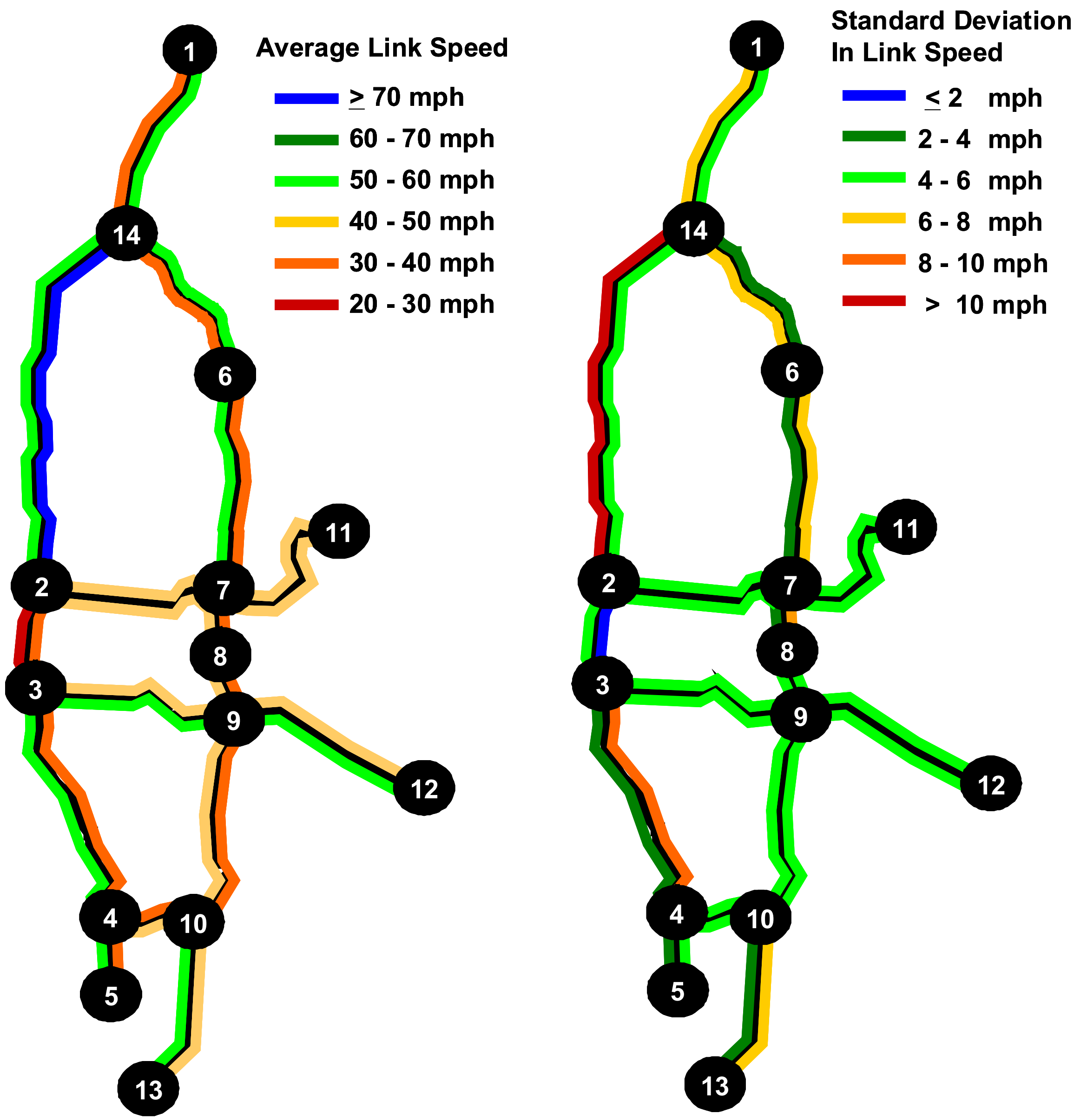

Figure 3. Average and Standard Deviation in Link Speed

The link with lowest average speed is I-5 southbound from SR 520 to I-90, having an average speed below 30 mph during the AM peak period. The link with greatest variability in speed, I-5 from I-405 to SR 520, precedes the link with lowest speed and has an average speed just over 50 mph with a standard deviation in speed of just over 10 mph.

4.4 Data Implications on Trip Benefits

Given that the ATIS users benefit most from reacting to variability in congestion and where congestion is significantly different from the training to the evaluation periods, one would expect the ATIS will be very useful for trips where these factors are present in greatest intensity. Links 1, 8, and 18 have the greatest travel time variability, and increase in variability from training to evaluation periods. Moreover, they all have an average travel time during the evaluation period that is somewhat higher than during the training period. Therefore, trips made using these links are likely to benefit most from ATIS use. In the following section, we explore the level of demand on these links compared with the links with greatest demand as well as the demand throughout the network.

5 SEATTLE REGION TRAVEL DEMAND

The set of HOWLATE nodes is translated to sub-areas within EMME/2 network for estimation and allocation of number of trips made between any two nodes. Figure 4 illustrates the sub-area translation from HOWLATE node (gray ovals) along with three additional non-nodal sub-areas (shaded gray ovals) to exclude trips made on freeways between two adjacent nodes that are likely not candidates for ATIS use.

Trips between the non-nodal sub-areas and adjacent sub-areas are excluded while trips between the non-nodal sub-areas to other node sub-areas are split equally as emanating or destined to adjacent nodes. For example, trips from sub-area 15 to sub-area 2 are excluded in conducting the weighted analysis, while trips from the sub-area 15 to sub-area 5 are categorized as half emanating from sub-area 2 and half emanating from sub-area 14, and both destined for sub-area 5.

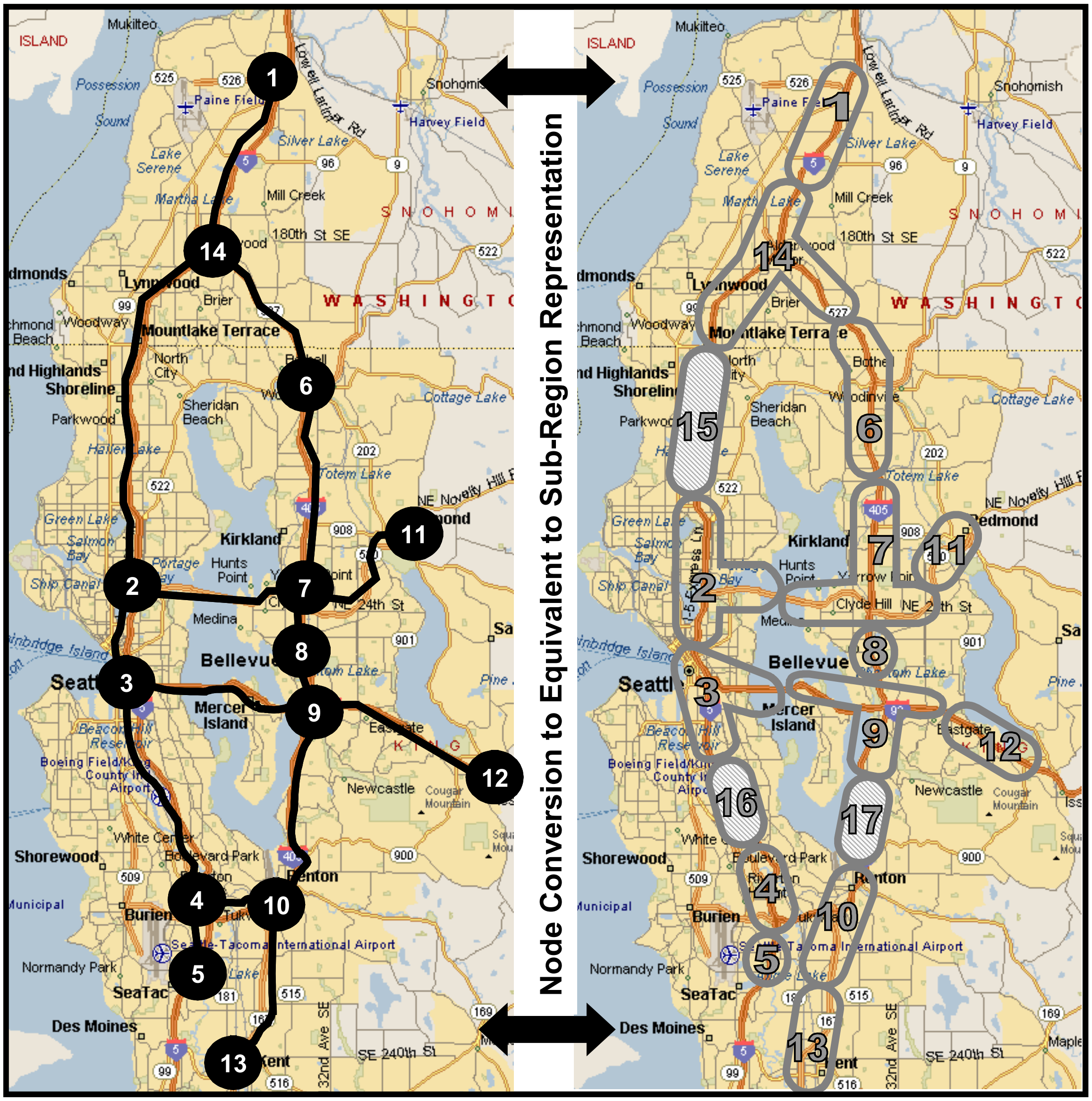

Figure 4. Translation of HOWLATE Nodal Network to Regional Sub-Areas

To identify the number of trips between a given sub-area to another sub-area, first each freeway entry and exit point is assigned to a one of the 17 sub-areas. Then, the trip assignment step in the EMME/2 regional model is run to record each vehicle's freeway entry and exit point during the AM peak period. At the completion of trip assignment, vehicles are assigned as starting from the sub-area associated with their freeway entry and going to the sub-area associated with their freeway exit point. Based on this process, Table 3 presents the number of trips made to/from each of the 17 sub-areas.

NUMBER OF VEHICLE-TRIPS MADE FROM/TO EACH SUB-AREA																		
Trip Start	**Trip End Sub-Area**																	
Sub-Area	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**TOTAL***
1	3418	446	601	321	3266	505	223	91	74	66	82	631	259	4335	392	118	31	**14.9**
2	4121	6203	1384	954	3771	1397	6289	367	1279	223	1337	773	209	2054	5082	442	53	**35.9**
3	2035	4889	5349	1644	4950	1234	1654	1417	8251	500	565	3853	324	909	2100	1806	149	**41.6**
4	943	724	1422	17890	8382	481	174	168	583	7400	131	296	1166	249	338	2470	1452	**44.3**
5	2481	501	2281	1964	0	99	25	45	83	474	16	29	1250	311	198	721	146	**10.6**
6	609	228	166	72	50	16070	1984	607	314	35	245	195	1273	3699	137	6	61	**25.7**
7	837	4971	505	61	76	5862	10171	1378	1066	81	4828	360	1568	1773	980	24	201	**34.7**
8	466	1106	1113	88	93	4307	2369	3251	4658	343	1303	1967	1717	1067	292	16	680	**24.8**
9	180	540	2930	178	329	702	819	1630	9851	450	139	7258	2424	266	151	37	1296	**29.2**
10	62	19	292	3423	340	188	78	188	365	16571	30	96	3455	75	6	229	404	**25.8**
11	80	260	121	27	12	214	1893	280	264	10	7787	104	327	136	20	14	33	**11.6**
12	125	90	763	6	1	102	245	347	1707	2	22	0	3	215	26	81	28	**3.8**
13	324	101	355	775	1472	783	285	360	613	1707	52	29	13653	376	39	126	165	**21.2**
14	5376	542	248	151	1473	3494	410	115	48	51	127	414	262	1959	1038	34	13	**15.8**
15	2597	1536	364	229	1172	156	388	46	122	69	53	117	59	1028	1955	84	10	**10.0**
16	98	169	289	1273	1227	42	45	33	122	200	15	72	95	38	95	7136	39	**11.0**
17	106	61	146	253	56	312	212	383	1653	223	89	269	1192	140	20	48	4140	**9.3**
TOTAL*	**23.9**	**22.4**	**18.3**	**29.3**	**26.7**	**35.9**	**27.3**	**10.7**	**31.1**	**28.4**	**16.8**	**16.5**	**29.2**	**18.6**	**12.9**	**13.4**	**8.9**	**370.2**
**** TOTAL trip columns are listed as thousands of vehicle-trips.***																		

Table 3. Number of Trips Made To/From the 17 Sub-Areas

A total of 370,235 vehicle-trips are identified as driving on some portion of the freeway network where ATIS trip times are available during the AM peak period in Seattle. Of these, 143,503 (39%) are trips that both start and end in the same sub-area. The effect of ATIS use on these trips can not be evaluated using HOWLATE given they are considered within-node trips. Still, these trips are less likely to use ATIS given their short distance and the current limited spatial detail of ATIS travel time information. Therefore, in considering the user benefit from ATIS, a set of 244,830 trips are identified as candidate daily AM peak ATIS users. Table 4 presents the percent of these trips made from/to the 14 sub-areas corresponding to the 14 HOWLATE nodes. Note that in this table, the trips from non-nodal sub-areas are reassigned to nodal sub-areas as explained earlier, and the trips within a sub-area are excluded from calculations.

Figure 5 presents an aggregate view of where the 244,830 candidate ATIS trips' start and end. Approximately 21% of the trips begin from the north and south extremes of the network, represented by nodes 1 and 5. And, more trips (27%) end at nodes that correspond to downtown Seattle and areas continuing south, represented by nodes 2 and 3.

Percent of Trips Made From/To Each Sub-Area*															
Trip Start	**Trip End Sub-Area**														
Sub-Area	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**TOTAL***
1		2.39%	0.90%	0.46%	1.09%	0.27%	0.37%	0.21%	0.10%	0.05%	0.04%	0.06%	0.14%	2.94%	**9.0%**
2	0.28%		2.63%	0.48%	0.26%	0.13%	2.41%	0.55%	0.29%	0.03%	0.12%	0.05%	0.05%	0.24%	**7.5%**
3	0.29%	0.80%		0.63%	1.16%	0.07%	0.23%	0.49%	1.34%	0.22%	0.06%	0.35%	0.18%	0.21%	**6.0%**
4	0.17%	0.58%	0.72%		1.03%	0.03%	0.03%	0.04%	0.15%	1.62%	0.01%	0.02%	0.37%	0.13%	**4.9%**
5	1.44%	1.92%	2.18%	4.24%		0.02%	0.03%	0.04%	0.16%	0.16%	0.01%	0.00%	0.65%	0.91%	**11.8%**
6	0.22%	0.65%	0.54%	0.23%	0.04%		2.59%	1.90%	0.38%	0.15%	0.09%	0.04%	0.35%	1.58%	**8.8%**
7	0.10%	2.86%	0.73%	0.10%	0.01%	0.87%		1.05%	0.41%	0.08%	0.83%	0.11%	0.13%	0.27%	**7.5%**
8	0.04%	0.17%	0.62%	0.09%	0.02%	0.27%	0.61%		0.80%	0.17%	0.12%	0.15%	0.16%	0.06%	**3.3%**
9	0.04%	0.60%	3.68%	0.64%	0.07%	0.15%	0.51%	2.20%		0.16%	0.12%	0.76%	0.31%	0.05%	**9.3%**
10	0.04%	0.13%	0.26%	3.68%	0.24%	0.03%	0.08%	0.30%	0.20%		0.01%	0.01%	0.79%	0.04%	**5.8%**
11	0.04%	0.60%	0.25%	0.06%	0.01%	0.11%	2.13%	0.57%	0.08%	0.03%		0.01%	0.02%	0.07%	**4.0%**
12	0.28%	0.37%	1.70%	0.16%	0.01%	0.09%	0.16%	0.87%	3.26%	0.10%	0.05%		0.01%	0.21%	**7.3%**
13	0.11%	0.10%	0.14%	0.56%	0.55%	0.56%	0.69%	0.76%	1.33%	1.79%	0.14%	0.00%		0.13%	**6.9%**
14	2.00%	0.91%	0.87%	0.21%	0.18%	1.66%	1.00%	0.54%	0.18%	0.07%	0.06%	0.10%	0.17%		**8.0%**
TOTAL	**5.0%**	**12.1%**	**15.2%**	**11.5%**	**4.7%**	**4.3%**	**10.8%**	**9.5%**	**8.7%**	**4.6%**	**1.7%**	**1.7%**	**3.3%**	**6.8%**	**100.0%**
***Percent based on set of candidate ATIS user trips, 244,830.**															

Table 4. Number of Trips Made To/From the Aggregated 14 Sub-Areas

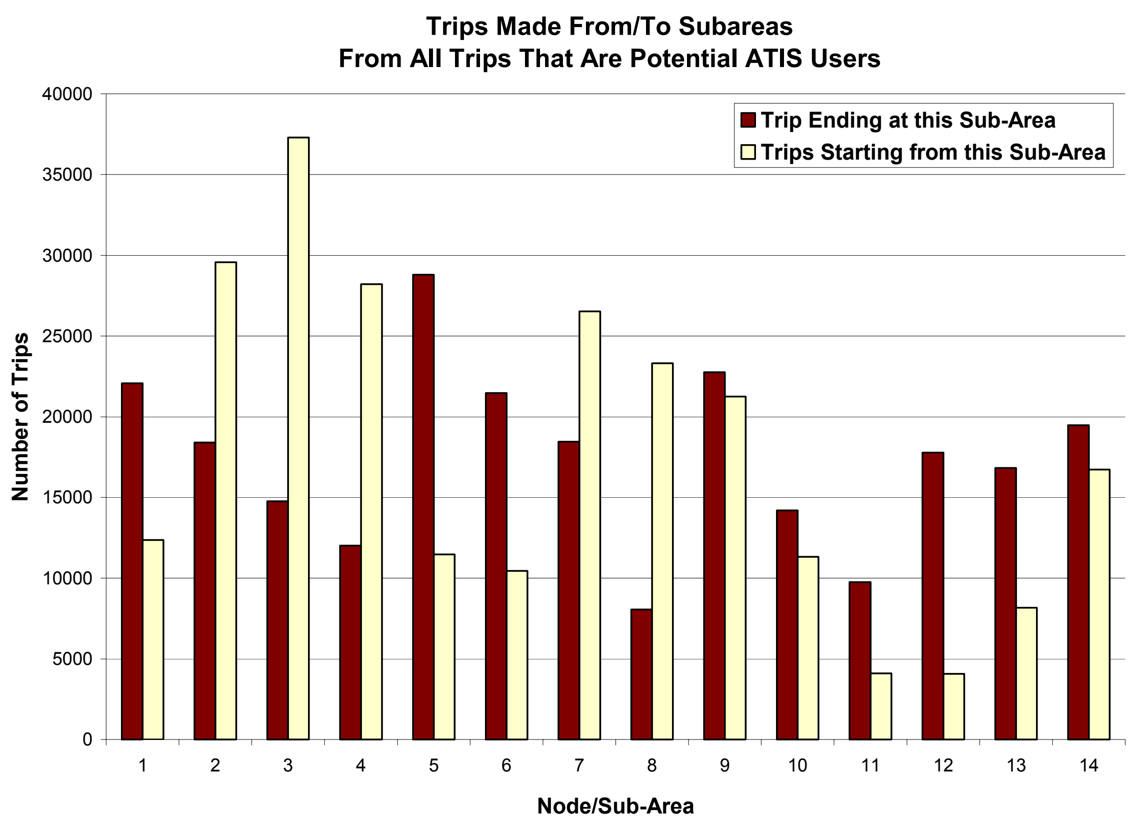

Figure 5. Number of Trips Made To/From Regional Sub-Areas

Figure 6 presents the cumulative distribution function of the percent of 244,830 trips that are made by a percent of the trip start-end options in the Seattle network. In previous HOWLATE analyses, because we assume that the same number of trips is made from all origins to all destinations, Figure 6 also presents a straight line that reflects this HOWLATE assumption. For the Seattle AM peak, approximately 31% of the trips are made over top 10 (5%) of the 182 potential OD pairs. Conversely, approximately 80% of the trips are made over the top 55 (30%) of the 180 potential OD pairs.

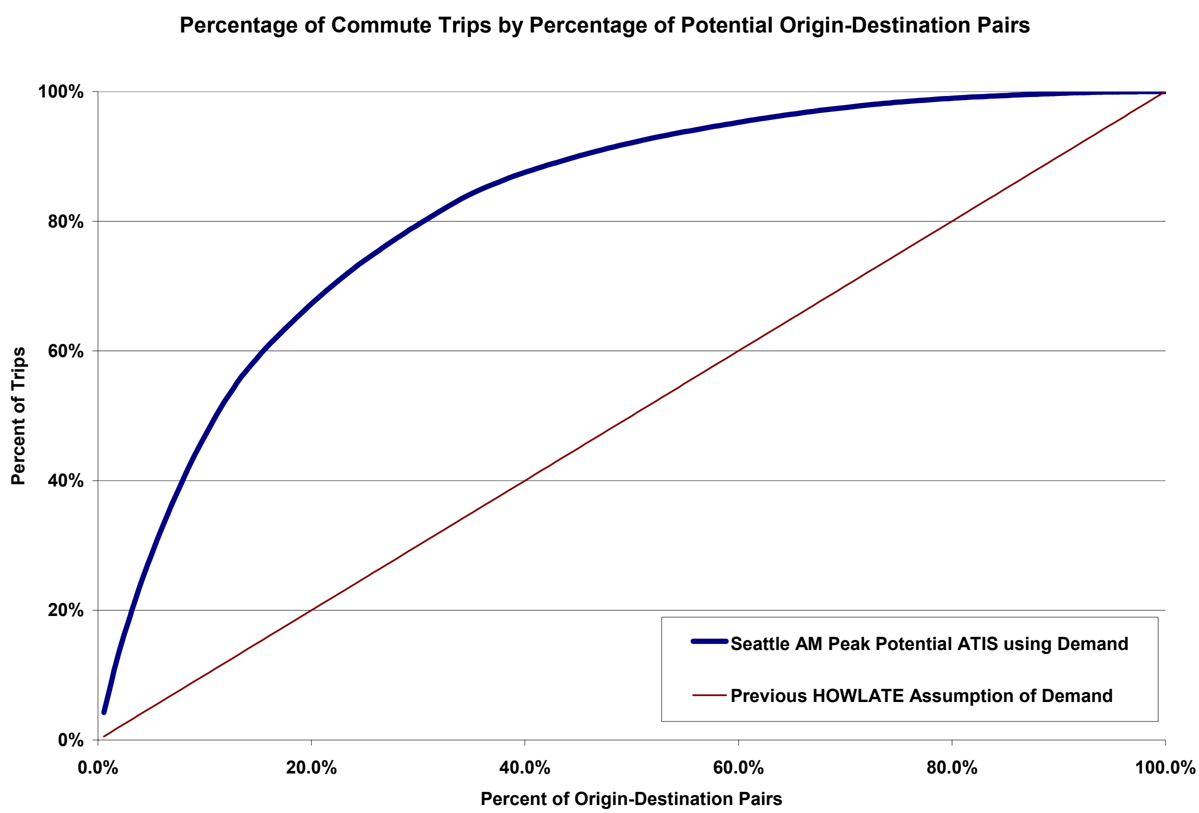

Figure 6. Cumulative Distribution Function of Trips by Percent of OD Pairs

The top 10 OD pairs and their respective trip counts are presented via the left map in Figure 7. Overwhelmingly, the top OD pairs are single link, short trips with the exception of the trips from Everett (Node 1) to downtown Seattle (node 3). These relatively short trips are likely not to benefit from ATIS, or achieve relatively small benefit from departure time diversion given that they also are not on one of the links with high travel time variability or increase in variability from training to evaluation periods. OD pairs with multiple route options, high trip variability, and longer distance; though not made by as many travelers, are likely to generate larger benefit. Five such OD pairs are presented via the right map in Figure 7. For example, a trip from Everett to the SeaTac Airport (Node 1 to 5) may more likely benefit from ATIS given the multiple routing options and influence of link 1 which has high travel time variability and increase in variability from training to evaluation periods.

The next section presents the HOWLATE analyses and compares outcomes with and without the regional demand patterns described in this section.

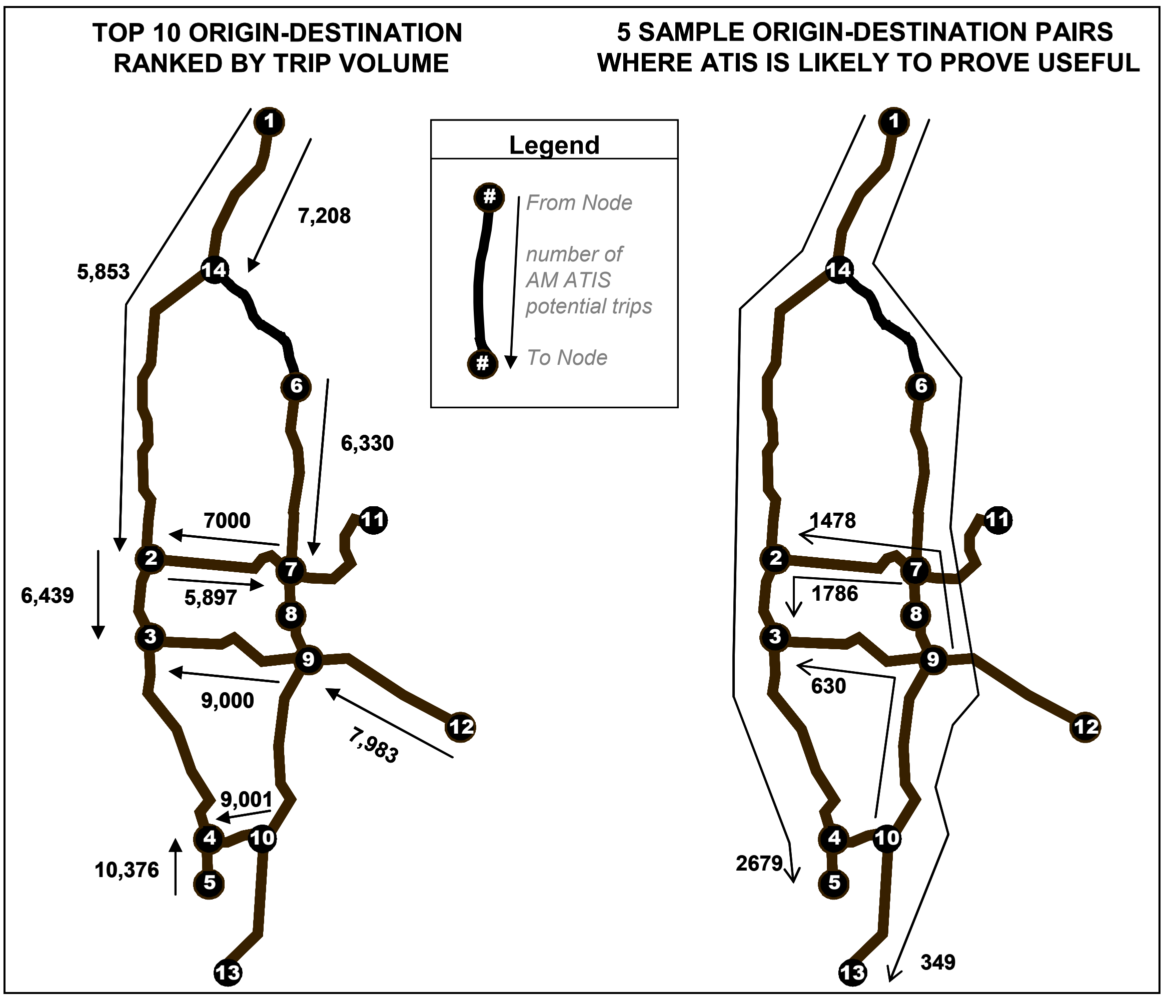

Figure 7. **OD Pairs with Greatest Number of Trips Versus OD Pairs where ATIS Users are Likely to Garner Greatest Benefit**

6 SEATTLE REGIONAL ANALYSIS RESULTS

The HOWLATE methodology recreates trip arrival outcomes of paired drivers given an archive of link-specific travel time, an estimate of travel time accuracy, and a threshold for drivers' late arrival tolerance. In this section we simulated paired driver runs over 111 days of data from September 2002 to March 2003 for a number of ATIS accuracy levels and drivers' on-time arrival thresholds.

Given that we do not know the accuracy of the travel time archive we examine scenarios where the ATIS trip-level error in travel time reports is 5%, 10%, 15%, and 20%. These error levels have been selected based on the work of Hardy et al. (1999) and Shah et al. (2003). These two studies respectively measure the levels of error for an ATIS instrumented corridor in another city and identify the range of ATIS error where users of ATIS would derive benefit for three metropolitan regions.

The threshold for drivers' late arrival tolerance, viewed as an acceptable on-time arrival rate is selected to be 95% as a baseline. Scenarios where the on-time arrival target is set at 90%, 80%, and 70% are also considered. These arrival thresholds represent different commuter perspectives on the need to be on time. Higher on-time arrival thresholds represent trips with significant penalties for late arrival such as trips to the airport, rigid work schedules, or school events. Conversely, lower on-time arrival thresholds may for example correspond to trips made for shopping purposes.

Each scenario is simulated 5 times with different starting random number streams to establish that differences in trip outcomes between paired drivers are statistically significant. Table 5 lists each scenario assessed in this study.

Scenario Number	1	2	3	4	5	6	7
ATIS Trip Time Reporting Error	10%	5%	15%	20%	10%	10%	10%
Drivers' On-Time Arrival Frequency Threshold	95%	95%	95%	95%	90%	80%	70%
Multiple Runs to Establish Statistical Significance	5	5	5	5	5	5	5

Table 5. Scenarios Evaluated in This Study

The total number of paired trips simulated for any given arrival time on a specific day is 182 assuming 1 paired trip made from each node to every other node. For each day, we simulate 13 distinct arrival times within the AM peak, corresponding to 15-minute arrival times beginning with 6:30 am and ending with a 9:30 am arrival. Thus, the total number of simulated paired driver runs in each scenario is 262,626 (111 days X 13 arrival times X 182 trips).

We will explore the outcomes of the baseline scenario, scenario 1, in Section 6.1. In this section we quantify the effect of ATIS use on trip plans and trip outcomes, highlighting the difference in outcomes based on the weighted and unweighted (traditional HOWLATE) results. We also examine what OD pairs benefit the most from ATIS use, and identify the sets of trips for which the travelers are likely to be routine ATIS users. In section 6.2, we explore the effect of lower and higher levels of ATIS reporting error on the benefit to users of ATIS through comparison of scenarios 1 through 4. Finally, in section 6.3 we explore how ATIS user benefit varies based on different thresholds for frequency of on-time arrival.

6.1 ATIS User Impacts Based on the Baseline Scenario

This section first explores the aggregate results of Scenario 1, where commuters' on-time arrival goal is 95% and ATIS trip-reporting error is 10%. Differences between ATIS users and non-users as well as differences in outcomes from the regional weighted and unweighted analyses are highlighted in terms of departure decisions, arrival outcomes, travel time, and trip disutility. Then, we explore which OD pairs can derive the greatest benefit from ATIS and are potentially the first market for a pre-trip notification-based ATIS as well as what the potential savings from varied market penetration levels.

6.1.1 Aggregate ATIS User and Non-User Differences

Table 6 summarizes the trip decisions and outcomes of ATIS users compared to the paired drivers maintaining fixed route and departure time assuming an equal distribution of ATIS usage. For about half (52%) of the trips, the ATIS user departed either earlier or later than their habitual counterpart assuming equal weighing of trips. In Seattle, based on the number of trips made from each origin to each destination this value drops to 42% of trips. Route switching by ATIS users occurs in approximately 2% of trips based on equal weighting, while based on the estimate of regional trips, in only 1% of trips do ATIS users switch route.

SCENARIO: 95% On-Time Arrival Objective 10% ATIS Reporting Error	Traditional	Weighted	Percent Difference (Weighted v. Trad.)
% Trips Where ATIS Users			
Switched Departure Time	52%	42%	-20%
Switched Route	2%	1%	-66%
Benefitted from ATIS Use	63%	64%	1%
Trip Disutility --For OD Pairs with Net Positive Benefit from ATIS Use			
Habitual Commuter	$ 1.73	$ 1.14	-34%
ATIS User	$ 1.43	$ 0.93	-35%
ATIS Users' Disutility Savings	***$ 0.30***	***$ 0.21***	-31%
Trip Disutility --All Trips			
Habitual Commuter	$ 1.67	$ 1.14	-32%
ATIS User	$ 1.44	$ 0.96	-34%
ATIS Users' Disutility Savings	***$ 0.24***	***$ 0.18***	-22%
Travel Time in Minutes--All Trips			
Habitual Commuter	15.5	22.8	47%
ATIS User	15.4	22.6	47%
ATIS User's Travel Time Savings	***0.10***	***0.22***	126%
Trip Arrival Outcomes --All Trips			
Early Arrival --Habitual Commtuer	6.4%	5.2%	-19%
Early Arrival --ATIS Commuter	14.5%	6.9%	-52%
ATIS Users' Early Arrival Decrease	***-8%***	***-2%***	-79%
Late Arrival --Habitual Commuter	8.8%	6.3%	-28%
Late Arrival --ATIS Commuter	1.4%	0.9%	-30%
ATIS Users' Late Arrival Decrease	***7%***	***5%***	-28%

Table 6. Summary of Trip Decisions and Outcomes of ATIS Users

Arrival Outcomes

By adjusting departure time and route, ATIS users reduce the frequency of late arrivals while arriving early with a somewhat higher frequency. Based on equal weighting of trips, approximately 6.4% of ATIS non-users are early by 10 or more minutes at their destination while 14.5% of their counterparts who use ATIS are early. Based on the weighing of results, approximately 5.2% and 6.9% of ATIS non-users and users, respectively, arrive early. Thus with respect to early arrivals, applying an equal weighing of trips inflates the difference between ATIS non-users and users' frequency of early arrival four fold (8% unweighted versus 2% weighted) compared to an estimate based on the regional demand weighted analysis.

With respect to late arrivals, approximately 8.8% of ATIS non-users are late while only 1.4% of their counterparts who use ATIS are late based on equal weighting of trips. Based on the weighting of trips by regional demand, approximately 6.3% and 0.9% of ATIS non-users and users are late, respectively. Thus with respect to late arrivals, applying an equal weighting of trips overestimates the difference between ATIS non-users' and users' frequency of early arrival by 39% compared to an estimate based on the regional demand.

In-Vehicle Travel Time

Differences in travel time between ATIS users and non-users, although statistically significant, are nominal. Based on a weighting of trips by regional demand, ATIS users save approximately 6 seconds for an average regional trip of 15.5 minutes. The equal weighting of trips estimated a 13 seconds reduction in travel time for an average regional trip of 22.8 minutes. To note, by weighting trips by demand we find that the longer trips are made far less frequently than shorter trips resulting in the average trip taking about 15.5 minutes.

Trip Disutility

Average trip disutility, a monetary reflection of travel time calculated by assigning a cost to the duration of travel time and deviations from the scheduled arrival time, is $1.14 for the ATIS non-user and $0.96 for the ATIS user based on an analysis of all trips weighted by regional demand. Thus, the per-trip benefit is $0.18. The per-trip benefit based on the unweighted demand is $0.24. Thus without accounting for regional demand, the estimate of trip disutility is overestimated by 28%. This is consistent with what was hypothesized.

If we consider that drivers would use ATIS at a minimum if ATIS proved on average across the 111 evaluation days to be beneficial, then approximately 64% of the trips would use the ATIS. The average per-trip benefit to these ATIS users is approximately $0.21 per trip. Without applying regional demand, the benefit to this set of ATIS users is over estimated by 45%, coming to $0.30 per trip. Figure 8 presents a graph of average per-trip ATIS benefit for trips ordered from those most benefiting to least benefiting. As illustrated in this Figure, approximately 10% of regional trips realize a benefit above $0.60, while some 36% of trips do not realize trip disutility reduction from ATIS use.

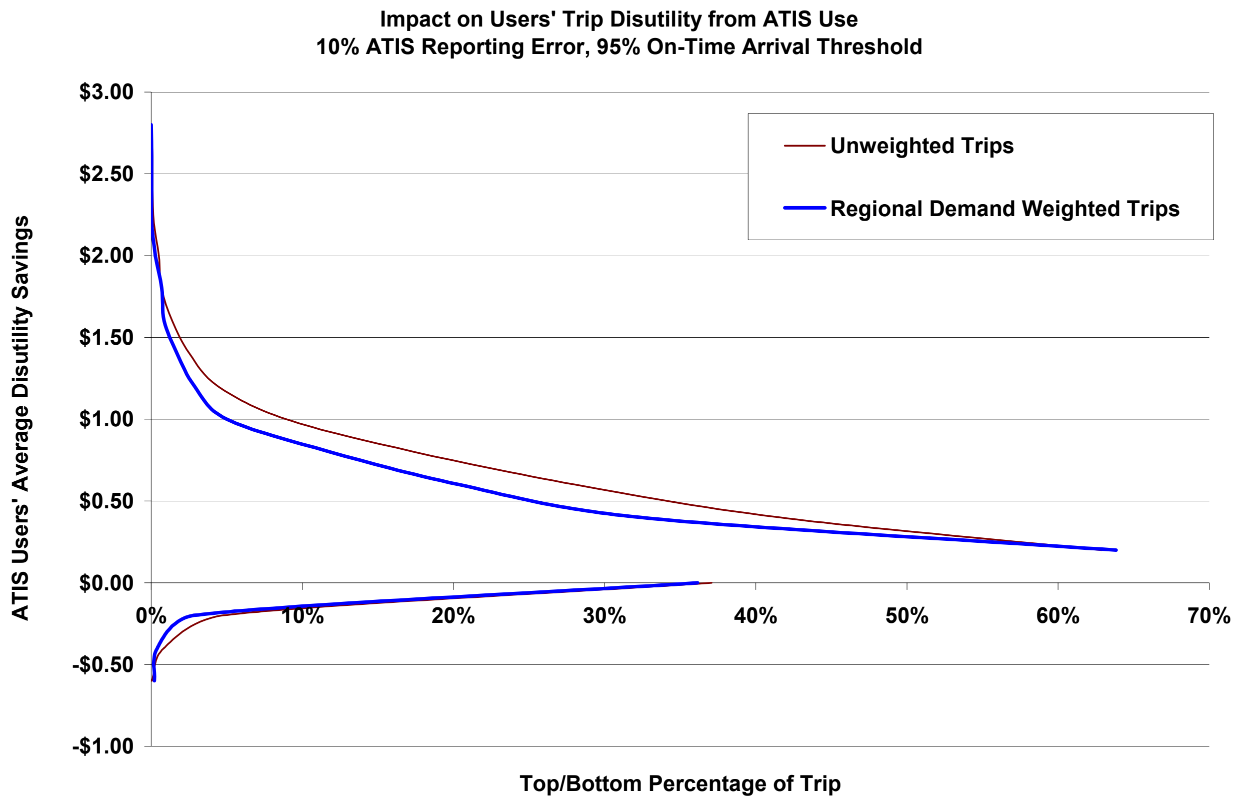

Figure 8. Trips' Average Disutility Savings Ranked from Most to Least Benefiting

6.1.2 Geography of ATIS Benefit

Figure 9 presents a chart of the average benefit to ATIS users for trips starting from or ending at each of the 14 sub-areas comprising the Seattle network. The vertical bars in this Figure represent the results based on a weighing of trips by regional demand while the diamonds correspond to results based on equal weighing of trips. This figure illustrates that for 10 of the sub-areas not weighting trips by regional demand significantly overestimates per-trip benefit, while for the remaining 4 sub-areas not weighting trips by regional demand results in an underestimation of per-trip benefit.

Trips coming from or going to sub-areas 1, 6, and 14 demonstrate the greatest potential for ATIS benefit. Also of note, all nodes have on average a net positive benefit suggesting that trips that start from or go to any node would benefit from ATIS use.

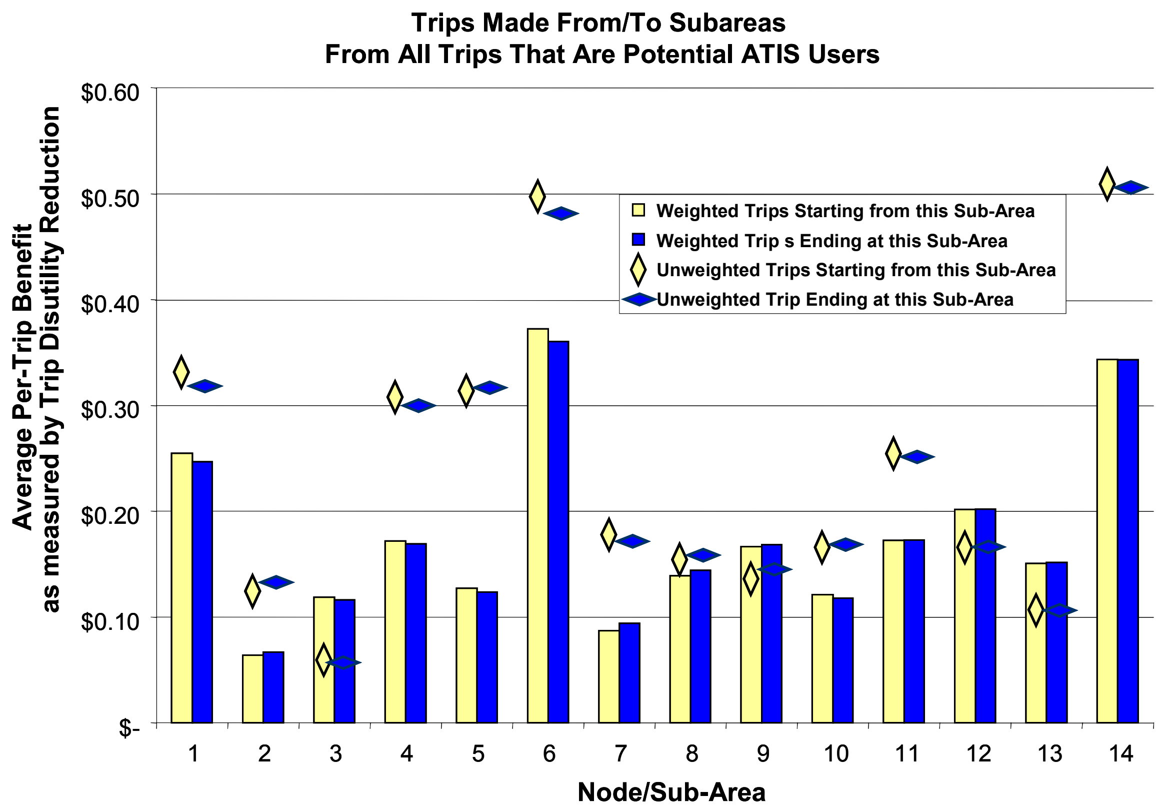

Figure 9. Average ATIS Users' Benefit by Trip Start and Trip End

Figure 10 presents three maps that identify the average per-trip benefit to users of ATIS across the 111 evaluation days on specific OD trips. The first map identifies the ATIS user benefit for the 10 OD pairs with the greatest demand; the second map identifies the ATIS user benefit for the 5 OD pairs likely to benefit significantly from ATIS, while the third map identifies the ATIS user benefit for the 5 OD pairs that do benefit most from ATIS. The 10 OD pairs with greatest demand are relatively short trips, and consequentially, 7 experience positive benefits from ATIS use of less than $0.15 per OD pair while the regional average benefit is $0.18 per trip. The five OD pairs expected to generate significant positive benefit were selected on the basis of multiple route options, trip length, and trip variability. The average benefit among these 5 OD pairs is approximately $0.45 per OD pair compared to the regional average of $0.18 per trip. The average benefit among the 5 OD pairs with greatest per-trip benefit is trips $0.76. These OD pairs are for relatively long trips, with highest trip time variability, and low roadway speeds. The number of trips made from these 5 OD pairs (2.7% of all OD pairs) is relatively small, at 1.6% of the 244,830 trips identified as potential ATIS users.

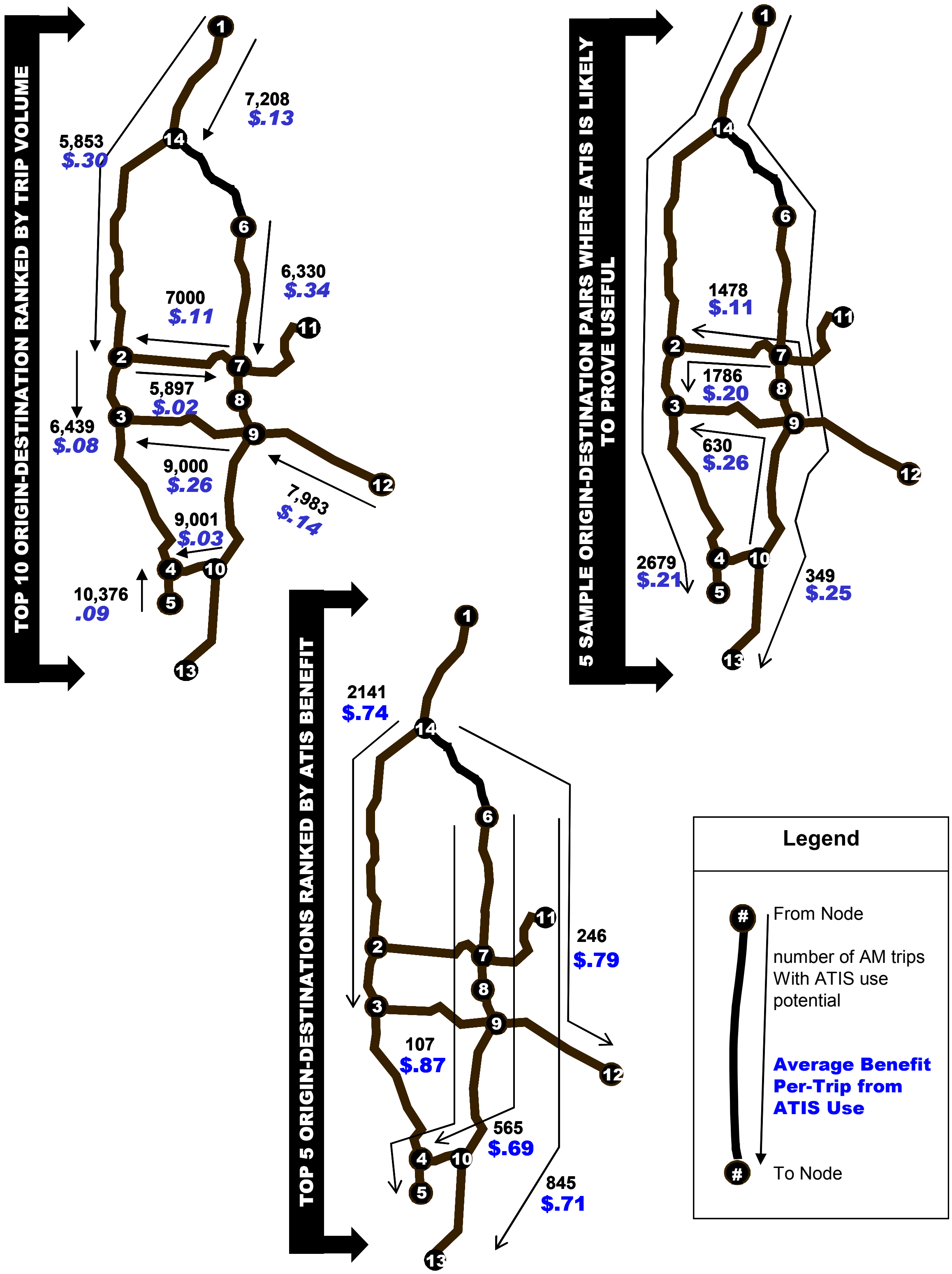

Figure 10. **Number of Trips and Their Benefit for Specific OD Pairs**

6.1.3 Market Penetration and Annual Benefit

In this section, we aggregate ATIS user benefit from improvements in on-time reliability to generate an annual regional monetary savings for ATIS users. This savings is contingent on the number of people that use ATIS and is compared to the population of potential ATIS users calculated in Section 5 (approximately 244,830 trips).

Traditionally, simulation studies assume that ATIS use is distributed equally among OD pairs, regardless of whether they benefit from ATIS use. Similarly, in the absence of regional demand patterns, previous HOWLATE studies assumed the same number of trips from each OD pair. In reality, users of ATIS are likely to be those who know the service is available and perceive the greatest benefit from its use. Also, those who do not benefit from ATIS information will likely not use it routinely. Figure 11 presents the annualized benefit to ATIS users based a 'highest benefit first' (HBF) ATIS user market penetration profile wherein users with greatest potential for benefit adopt the technology first followed by users with lesser potential for ATIS benefit.

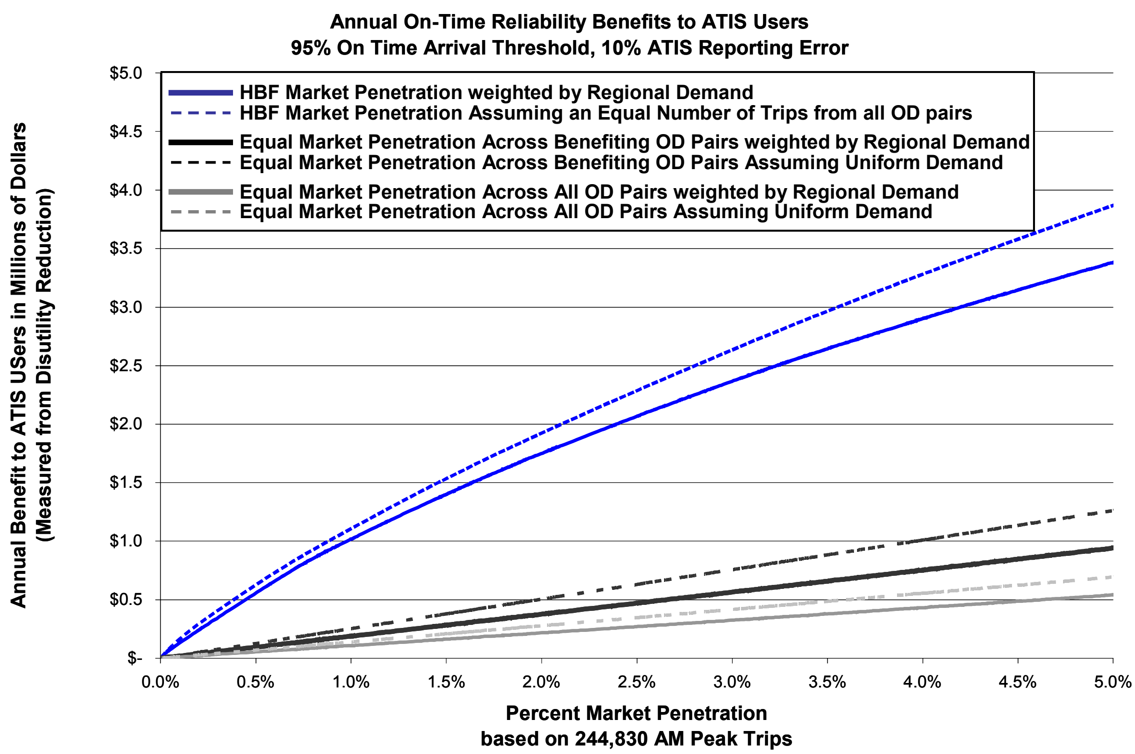

Figure 11. Annual Regional User Benefit for Different Market Penetration Scenarios

The HBF strategy of market penetration is demonstrated by the dark blue line, while the same strategy based on the absence of regional demand patterns is presented by the dotted dark blue line. At 1% HBF market penetration (approximately 2450 routine AM peak ATIS users), ATIS users' benefit in terms of on-time reliability is approximately $1.02 million per year for the AM peak. At 2% HBF market penetration (approximately 4900 routine AM peak ATIS users), annual ATIS user benefit from on-time reliability improvements in the AM peak would total $1.75 million per year. This is based on the assumption of 240 commute trips made per year in the AM where ATIS is consulted.

Also presented in Figure 11 are annualized benefits to ATIS users at varied market penetrations based on the assumption of equal ATIS market penetration among all OD pairs and among the subset of OD pairs that benefit from ATIS. These two scenarios are represented by the solid gray and black lines, respectively. The dotted gray and black lines parallel the previous assumption of equal ATIS market penetration, but also assume an equal number of trips among all OD pairs. These scenarios represent calculation of benefit based on the least amount of regional knowledge of demand and congestion while the first scenario, represented by the dark blue line, presents the more likely course for ATIS market penetration. The reality likely lies somewhere in between given that ATIS users may weight on-time reliability benefits differently compared to other benefits of ATIS, that ATIS use may be more accessible for some populations, and that knowledge of ATIS availability is not commonplace.

6.1.4 Implications of Annual Peak Results on Annual Full-Day Results

Results for the Seattle region suggest that traditional HOWLATE analyses tend to overestimate benefit for the AM peak period. This overestimation of benefit is likely to be consistent for the PM peak and perhaps even for the off-peak given that the equal weighing of trips by OD pairs will over represent longer trips regardless of time of day. This outcome of overestimation of ATIS benefit, however, can not be transferred for aggregate benefit throughout the day given the complexity of demand, congestion and regional benefit variations between peak and off-peak periods.

The traditional HOWLATE process, in estimating aggregate daily ATIS user benefit, weights all trips across the day equally and thereby generally over-represents trips made mid-day. The mid-day trips are likely to benefit less from ATIS use compared to peak period trips. Thus, the average benefit throughout the day, calculated based on equal weighing of demand, is less likely to overestimate benefit compared to the peak-period overestimation that occurred due to the absence of regional demand consideration. This is illustrated by Table 7, scenario A, where a hypothetical peak demand is higher than mid-day demand, ATIS benefit is higher in the peak compared to the mid-day, and ATIS benefit for all periods is overestimated by 25% using traditional HOWLATE. In this scenario, the net daily benefit through the traditional HOWLATE calculations is actually underestimated by 6% compared to the demand-weighted calculation of benefit.

	Time of Day	*HOURS*	**Regional Demand Outcome** *# Trips*	*Per Trip Benefit*	**Unweighted Trips Outcome** *# Trips*	*Per Trip Benefit*
Scenario A	AM Peak	6:30 AM - 9:30 AM	350 trips	$0.40	250 trips	$0.50
	Mid-Day	9:30 AM - 3:30 PM	250 trips	$0.08	500 trips	$0.10
	PM Peak	3:30 PM - 6:30 PM	400 trips	$0.40	250 trips	$0.50
	Average Daily Per-Trip Benefit			$0.32		$0.30
			Error in Unweighted Daily Per-Trip Benefit			**-6%**
Scenario B	AM Peak	6:30 AM - 9:30 AM	350 trips	$0.19	250 trips	$0.24
	Mid-Day	9:30 AM - 3:30 PM	250 trips	$0.22	500 trips	$0.27
	PM Peak	3:30 PM - 6:30 PM	400 trips	$0.76	250 trips	$0.95
	Average Daily Per-Trip Benefit			$0.43		$0.43
			Error in Unweighted Daily Per-Trip Benefit			**2%**

Table 7. Hypothetical Scenarios of Aggregated Daily Per-Trip Benefit Calculations

In other circumstances, such as when off-peak benefit is greater than benefit during a peak period, the overestimation of unweighted all-day ATIS user benefit may actually be greater than the overestimation of unweighted peak-period benefit. This is illustrated in Figure 7, scenario B, where although the in the peak, benefit is overestimated by 25%, the average full day per trip benefit is overestimated by 36%. Variations in the distribution of demand amongst the peak and off-peak periods will also affect the magnitude and direction of deviation of per-trip benefit estimation based on equal weighing of demand compared to estimations considering regional demand.

6.2 Sensitivity of Results to ATIS Reporting Error

Results presented in Section 6.1 are based on the assumption that ATIS trip-based reporting accuracy is at the 90% level. That is, the differences between individual trip experiences and ATIS reports average to zero and have a standard deviation of 10% of the average trip time. This section explores how travel decision, and consequently travel outcomes vary if the true regional ATIS accuracy is higher or lower. Table 8 presents the outcomes of experiments where the on-time arrival threshold is maintained at 95% and the level of ATIS trip-based reporting error is set at 5%, 15%, and 20%.

Effect of ATIS Reporting Error For 95% On-Time Arrival Objective

	Level of ATIS Reporting Error			
Scenario Results	**5%**	**10%**	**15%**	**20%**
Percent of Trips That Benefit	74%	64%	51%	35%
ATIS Users Disutility Savings (All Trips)	$0.24	$0.18	$0.09	-$0.03
ATIS Users Disutility Savings (Trips That Benefit)	$0.26	$0.21	$0.16	$0.11
Reduction in Frequency of Early Arrivals	4%	-2%	-10%	-18%
Reduction in Frequency of Late Arrivals	6%	5%	5%	5%
Frequency of Route Changes	1%	1%	1%	1%
Frequency of Departure Time Changes	36%	42%	50%	57%

Table 8. Trip Decisions and Outcomes of ATIS Users at Varied Levels of ATIS Error

At higher levels of error, the ATIS tends to promote users to depart way too early, resulting in arrivals far earlier than their desired arrival times. Thus, at higher levels of ATIS error, fewer trips benefit from its routine use.

When the error is set to 5%, an additional 10% of all trips benefit from ATIS compared to the 10% reporting error. At the higher error levels of 15% and 20%, significantly fewer trips derive a net benefit from ATIS use across the 111 days of evaluation. At the 15% error level, approximately half of the population does not benefit from ATIS use; while at the 20% error level, 65% of the trips would find ATIS useless in improving their on-time reliability.

Still, at the 20% error level, there are trips that derive benefit; although, the population as a whole would generate an average negative impact from ATIS use of approximately 3 cents per trip. Figure 12 presents the annualized benefit at low market penetrations similar to Figure 11. Clearly, at these market penetration levels with HBF ATIS use, even high reporting error (20%) can generate significant user benefit to a targeted population of users. Approximately 1% of the potential ATIS users that have greatest potential from using ATIS can experience an annual benefit ranging from a high of $1.0 million (5% ATIS reporting error) to a low of $0.9 million (20% reporting error) as illustrated by the thick set of upper lines in Figure 12. At a slightly higher market penetration level of 4%, the benefit gap between a 5% and 20% reporting error widens to $0.81 million, where the annual benefits are $3.16 and $2.35 million, respectively.

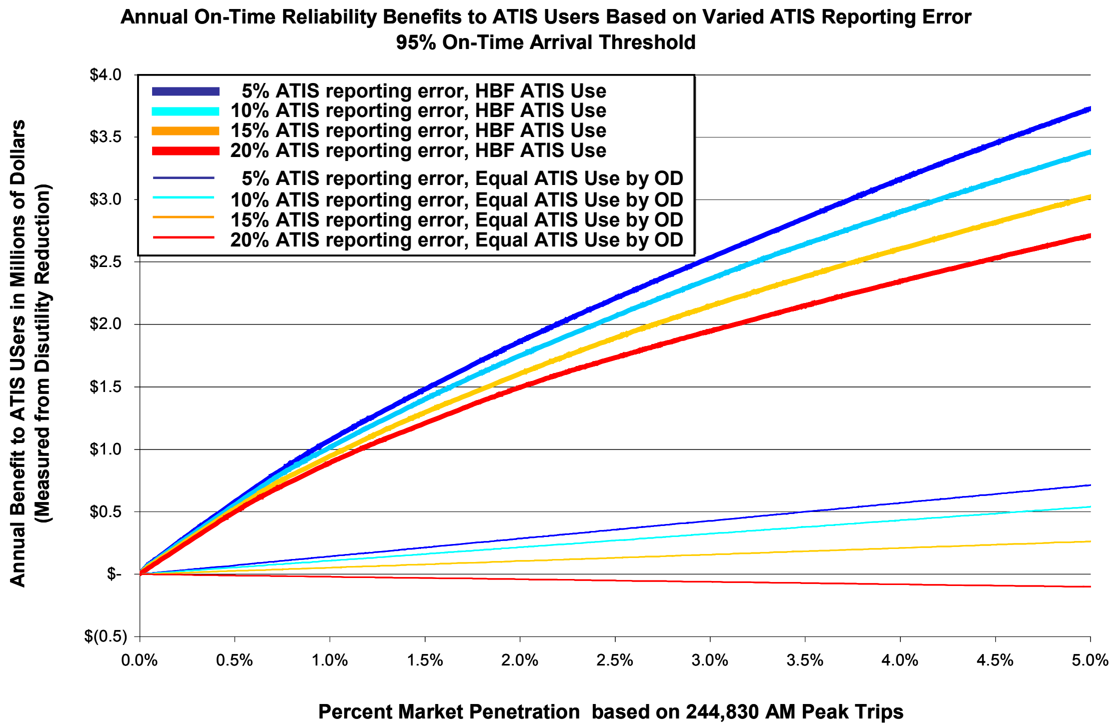

Figure 12. Annual Regional User Benefit at Varied ATIS Reporting Error

If ATIS use, however, is distributed evenly across all OD pairs regardless of user benefit, then users' will on average not benefit from traveler information at high levels of ATIS reporting error, as is illustrated by the thin red line (bottom most line) in Figure 12. At lower ATIS reporting error levels (15% or lower) the net regional benefit is positive for ATIS usage based on even geographic distribution of ATIS users. As stated in previous sections, the reality of how ATIS is adopted by travelers is somewhere between the set of thick and thin lines.

6.3 Sensitivity of Results to On-Time Arrival Thresholds

Results presented in Section 6.1 are based on the assumption that ATIS users' threshold for on-time arrivals is 95%. This section explores how travel decision, and consequently travel outcomes vary if commuters have a lower threshold for on-time arrivals. Table 9 presents the outcomes of experiments where the ATIS reporting error is maintained at 10% and the on-time arrival threshold set at 90%, 80%, and 70%.

ATIS User impacts based on Varied Thresholds for On-Time Arrival with ATIS Reporting Error Fixed at 10% (Seattle AM Peak Period)				
	Threshold for On-Time Arrival Frequency			
Scenario Results	**95%**	**90%**	**80%**	**70%**
Percent of Trips That Benefit	64%	64%	64%	66%
ATIS Users Disutility Savings (All Trips)	$0.18	$0.25	$0.34	$0.44
ATIS Users Disutility Savings (Trips That Benefit)	$0.21	$0.28	$0.37	$0.48
Reduction in Frequency of Early Arrivals	-2%	-1%	-1%	-1%
Reduction in Frequency of Late Arrivals	5%	7%	9%	12%
Frequency of Route Changes	1%	1%	1%	1%
Frequency of Departure Time Changes	42%	41%	39%	39%

Table 9. Trip Decisions and Outcomes of ATIS Users at Varied Levels of On-Time Arrival Thresholds

Clearly, at lower on-time arrival thresholds, commuters tend to arrive late with greater frequency. As such, ATIS has the opportunity to mitigate late arrivals with greater frequency for lower on-time arrival thresholds. At the 95% threshold level, 5% fewer ATIS users are late compared to ATIS non-users. At the 70% on-time arrival threshold level, 12% fewer ATIS users are late compared to ATIS non-users. Consequently, ATIS users can reduce trip disutility with a greater magnitude on average. This is borne by the average ATIS users' disutility savings compared to their counterparts who do not use ATIS. Across all trips, the savings go from $0.21 per trip to $0.44 per trip as the on-time arrival threshold is reduced from 95% to 70%.

The formula for calculating trip disutility remains the same across these varied on-time arrival threshold levels. That is, the coefficients representing penalties for late and early arrivals remain fixed regardless of commuters' perceived need to be on-time and consequences for late or early arrivals. In reality, commuters with lower on-time arrival thresholds would find arriving late less onerous that commuters with higher on-time arrival thresholds; and therefore, are likely to have lower disutility coefficients associated with late arrivals. Research, however, does not exist to indicate the levels of disutility differences. As such the disutility calculations in these analyses may somewhat overstate the benefit of ATIS for lower on-time arrival thresholds.

The following section places the finding presented in this section, Section 6, in the greater context of annual benefits and costs of ATIS as well as current literature on ATIS usage characteristics. The findings as they relate to hypotheses presented in Section 1.1 are also summarized in the following section.

7 CONTEXT SETTING, KEY FINDINGS, AND NEXT STEPS

This study explores the benefit in terms of on-time reliability to potential users of a personalized ATIS providing real-time pre-trip roadway information for the Seattle AM peak period. Regional savings via trip disutility reductions are measured for low levels of market penetration (0% - 3%) where ATIS user's individual trips decisions are not expected to affect traffic dynamics. Market penetration percentages are based on the population of travelers using roads where ATIS is available rather than the population of the region.

Based on our calculations, regional benefit to routine users of the ATIS ranges from negligible to substantial ($2.5 million annually) depending on the market penetration strategy and ATIS accuracy level. Other significant benefits to ATIS users related to serenity, opportunities to reschedule other priorities, and to making small incremental changes to trip route are not assessed in this study or translated to the monetary savings calculated in this study.

Market penetration at the 1% level translated to approximately 2445 routine, or daily, AM peak trips where the pre-trip ATIS is consulted. To put this number in perspective, we draw upon a recent study published by Peirce and Lappin, 2003 wherein the travel information usage of 3,300 individuals in the Puget Sound Region were analyzed through a 2-day travel diary. For approximately 35 trips daily, the use a traffic website was noted that is similar in concept to the ATIS modeled in this study. Maintaining this ratio of trips to individuals suggests a current potential of 17,000 trips throughout the entire day for a population of 2.26 million (King and Snohomish counties, 1999).

The findings as they relate to hypotheses presented in Section 1.1 are also summarized in the following section. The final section highlights concepts for further research.

7.1 Key Findings

This study conducted a number of experiments to estimate aggregate regional benefit to pre-trip ATIS users within a peak period in Seattle, Washington. In addition, these experiments examined how the magnitude of ATIS users' on-time reliability benefits varied with different levels of ATIS accuracy and ATIS users' need for on-time arrivals. Three key hypotheses formulated and assessed through the conduct of HOWLATE experiments are:

1. The traditional aggregation of ATIS user benefit as measured by trip disutility will be higher than results weighted by regional demand for the AM peak because of an overrepresentation of very long trips that are likely to have high benefit from ATIS use.

2. At high levels of reporting error, in the order of 15% to 20%, there will still exist a pocket population of ATIS users that will derive significant benefits from ATIS.

3. Commuters without stringent on-time arrival needs may benefit more frequently from ATIS use compared to commuters with stringent on-time arrival needs.

With regard to hypothesis 1, we confirm that in the Seattle AM peak evaluation, the equal weighting of trips over estimates regionally, ATIS users' reduction in late arrivals and increase in early arrivals by 28% and 79%, respectively, compared to counterparts with fixed departure time and route. Regional reduction in trip disutility of ATIS users is consequently overestimated in the Seattle AM peak by 22% across all trips and by 31% across those trips that benefit from ATIS use. These results are based on the baseline scenario of 10% ATIS reporting error and 95% on-time arrival threshold of commuters. This outcome of overestimation of ATIS benefit for peak periods based on the traditional HOWLATE process, however, can not be transferred for aggregate per-trip benefit throughout the day given the complexity of demand, congestion and regional variations between peak and off-peak periods as explored in Section 6.1.4.

In addition, we explored the regional aggregate on-time reliability benefit of ATIS at low levels of market penetration based on three market penetration strategies. Figure 11 charts regional on-time reliability of benefits to ATIS users in terms of dollar-valued disutility reduction for low levels of market penetration. Annualized ATIS users' trip disutility reductions for the AM peak period in Seattle at a 1% level of market penetration (approximately 2450 routine users) ranged from $0.2 million based on a uniform market penetration assumptions to $1.0 million based on a market penetration strategy where those who benefit most use ATIS first. A more comprehensive assessment of ATIS benefit, that also considers transportation system and users' serenity-based impacts from ATIS use, would surely raise estimates calculated and presented in Figure 11.

With regard to hypothesis 2, we evaluated the on-time reliability impacts of ATIS at the 5%, 10%, 15%, and 20% levels of ATIS reporting error. At a low market penetration level of 1%, the annual benefit based on a market penetration strategy where those who benefit most use ATIS first is approximately $1.1 million at the 5% ATIS error level and $0.8 million at the 20% ATIS error level. The same market penetration strategy based on 3% of the population using ATIS yields benefits of $2.6 and $1.9 million for ATIS reporting error levels of 5% and 20%, respectively. Yet, the percentage of trips that benefited from ATIS dropped from 74% to 35% when the error level increased from 5% to 20%; and, ATIS users' disutility savings drop from $0.24 per trip at the 5% error level to -$0.03 at the 20% error level, when outcomes for all trips are averaged. Thus we conclude that although the region as a whole may not benefit from ATIS when reporting error is high, pocket populations can still garner significant ATIS on-time reliability benefits from routine ATIS use.

Our third hypothesis, that commuters without stringent on-time arrival needs may benefit more frequently from ATIS use compared to commuters with stringent on-time arrival needs, proved to be the case. The frequency of late arrivals was reduced by ATIS users by 5% for those with a 95% on-time arrival budget and by 12% for those with a 70% on time arrival budget under a baseline ATIS error level of 10%. These savings, in both scenarios were at the expense of slight increases in the frequency of early arrivals – a 2% increase for the traveler with a 95% on-time arrival budget, and a 1% increase for the traveler with a 70% on-time arrival budget. Given that the penalties for early and late arrivals were fixed among all scenarios, and that those budgeting less time for travel had more opportunities to eliminate late arrivals, the average disutility savings increase from $0.18 per trip to $0.25, $0.34, and $0.44 per trip, respectively for 95%, 90%, 80%, and 70% on-time arrival budgets.

7.2 Next Steps

This study establishes the importance of regional demand on accurate calculation of regional ATIS user benefit and highlights how regional benefit can vary tremendously geographically. These findings are based on the assessment of the AM peak period. To what extent these findings translate to the off-peak periods, to the PM peak, and to the entire day is a more complex issue that should be further studied. Also, the quantification of benefits is based on vehicle trips. For regions with significant carpooling activities, which tend to be concentrated during peak periods, current estimates of benefit may be understated.

In improving the extent of level of understanding of geographic market penetration concepts, we should explore how frequently users for certain recurrent trips derive benefit and whether comparison against fixed departure time and routes may generate overly optimistic benefits. Perhaps applying HOWLATE based on a rolling horizon of habitual travel setting and evaluation scheme may produce more a robust base for comparison to ATIS users. Similarly, benefits from ATIS use compared to use of en-route radio or other traveler information can shed greater light on realistic market size for ATIS.

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