Corroborating Qualitative Benefits of Online ATIS With Modeling

Los Angeles Case Study

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Background

This report documents a modeling study performed as a follow-up to a qualitative online evaluation of the Traveler Advisory News Network (TANN) and SmarTraveler traffic information web sites (7,8) by researchers at the Volpe National Transportation Systems Center (9). The Volpe study found that users of these web sites perceived that they saved time and arrived on time more reliably as a result of accessing these web sites for real-time traffic information. As a follow-up to this qualitative study, the study presented in this paper uses an analytic approach using field data to empirically corroborate these findings.

The Volpe study was funded by the Southern California Association of Governments (SCAG), the Federal Highway Administration, and several private corporations. The project was managed by John Cox of The Partnership, a private, nonprofit corporation that develops strategies to accelerate the growth of advanced transportation technologies in Southern California, and performed by Jane Lappin and Margaret Petrella of the Volpe Center. Its purpose was to better understand customer satisfaction with Los Angeles traffic web sites, the impact of traffic information on driver behavior, and the nature of the market for online traffic information services. The study approach included both focus groups and an online intercept survey. Four focus groups were convened in August 2001. The composition of the focus groups was weighted toward users who had been using the service over a longer period of time and who used it more frequently. The objective of the focus groups was to listen to customers talk about the online service: how they used it, what benefits it provided to them, and what improvements (if any) they wanted to see to it. Findings from the focus groups were then used to design questions for the online survey. Banners advertised the online intercept survey, which was conducted during the period January 7, 2002 through March 9, 2002. Respondents clicked on the banner and were taken to a page introducing the study and the questionnaire. There were 336 respondents who completed the online questionnaire. The quantitative data collected from the survey were used to measure customer satisfaction with LA traffic web sites and to better understand the impact of traffic information on traveler behavior.

According to the findings from the Volpe study, these services were likely to influence the behavior of their users. In addition, many users believed online traffic information helped them save time by avoiding congestion; others believed it helped them to arrive on time more reliably. Furthermore, survey respondents reported less congestion delay, on average, than what was reported for the Los Angeles metropolitan area by the Texas Transportation Institute[1] (10).

Approach

Many of these findings from the Volpe study regarding the effectiveness of ATIS were perceptual in nature. Travelers who changed their behavior due to online traffic information did not know what would have happened had they kept to their normal routines. The study presented in this paper is designed to corroborate these survey results with an analytic approach. We employed a retrospective simulation technique using archived travel time data from an ATIS, This technique, which is called HOWLATE

[1] Although similar in intent, congestion delay was calculated differently in the Volpe study and the Texas Transportation Institute (TTI) report. The Volpe figure is based on two survey questions: one asking for the respondent's average trip travel time in peak periods and the other for the travel time in free flow conditions. The TTI figure is based on calculations based on traffic volume data.

(Heuristic On-Line Web-Linked Arrival Time Estimator), allowed us to conduct controlled experiments asking the question "What would have happened if...?" based on travel times for different driving trips at different times on different days in the archive (11,12,13). In this simulated environment, we could determine the effectiveness of ATIS for freeway trips across the region by comparing the outcome of an ATIS user who may leave earlier or later or change route in response to real-time traffic information and a "habitual" commuter who maintained the same time of departure and route from day to day. The results from this type of study can lend credence to or cast doubt upon the conclusions made from ATIS users' perceptions of time savings and on-time reliability improvements, answering the question of whether the perceived benefits from ATIS are realized by users over the long term.

To address this issue, we applied the HOWLATE methodology to an archive of travel times and loop detector speed data on the major freeways in the Los Angeles metropolitan area. This data archive came from the Highway Performance Measurement System (PeMS), developed by Partners for Advanced Transit and Highways (PATH) in California (14). We attempted to model, as closely as possible, the travel experiences of the Volpe study participants in order that our results were as applicable as possible to the Volpe study results. To this end, this study had the following elements:

- The Volpe study participants were users of the TANN web site whose main feature was a map of Los Angeles, which was color-coded to indicate current congestion levels. Detector locations on the major area freeways were denoted by dots that were either green, yellow or red to represent current speeds. The archive of loop detector speeds allowed us to recreate what the map would have shown at any point in time. The archive of travel times allowed us to recreate how long trips would take for a given trip origin, destination, route, and departure time.
- ATIS users used the map to decide when to leave and which route they should take. We devised a training process to model how travelers learn over time what trip travel time to expect based on the colors of the map on their habitual and alternative routes. In addition, we ran a second set of trials where instead of providing the map, the ATIS service provided customized route and departure time guidance based on travel time estimates of reasonable accuracy.
- The set of Volpe study participants did not have a common degree of flexibility regarding when they could leave and whether or not they had a strict on time requirement. Therefore, we defined archetypes to describe subsets of ATIS users. This paper deals exclusively with the subset of travelers who needed to be on time, called the fixed arrival archetype. We defined a model describing how ATIS users and non users select route and departure time with the goal of arriving on time.
- We modeled trip making behavior and trip results over the same time period as the Volpe study.
- We simulated all possible trips, and also aggregated results for the subset of trips corresponding to the Volpe study respondents' work and home zip codes.

Key Findings

Simulated users of the TANN and SmarTraveler web sites improved their on-time reliability compared to simulated commuters familiar with the dynamics of LA traffic patterns. This improved on-time reliability observed in simulation is consistent with the perceptions of actual ATIS users measured in the Volpe study.

On the basis of the average of all possible origin, destination, and target arrival time combinations, an ATIS user with a three-colored congestion map like that on the TANN web site arrived on time more reliably than a traveler without ATIS in Los Angeles assuming both were familiar with their trip, i.e., they made it regularly. On average, there was benefit to congestion map users at all times of day.

Using a disutility function that considered earliness, lateness, and travel time, we calculated a disutility for each trip (15). The difference between the disutility for the ATIS user and the ATIS non-user for the same trip revealed, in monetary terms, the benefit from using ATIS for that trip. At $0.52 per trip, the greatest benefit was realized by PM peak trips, followed by the off-peak and the AM peak at $0.20 per trip and $0.02 per trip, respectively. That there was less benefit in the AM than the off peak ($0.02 vs. $0.20) is a somewhat puzzling result. It may be due to the fact that green dots, which seem to indicate free flow but actually indicate speeds as low as 35 mph, were more often misleading in the AM peak than the off peak or the PM peak in that speeds were more often be in the 35-40 mph range. The PM peak, because it was more congested than the AM peak, was more likely to have congestion in the yellow or red range on the map.

Due to the limitations inherent in color-coded congestion maps, simulated commuters arrived on time more reliably with a personalized traffic information service based on route travel times.

Users of a travel time-based ATIS benefited more than congestion map users. An ATIS service that provides route and departure time guidance based on reasonably accurate travel time estimates is a higher quality service. Users of an ATIS service of this type benefited $0.93 per trip for all trips compared with $0.21 per trip for congestion map users. In certain cases, however, congestion maps are preferable to personalized route guidance based on travel times. Maps allow the user to see more precisely where freeway congestion lies so that if surface street alternatives are available, short diversions from the freeway may be exploited. Since ITS surveillance is typically limited to freeways, a service based on route travel times will not be able to consider these short diversions. Such is the case in LA – since we only had speed and travel time data for freeways, this is not something we could capture in this study.

For congestion map users, 40% of all trips benefited (a trip is defined by a unique origin, destination, and arrival time), though a higher percentage (60%) benefited in the PM peak. That is three days out of every week. Someone needing to be on time who paid $1 per trip for ATIS would have gotten his money's worth 20% of the time (once per week) – 36.9% of the time for PM peak trips (approximately twice a week).

For our simulated Los Angeles commuters, the most important decision one who needs to be on time can make is when to leave. As a result, guidance in selecting an optimal departure time is the primary means through which ATIS benefits people who need to be on time.

ATIS users could respond to real-time traffic information by changing route or departure time. In our results, the only ATIS response that provided a consistent benefit for congestion map users was later than normal departure at $0.42 per trip. This was also the most frequent response at 54% of trips. All other responses had negative benefit; alternate routes led to disbenefit of over $1.40. This could be partly attributed to the model of training to the congestion map. Training was done on the basis of the habitual route. Therefore, alternate route travel times were estimated with far less precision than habitual route travel times. Note that this result simply highlights the importance of departure time adjustment in response to congestion reports in ensuring on-time reliability. The habitual commuter (ATIS non-user) serving as the base case was very conservative; he selected a departure time to aim to be on time 95% of the time. As a result he was rarely late at the expense of often being early. If a less conservative habitual user were chosen as the base case, it is likely the value and frequency of earlier than normal departures would increase relative to later than normal departures.

An analysis of simulated commuters making trips corresponding to the participants of the Volpe study (based on their work and home zip codes) showed that these tripmakers improved on time reliability by referring to the congestion map prior to their trips. However, their results were mixed relative to the general population.

We mapped trip origin and destination nodes to the home and work zip codes of the Volpe study participants and calculated average trip results for this subset of trips. In the AM peak, we included trips from home to work and in the PM peak, work to home. This subset of trips realized benefit in both the AM and PM peaks. The AM peak subset had more benefit than the set of all AM peak trips ($0.11 vs. $0.02 per trip) but the PM peak subset had less ($0.28 vs. $0.52 per trip). This gives credence to the on-time reliability benefits perceived by the Volpe study participants. However, it is somewhat surprising that PM peak trips did not benefit as much for this subset of trips. The focus group respondents were heavy users of ATIS but we do not know the regularity of usage of the survey respondents. Furthermore, a confounding factor is that we do not know which of the trips correspond to travelers of the archetype that needs to be on time and which are of other archetypes.

Simulated users of traffic information did not all receive equal benefit. In fact, there could be a big difference between the benefit realized by one user versus another. Those who made trips that were very long and in the peak periods benefited the most from pre-trip traffic information. The top 1% of trips in terms of benefit realized 36 times more benefit than the average trip.

The trips that benefited the most in Los Angeles were those passing through the most congested part of the network, which in the morning was I-405 Northbound and in the afternoon was the central business district, where there were no competitive alternate routes (on freeways). The top 1% of trips benefited more than 50% over non users of ATIS, a utility improvement of $7.15 per trip. This was much more than the set of all trips, which benefited $0.20 per trip. The top 1% of trips benefited 36 times more than the average trip ($7.15 vs. $0.20). These were generally longer trips, as expected.

Drawing on previous work correlating ATIS benefits with accuracy, we were able to equate the precision of the congestion map with that of a comparable travel time service. The congestion map was determined to be comparable to a moderately accurate travel time service.

Congestion map users realized benefit comparable to travel time-based ATIS users where travel time estimates had an error of 13% in uncongested conditions and 19% in congested conditions. This was the most precise a three-colored map can be since the speeds from which the colors were based were accurate in this study. In Los Angeles, the average trip could still benefit using traffic information with this much uncertainty. However, the day-to-day variability in Los Angeles is high relative to other metropolitan areas. In other cities where variability is not as high, better resolution may be required for the average trip to benefit. The only way for a map to improve precision would be to add more colors to the map to provide a finer scale. Theoretically, the precision of the map would improve to an optimum as the number of available colors goes to infinity. However, there is a limit as to how many colors a person can meaningfully differentiate. Examining this limit and the associated tradeoffs of a map with more colors was beyond the scope of this work.

1. Introduction

Online Advanced Traveler Information Systems (ATIS) have proliferated in the last decade and now number 37 in the U.S. (1) Among ATIS web sites, a common format is a map of a metropolitan area where major roads are color-coded to indicate current congestion levels. The Internet is conducive to presenting such spatial information. Users can quickly and easily attain relevant information from maps while ignoring what is irrelevant.

Past studies have shown that people like these web sites (2,3,4,5,6). Users report "serenity" benefits. That is, they feel less stressed if they can find out about an accident ahead even if there is nothing they can do about it. Furthermore, they can call ahead if they know they will be delayed or simply feel in control of their fate whether or not they can truly improve their lot. Though they are hard to quantify, these are real benefits because they improve our quality of life. Many also report that ATIS helps them to save time or arrive on time more reliably. These mobility and productivity benefits are difficult to demonstrate. ATIS users may believe real-time traffic information helps them to save time or arrive on time more reliably, but often it is difficult to be sure.

An online evaluation of the Traveler Advisory News Network (TANN) and SmarTraveler traffic information web sites (7,8) was conducted in order to better understand customer satisfaction with Los Angeles traffic web sites, the impact of traffic information on driver behavior, and the nature of the market for online traffic information services. The Southern California Association of Governments (SCAG), Federal Highway Administration, and several private corporations funded the study. The project was managed by John Cox of The Partnership, a private, nonprofit corporation that develops strategies to accelerate the growth of advanced transportation technologies in Southern California, and performed by Jane Lappin and Margaret Petrella of the Volpe National Transportation Systems Center.

The Volpe study approach included both focus groups and an online intercept survey. Four focus groups were convened in August 2001. The composition of the focus groups was weighted toward users who had been using the service over a longer period of time and who used it more frequently. The objective of the focus groups was to listen to customers talk about the online service: how they used it, what benefits it provided to them, and what improvements (if any) they wanted to see to it. Findings from the focus groups were then used to design questions for the online survey. Banners advertised the online intercept survey, which was conducted during the period January 7, 2002 through March 9, 2002. Respondents clicked on the banner and were taken to a page introducing the study and the questionnaire. There were 336 respondents who completed the online questionnaire. The quantitative data collected from the survey were used to measure customer satisfaction with LA traffic web sites and to better understand the impact of traffic information on traveler behavior.

According to the findings of the Volpe study, these services were likely to influence the behavior of their users (9). In addition, many users believed online traffic information helped them save time by avoiding congestion; others believed it helped them to arrive on time more reliably. Furthermore, survey respondents reported less congestion delay, on average, than what was reported for the Los Angeles metropolitan area by the Texas Transportation Institute[2] (10).

Many of these findings regarding the effectiveness of ATIS were perceptual in nature. Travelers who changed their behavior due to online traffic information did not know what would have happened had they kept to their prior routines. Only by conducting an experiment with both an experimental subject (one who may change behavior due to ATIS information) and a control subject (one who keeps to his habitual behavior irrespective of day-to-day fluctuations) and comparing trip-by-trip outcomes can we make conclusions regarding time savings or on-time reliability improvements from ATIS.

The study presented in this paper was designed to corroborate these survey results with an analytic approach. We employed a retrospective simulation technique using archived travel time data from an ATIS (11,12,13). This technique, which is called HOWLATE (Heuristic On-Line Web-Linked Arrival Time Estimator), allowed us to conduct controlled experiments asking the question "What would have happened if...?" based on travel times for different driving trips at different times on different days in the archive. In this simulated environment, we could determine the effectiveness of ATIS for freeway trips across the region by comparing the outcome of an ATIS user who may leave earlier or later or change route in response to real-time traffic information and a "habitual" commuter who maintains the same time of departure and route from day to day. The results from this type of study can lend credence to or detract from the conclusions made from ATIS users' perceptions of time savings and on-time reliability improvements.

This study used an archive of freeway travel times for the Los Angeles metropolitan area for the time period of the Volpe study. This archive comes from the Highway Performance Measurement System (PeMS), developed by Partners for Advanced Transit and Highways (PATH) in California (14). PeMS is a database of traffic data from Caltrans loop detectors in the major metropolitan areas in California developed to support various research, operations, and planning tasks. In addition to collecting loop detector data in real-time and estimating point-to-point travel times, it maintains an extensive archive of both the loop data and travel time estimates. Using this archive, we could recreate what trip travel times may have been on a given day for various origins and destinations in the Los Angeles metropolitan area for departure times throughout the day, as well as calculate the fastest paths. We could also recreate a color-coded congestion map a user of online ATIS would have seen at any given time based on five-minute average speeds at each loop detector.

2. Modeling Approach

In this study, in order to gain the best possible insight into the mobility benefits of ATIS for the Volpe study participants, we wanted to model the reality they experienced as closely as possible. This includes the type of ATIS service they used as well as their different behavioral characteristics. The ATIS service featured a refreshable color-coded congestion map where speeds are denoted with colors (Figure 1). The behavioral characteristics among the participants were varied but could be classified into four main categories or “archetypes:”

- Those who had to arrive at their destination (e.g., work place, day care center) at a fixed time

[2] Although similar in intent, congestion delay was calculated differently in the Volpe study and the Texas Transportation Institute (TTI) report. The Volpe figure is based on two survey questions: one asking for the respondent’s average trip travel time in peak periods and the other for the travel time in free flow conditions. The TTI figure is based on calculations based on traffic volume data.

- Those who had flexibility in their arrival time whose objective is to save time by avoiding congestion
- Those with flexible schedules whose jobs required them to make appointments throughout the day
- Those who needed to balance a work schedule and also pick up and drop off children and who had little scheduling flexibility.

Each of these traveler behavior archetypes could also be further distinguished by their familiarity or lack of familiarity with the ATIS web site.

2.1. Modeling Trips Using the HOWLATE Methodology

The HOWLATE methodology used segment travel time data archived from an ATIS provider to recreate hypothetical trips over a transportation network. In order to determine how long a certain trip would have taken, we traversed a simulated traveler over the segments that comprised his trip over time, basing his trip time on the travel times archived for those segments at the time he reaches them. Using this data, we could answer "What if" questions such as, "What if a traveler had left five minutes earlier?" or "What if a traveler had taken an alternate route to his destination?" This allowed us to simulate controlled "field" trials where a control subject (a non-user of ATIS) and an experimental subject (a user of ATIS) both make the same trip. Pairing two travelers with the same target time of arrival or the same habitual departure time, we could isolate whether ATIS helped a traveler to arrive on time or to save travel time. The results of large numbers of these paired trials enabled us to estimate the benefits of ATIS in a metropolitan area.

The HOWALTE methodology has the following elements:

- **Data Archive** – The travel time archive forms the basis of our simulated trips. With it, we have estimates of how long trips took on different routes at different times on different days. In this study, we also have an archive of detector speeds with which we can recreate the congestion map that would have been available for ATIS users at any day and time in the archive.

- **Training** – Non-users of ATIS select their habitual route and habitual departure time on the basis of historical average travel times and day-to-day travel time variability for their trip. For this historical data, we take a portion of the beginning of the travel time archive and designate it as a training period, with the remaining days set aside for an evaluation period. The habitual routes for ATIS non-users are the shortest time paths for each origin, destination and target arrival time based on the average travel times in the training period. Habitual departure time is calculated by subtracting the average travel time on the habitual path and an additional buffer time from the target arrival time at the destination. Under the assumption that trip travel times are normally distributed from day to day, the additional buffer time is set to ensure the likelihood of late arrival is equal to the late arrival tolerance level. The greater the day-to-day travel time variance for a trip and the lower the tolerance for late arrivals, the larger this buffer will be. In this study, we assume the ATIS non-user selects a buffer large enough to ensure an on time arrival 95% of the time (one late arrival for every 20 trips).

- **Evaluation** – On each day in the evaluation period, the ATIS non-user departs from his trip origin at the habitual trip start time and follows the habitual path to his destination. ATIS users on the other hand, prior to each trip, select a departure time and path based on real-time traffic information from the ATIS. In-vehicle travel time and on-time performance are computed for both the ATIS user and the ATIS non-user based on time-variant travel times for each day. Results for each traveling pair are recorded and compiled.

2.2. Modeling User Response to a Color-Coded Congestion Map

The most common type of online ATIS service available today is a color-coded, refreshable congestion map of a metropolitan region. According to most recently available data kept by the ITS Deployment Tracking task of the US DOT ITS JPO, 37 different metropolitan regions in the U.S. offer ATIS in this format (1). Furthermore, while people like these web sites, it is not known whether users derive measurable mobility benefits. As the subjects of the Volpe study were regular users of TANN[3], which features a congestion map of this type on its web site, this is the service we wanted to model. The TANN map shows dots along the major freeways in the Los Angeles metropolitan area corresponding to point speed measurements from Caltrans loop detector stations. Green dots denote speeds greater than 35 miles per hour, yellow dots 15 to 35 miles per hour, and red less than 15 miles per hour. Users of this service, therefore, must judge traffic conditions on their preferred and alternate paths and determine when to leave based on these dots. The TANN map also included icons showing incident locations and details from the California Highway Patrol (CHP). However, we do not have an archive of incident information so we could not incorporate this into our analysis. While this would have been valuable, we had to rely on the fact that any delays caused by incidents are reflected in the speed data.

In modeling user response to the color-coded map, we assumed all ATIS users translated the map into travel time estimates on their primary and secondary routes. With these travel time estimates, they determined which route to take and when to leave. How this was done depends on whether the web site users were familiar or unfamiliar with the service. ATIS users familiar with the service, i.e., those who use it regularly, were able to draw upon past experience to interpret the color-coded map. According to focus group respondents, these commuters knew the ins and outs of the traffic patterns for their particular routes at the times they travel. In addition, they had a good idea what delays to expect when they saw various levels of congestion on the web site. For these users, there is undoubtedly a complex learning process whereby over time, they can translate various arrangements of the colored dots into expected travel times on primary and secondary routes. As an approximation of this process, we used a multiple linear regression model, where the fraction of yellow and the fraction of red dots along a traveler's habitual route became predictors of his travel time. For each day in a training period, prior to departure, the fraction of yellow and red dots was noted, and upon arrival at the destination the travel time was noted. In order for us to apply this model to evaluate alternate routes, we considered the fraction of each color dot instead of the number of dots and average speed over the trip instead of travel time so that we could evaluate routes of differing lengths.

The model parameters were:

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[3] Respondents were drawn from users of the TANN and SmarTraveler web sites. These web sites were very similar in format and obtained information from many of the same sources. SmarTraveler, however, stopped servicing Los Angeles between the time of the survey and when this study was conducted. Therefore, our aim will be to model the TANN service as well as possible.

N_y = number of yellow dots on a route
N_r = number of red dots on a route
$P_y = N_y / (N_g + N_y + N_r)$ = fraction of yellow dots
$P_r = N_r / (N_g + N_y + N_r)$ = fraction of red dots

T = travel time
L = trip length
b_0 = expected travel speed if all dots are green [miles per hour]
b_y = adjustment for the fraction of yellow dots [miles per hour per fraction yellow]
b_r = adjustment for the fraction of red dots [miles per hour per fraction red]

The values b_0, b_y, and b_r were the coefficients resulting from the regression model where the number of observations was equal to the number of days in the training period for each trip (a trip is defined as a specific origin, destination, and time of day). Note that b_0 was not necessarily the free flow speed, but the expected average trip speed when all dots on the route were green. Because a green dot could indicate speeds as low as 35 mph, a route with all green dots did not mean it was without delay. Because of this, it there was a good deal of variation in this estimate, i.e., the standard error of b_0 was relatively high. The expected average trip speed for each day in the evaluation period was then:

$$\frac{L}{T} = b_0 + b_y \cdot P_y + b_r \cdot P_r$$

2.3. Travel Time-Based ATIS

For purposes of comparison, we also conducted trials with a second type of ATIS service – one that provided personalized route and departure time guidance based on travel time estimates with a specified amount of error. This error corresponded to an estimate of the best possible accuracy for the conversion of loop detector speeds to travel times (13). In congested conditions it was 10% and in uncongested conditions it was 5%. Results from the travel time based ATIS served to show an upper bound, i.e., the benefit of a much more precise service. While the precision of travel time estimates gleaned from the map were limited by the number of colors and spacing of dots, the provision of travel times was not so limited and could therefore be more precise.

2.4. Modeling the Traveler Behavior Archetypes

Not all travelers are the same. Different people have different amounts of flexibility in their schedules and different objectives for using traveler information. The subjects of the Volpe study could be classified into four archetypes: those who had to arrive at their destination on time, those who had flexibility in their departure time and wanted to minimize their travel time, and trip chaining variations of these two.

The first archetype's highest priority was to arrive at his destination on time. This archetype was what inspired previous ATIS evaluation studies using the HOWLATE methodology. In our controlled experiment of ATIS benefit, the ATIS user and non-user each had a common origin, destination and target arrival time. Their mutual objective was to select a departure time and route in order to arrive on time. This type of traveler used ATIS in order to know whether to leave earlier or later, depending on congestion, to reliably arrive on time but not too early (i.e., "just-in-time"). The ATIS non-user must leave himself a fixed buffer time in order to ensure an on time arrival a sufficient percentage of the time. This may cause him to be very early when traffic is especially light and late when traffic is especially heavy. For details on how this archetype is modeled, see (9,12). A flowchart detailing the decision mechanism is shown in Figure 2.

The second archetype did not have an on-time requirement, but rather had flexibility in his departure time. His goal was to save time by avoiding congestion and he did this by delaying his departure when traffic was bad at the time he would normally leave. This traveler was fundamentally different from the traveler who needed to be on time. The ATIS user and non-user of this type had a common habitual departure time instead of a common target arrival time. Instead of using ATIS to improve "just-in-time" reliability, he used it with the hope that he could reduce his in-vehicle travel time. As with the traveler who needed to be on time, this traveler sought time management benefits from ATIS. However, instead of trying to minimize early time at his destination, the traveler with flexible departure made use of the time he waited for traffic to lessen by working later or running errands close to his trip origin. The exact decision mechanism we will use to model this archetype is still under development.

Two other archetypes that came out of the Volpe study were variants of these two, each adding a trip chaining component. The first had flexibility to rearrange or postpone his various appointments throughout the day based on traffic; he was most similar to the flexible departure archetype. The second had very strict scheduling constraints; he was most similar to the archetype who must be on time. The benefits for this traveler may only lie in the realm of "serenity" or being able to call ahead if he knows he will be delayed. We will consider modeling these two archetypes at a later time.

3. Experimental Design

3.1. Study Period and Data

The PeMS data archive goes back as far as September 20, 2001 and despite a few missing days is complete to the current time. The Volpe study was conducted between January 7 and March 7, 2002. That allowed us a 42 day training period prior to this time: September 20, 2001 through December 19, 2001. The evaluation period consisted of 43 days from January 10, 2002 through March 27, 2002.

For each day, PeMS maintains travel times on 122 distinct unidirectional segments, every five minutes at all times of day. This study considered only trips with habitual departure times or target arrival times, depending on the archetype, between 5:30 a.m. and 9:00 p.m. Based on a clustering analysis of the travel time data, the morning and afternoon peak periods were determined to extend from 6:30 a.m. to 9:00 a.m. and 2:30 p.m. to 6:45 p.m., respectively. These definitions were used to aggregate performance measures by peak vs. off-peak. The network consisted of 41 nodes, which are the intersection points of the 122 segments. This is shown in Figure 3. Trips were modeled between all possible origins and destinations, with target arrival time every fifteen minutes during the study period. In all, that is 103,320 (41 origins × 40 destinations × 63 arrival times) trips per day. That is over 4.3 million trips in each of the training and evaluation periods.

<Figure 3. The network of nodes and links.>

In addition to segment travel times, PeMS also maintains an archive of the loop detector data. Speeds at detector stations are aggregated and archived every five minutes. Using this data, we recreated the number of green, yellow, and red dots that would appear on each segment of the color-coded map, based on the speed ranges for these colors used by TANN. This data formed the basis for the training methodology.

3.2. Performance Measures

For the Fixed Arrival archetype, the key performance measure was dollar-valued trip disutility. Dollar-valued disutility provides 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 based on the work of Small, et al. (15). The disutility of in-vehicle travel time was set at $3.38/hour based on their research. The cost of early arrival is a quadratic function of the magnitude of early arrival. The cost of a late arrival is a linear function of the magnitude of late arrival plus a one-step penalty for arriving late. Note that the cost of late or early arrival is not sensitive to the duration of the trip, however. That is, 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 for two sample trips of different lengths is shown in Figure 4. Based on the parameters fitted by Small, et al, the disutility function has the following cost values:

- $2.00 = arriving 8 minutes early on a 30 minute trip.
- $5.00 = arriving 1 second late on a 30 minute trip.
- $2.00 = value of reducing lateness by 6 minutes for any length trip.
- $2.87 = value of going from late to on time for any length trip.

<Figure 4. Disutility as a function of early and late schedule delay and trip travel time>

We also wanted to determine how accurate the color-coded map is relative to travel times. We could do this by drawing upon previous work on the relationship between ATIS benefit and accuracy.

3.3. Study Hypotheses

We hypothesized the following:

3.3.1. Hypothesis #1:

Relative to the baseline case of habitual ATIS non-users, users of the congestion map will realize on-time reliability benefit, but users of the travel time-based ATIS will realize more benefit.

3.3.2. Hypothesis #2:

Guidance in selecting an optimal departure time is the primary means through which ATIS benefits people who need to be on time. The most frequent and beneficial response to the congestion map and travel time-based ATIS services will be departure time adjustment.

3.3.3. Hypothesis #3:

Because the participants of the Volpe study were users of online ATIS and because they reported benefits from using ATIS services, we expect trips with corresponding zip codes will have more benefit than the set of all trips.

3.3.4. Hypothesis #4:

The trips having the most benefit will be predominately longer trips in the peak periods. Past research on ATIS benefits has shown there to be significant variation in benefit across trips for users seeking to improve on time reliability. Therefore, the 1% of trips realizing the most ATIS benefit will realize significantly more benefit than the set of all trips.

3.3.5. Hypothesis #5:

Drawing on previous work correlating ATIS benefit with accuracy, we will be able to estimate the effective accuracy of the congestion map. The congestion map will have more effective error and therefore will provide less benefit to its users than reasonably accurate travel times because it is limited by having only three colors with which to represent speeds.

4. Results

4.1. Fixed Arrival Archetype Results for All Trips

The familiar traveler who needed to be on time and who used the congestion map arrived on time more reliably than his habitual counterpart as shown in Table 1 and Figure 5. He did not do as well as when the ATIS user was given travel times, however. Therefore, while the lesser precision of the map relative to travel time estimates reduced the potential benefit to ATIS users, users of the map still performed better than travelers who did not use ATIS. This demonstrates the limitation of the congestion map. Even if the speeds measured by the detectors were perfectly accurate, a three-colored map is not as precise as accurate travel time estimates.

	Habitual (Base Case)	ATIS (using map)	ATIS (travel times)
All Trips	$2.94	$2.73	$2.01
AM Trips	$3.38	$3.36	$2.22
Off-Peak Trips	$2.14	$2.05	$1.70
PM Trips	$4.16	$3.64	$2.48

Table 1. Trip Disutility by Time of Day ($)

Table 2 shows the same results as Table 1 in terms of utility improvement and percent reduction in disutility. The most benefit, both in absolute and percentage terms was seen in the PM peak. In a paradoxical result, more benefit was realized for off peak trips than for AM peak trips. Given that this was not the case for the travel time-based ATIS, results for which are shown in Table 3, the explanation for this must be related to how the map is interpreted. Because green dots could indicate such a large range of speeds (35 mph and up), green did not necessarily mean speeds were at free flow levels. In the off peak, congestion delays were most likely due to accidents, which cause catastrophic drops in speed in localized areas, which would be clearly seen as red or yellow on the map. In the morning peak, however, where there was a more gradual rise and fall of demand, the map may have shown more moderate congestion where speeds fell in the 35-45 mph range. This congestion is harder to detect because it still appears green on the map. It is possible that this phenomenon was the cause of the inferior performance in the AM peak compared with the off peak even though the off peak was a less congested time of day with less day-to-day variability as seen in Figure 6. This explanation can be supported by the fact that users of travel time-based ATIS benefited more in the AM and PM peaks ($1.16 and $1.68, respectively) than the off peak ($0.44), which is more in line with what we would expect given the higher variability in the peaks.

	Utility Improvement	Percent Reduction	Percent of Trips
All Trips	$0.20	7.0%	100.0%
AM Trips	$0.02	0.7%	17.5%
Off-Peak Trips	$0.10	4.5%	54.0%
PM Trips	$0.52	12.5%	28.6%

Table 2. ATIS Utility Improvement for Congestion Map Users

	Utility Improvement	Percent Reduction	Percent of Trips
All Trips	$0.93	31.6%	100.0%
AM Trips	$1.16	34.3%	17.5%
Off-Peak Trips	$0.44	20.6%	54.0%
PM Trips	$1.68	40.4%	28.6%

Table 3. ATIS Utility Improvement for Users of Travel Time-Based ATIS

<Figure 6. Average speed and day-to-day speed variability by time of day>

Table 4 shows utility improvement and percent reduction in utility from ATIS, as well as frequencies of ATIS user responses. For most trips (54.4%) the ATIS user left later than his habitual departure time based on what he gleaned from the map. The second most frequent response (38.5%) was to leave at the normal time. Only 7.1% of the time did the ATIS user leave earlier. This would suggest the biggest malady of ATIS non-users were early arrivals, which were remedied by leaving later. This is a function of the baseline we chose. The habitual commuter set his departure time to ensure an on time arrival 95% of the time. As a result, he tended to arrive early often. If we had chosen a different, less conservative baseline, we would expect more earlier departures and fewer later departures. In addition, we would expect there to be more benefit associated with earlier departures. The frequency of alternate routes would not have been affected. Regardless of the baseline case used, whether the predominant response to ATIS is earlier or later departure, the importance of departure time adjustment is not diminished.

	Utility Improvement	Percent Reduction	Percent of Trips
Leave Early	-$0.33	-20.4%	7.1%
Leave On Time	-	-	38.5%
Leave Late	+$0.42	10.2%	54.4%
Alt. Route (Leave Early)	-$1.47	-49.7%	0.0%
Alt. Route (On Time)	-$1.41	-45.3%	0.0%
Alt. Route (Leave Late)	-$1.59	-28.1%	5.3%

Table 4. ATIS Utility Improvement by Response to Congestion Map

The other key result from Table 4 is the benefit (or lack thereof) when the ATIS user took an alternate route. Because this occurred with such low frequency (5.3%), it did not adversely affect the overall utility benefit from ATIS. However, it suggests that for congestion map users training on the habitual route did not translate well to alternate routes. This is supported by the results in Table 5, which shows that when the ATIS service calculated travel times and did not rely on the user to train his expectations from the congestion map, alternate routes provided benefits comparable to departure time adjustment. In reality, travelers know their habitual routes better than their alternate routes, so this is not unreasonable.

	Utility Improvement	Percent Reduction	Percent of Trips
Leave Early	$0.21	6.0%	9.7%
Leave On Time	-	-	40.2%
Leave Late	$1.71	44.3%	50.1%
Alt. Route (Leave Early)	$1.86	29.6%	1.8%
Alt. Route (On Time)	$1.28	30.5%	2.1%
Alt. Route (Leave Late)	$1.65	34.0%	5.8%

Table 5. ATIS Utility Improvement by Response to Travel Time-Based ATIS

Table 6 reveals how often utility benefit was realized by the ATIS user and the frequency with which benefits of different magnitudes were realized. At all times of the day, ATIS users benefited more often than not. If we were to select an AM peak trip and an PM peak trip per day to emulate a commuting experience, an ATIS user benefited a little more than twice per week on the morning trip and three times per week on the afternoon trip. However, ATIS led him to do worse a little more than once per week both in the morning and in the afternoon.

Of those trips that benefited, we broke down the frequency of benefit by magnitude. We translated the dollar value of ATIS to the amount one might be willing to pay for the service. Therefore, if one had paid $1 per trip for such an ATIS service, one would have gotten his money's worth 24% of the time for his morning trip and 37% of the time for his afternoon trip. That translates to approximately once per week and twice per week, respectively.

Utility Improvement	All	AM	Off	PM
Negative Improvement:	21.7%	28.9%	5.5%	24.0%
Zero Improvement:	38.6%	24.0%	55.7%	15.0%
Positive Improvement:	39.8%	47.1%	38.7%	60.9%
$0.01- $1 Improvement	20.0%	23.1%	29.4%	24.0%
$1-$2:	8.0%	9.6%	5.4%	12.0%
$2-$4:	6.8%	8.0%	3.0%	13.3%
$4-$6	2.5%	3.2%	0.6%	5.6%
$6-$8	1.2%	1.5%	0.2%	2.8%
$8-$10	0.6%	0.7%	0.1%	1.4%
>$10	0.7%	1.1%	0.1%	1.8%

Table 6. Percentage of Trips Realizing ATIS Utility Benefit over Habitual

4.2. Fixed Arrival Archetype Results for Representative Trips

The results to this point have treated each trip equivalently. In reality, we were most interested in the trips made by the Volpe study participants so we could relate our results to their trip-making characteristics and perceptions of ATIS benefits. In addition, since not all trips benefited equally, we were interested in the distribution of that benefit and in particular, the potential benefit of the trips that benefited the most. The following results are broken down in this way.

4.2.1. Trips Corresponding To Volpe Study Participants Based on Work and Home Zip Codes

The Volpe study participants gave their work and home zip codes. In order to identify the benefits for their approximate trips, the nearest network node to the centroid of the zip code was assigned as the trip origin or destination. We then identified per trip benefits for trips from home to work in the AM peak and work to home in the PM peak. There were 211 home-to-work and work-to-home pairs. Results are shown in Table 7.

Peak	Habitual Disutility	ATIS Disutility	Utility Improvement	Percent Reduction	# of Trips
AM	$4.24	$4.13	$0.11	2.7%	64988
PM	$4.74	$4.46	$0.28	5.8%	106344

Table 7. ATIS Utility Benefit for Volpe Study Subjects' Approximate Trips

The Volpe study participants, who were regular users of ATIS, realized benefit in the morning and afternoon peak periods. In the afternoon, they benefited less ($0.28 vs. $0.52 or 5.8% vs. 12.5%) than the average aggregate trip. In the morning, they benefited more ($0.11 vs. $0.02 or 2.7% vs. 0.7%). These results provide some confirmation of the Volpe study participants' perceptions of improved on-time reliability, though it is confusing that there is less benefit in the PM peak than for the general population. One confounding factor is that we do not know which zip codes are of fixed arrival archetypes, which was just one of four archetypes in the set of participants. We do not know what the benefits are for that specific subset of participants.

4.2.2. Trips Where ATIS Benefits the Most

It is useful to identify the trips for which ATIS holds the most potential benefit for its users. Because of the dominance of departure time shifting and relative unimportance of route switching, the trips that benefited the most were likely to be affected most by the speed variability on their routes and less on the availability of competitive alternative routes. In fact, they may be characterized by having habitual routes with relatively high speeds, but highly variable segments. Having high average speeds would make segments more likely to be a part of a habitual route; having high variability would make ATIS potentially more beneficial.

The trips that benefited most from ATIS in terms of absolute and percentage utility improvement were largely consistent within each of the morning and afternoon peaks. Figure 7 and Figure 8 show where the clusters of high benefit trips originated and terminated. There were trips outside of these clusters that benefited more than those within the clusters, but in general, the trips that benefited most are those shown. Trip results were averaged for each hour of the day for each origin and destination. The trip that benefited the most, for example, started at node 16 near Inglewood and LAX Airport and ended at node 29 near the San Fernando Valley in the 8:00 a.m. hour. This includes trips with target arrival times at 8:00 a.m., 8:15 a.m., 8:30 a.m. and 8:45 a.m.

The morning trips shown may have held the greatest potential benefit because of the characteristics of segments 39 and 40, I-405 between I-105 and the Ventura Freeway, which connect the two clusters. These segments were ranked 12th and 21st in terms of travel time variability in the morning peak (out of 122 segments), respectively. In addition, the best routes for these trips undoubtedly used segment 39, while many also used segment 40. The only alternatives, which passed through the central business district, were clearly not preferable for any of these trips because they were less direct and speeds in the CBD were generally low.

<Figure 7. Best Trips for ATIS in the AM Peak>

Based on segment average speed and speed variability, the most congested part of the network in the afternoon was the central business district. As a result, many of the trips benefiting most from ATIS were those that started in, ended in, or could avoid this area. Many trips with substantial benefit originated at node 38 in Santa Monica and terminated in the central business district and points beyond. Because of the network structure, avoiding the CBD to the north or to the south was too far out of the way.

Another subset of afternoon trips with high benefit originated in the CBD and terminated to the south, near Long Beach. Another subset was in the reverse direction, originating near Long Beach and terminating in the CBD.

<Figure 8. Best Trips for ATIS in the PM Peak>

The magnitude of potential benefit for the top 1% of trips for ATIS users in terms of utility improvement is shown in Table 8. Because trip travel time is a component of the utility function, it comes as no surprise that the top 1% of trips consisted of generally long trips. This is consistent with what we should find. Travelers making longer trips clearly had more use for ATIS because there were more opportunities for benefit over those making shorter trips.

Habitual Disutility	ATIS Disutility	Utility Improvement	Percent Reduction	Average Trip Length
$13.58	$6.43	$7.15	53.2%	39.9 mi.

Table 8. ATIS Utility Benefit for the Most Beneficial 1% of Trips

4.3. The Effective Accuracy of the Congestion Map

In a previous study using this same data and methodology, the sensitivity of ATIS benefits to ATIS accuracy was derived (13). The objective of that study was to determine the sensitivity of benefit to varying amounts of random error in travel time estimates provided to ATIS users. Based on the resulting benefit vs. accuracy curves derived for Los Angeles, we could correlate the benefits seen by users of the congestion map with the corresponding level of ATIS accuracy that resulted in the same amount of benefit. For the amount of benefit in Table 1, the effective error of the congestion map was 13% in the off-peak and 19% in the peaks as shown in Figure 9. This means the congestion map was of the same precision as an ATIS service that estimated travel times with these amounts of random error. In Los Angeles, as the results in Table 1 show, this was sufficient for the average aggregate trip to realize benefit from using ATIS assuming their objective was to arrive on time reliably. Note that these results are averaged per trip whereby each trip (each combination of origin, destination and target arrival time) was given equal weight. In reality, trips for which there is more demand should be weighted more heavily to calculate benefits on a per traveler basis.

<Figure 9. ATIS Benefit vs. Accuracy Relationship for Los Angeles>

5. Key Findings

Through the application of the HOWLATE methodology, we were able to generate quantitative estimates of ATIS user benefits that supported survey-based qualitative ATIS user satisfaction and perceptions of benefit in the Los Angeles metropolitan area. Given an archive of roadway segment travel times and an archive of speeds at detector locations, we were able to model the potential benefit to travelers utilizing a color-coded congestion map whose objective was to arrive on time reliably.

Congestion maps allow users to quickly size up congestion across their intended area of travel while ignoring irrelevant information. People are able to process visual information quickly making maps easy to understand. However, maps necessarily have a lower precision than services that estimate travel times because colors represent ranges of speed or travel time. The best available precision depends on how many different colors may be shown and the range of speeds each represents. Depending on how accurate travel time estimation is, maps may be just as good as services based on moderately accurate measurement technologies. In many cases, however, ATIS users may benefit more from congestion maps than from travel times. Maps allow the user to see more precisely where congestion lies so that if surface street alternatives are available, short diversions from the freeway may be exploited. Since we only had speed and travel time data for freeways, this is not something we could capture in this study.

The following key findings relate to the study hypotheses presented in Section 3.3.

5.1.1. Hypothesis #1: Congestion map users will outperform ATIS non-users but users of travel time-based ATIS will do even better.

On the basis of the average of all possible origin, destination, and target arrival time combinations, an ATIS user with a three-colored congestion map like that on the TANN web site arrived on time more reliably than a traveler without ATIS in Los Angeles assuming both were familiar with their trip, i.e., they make it regularly. On average, there was benefit to congestion map users at all times of day.

Using a disutility function that considered earliness, lateness, and travel time, we calculated a disutility associated with each trip. The difference between the disutility for the ATIS user and the ATIS non-user for the same trip revealed, in monetary terms, the benefit from using ATIS for that trip. At $0.52 per trip, the greatest benefit was realized by PM peak trips, followed by the off-peak and the AM peak at $0.20 per trip and $0.02 per trip, respectively. That there was less benefit in the AM than the off peak ($0.02 vs. $0.20) is a somewhat puzzling result. It may be due to the fact that green dots, which seemed to indicate free flow but actually indicated speeds as low as 35 mph, were more often misleading in the AM peak than the off peak or the PM peak in that speeds were more often be in the 35-45 mph range. The PM peak, because it was more congested than the AM peak, was more likely to have congestion in the yellow or red range on the map.

Users of the travel time-based ATIS benefited more than congestion map users. Trip-based ATIS guidance based on reasonably accurate travel time estimates is the best quality traffic information available. Users of an ATIS service of this type benefited $0.93 per trip for all trips compared with $0.21 per trip for congestion map users.

For congestion map users, 40% of all trips benefited (a trip is defined by a unique origin, destination, and arrival time), though a higher percentage (60%) benefited in the PM peak. That is three days out of every week. Someone needing to be on time who paid $1 per trip for ATIS would have gotten his money's worth 20% of the time (once per week) – 36.9% of the time for PM peak trips (approximately twice a week).

5.1.2. Hypothesis #2: Departure time selection is the primary benefit of ATIS for users who need to be on time.

ATIS users responded to real-time traffic information by changing route or departure time. In our results, the only ATIS response that provided a consistent benefit for congestion map users was later than normal departure at $0.42 per trip. This was also the most frequent response at 54% of trips. All other responses had negative benefit; alternate routes led to disbenefit of over $1.40. This can be partly attributed to the model of training to the congestion map. Training was done on the basis of the habitual route. Therefore, alternate route travel times were estimated with far less precision than habitual route travel times. Note that this result simply highlights the importance of departure time adjustment in response to congestion reports in ensuring on-time reliability. The habitual commuter (ATIS non-user) serving as the base case was very conservative; he selected a departure time to aim to be on time 95% of the time. As a result he was rarely late at the expense of often being early. If a less conservative habitual user had been chosen as the base case, it is likely the value and frequency of earlier than normal departures would increase relative to later than normal departures.

5.1.3. Hypothesis #3: Trips made by Volpe study participants will show more benefit than the general population.

We mapped trip origin and destination nodes to the home and work zip codes of the Volpe study participants and calculated average trip results for this subset of trips. In the AM peak, we included trips from home to work and in the PM peak, work to home. This subset of trips realized benefit in both the AM and PM peaks. The AM peak subset had more benefit than the set of all AM peak trips ($0.11 vs. $0.02 per trip) but the PM peak subset had less ($0.28 vs. $0.52 per trip). This gives credence to the on-time reliability benefits perceived by the Volpe study participants. However, it is somewhat surprising that PM peak trips did not benefit as much for this subset of trips. The focus group respondents were heavy users of ATIS but we do not know the regularity of usage of the survey respondents. Furthermore, a confounding factor is that we do not know which of the trips correspond to travelers of the archetype that needs to be on time and which are of other archetypes.

5.1.4. Hypothesis #4: The 1% of trips showing the most benefit will have significantly more benefit than the general population.

The trips that benefited the most in Los Angeles were those passing through the most congested part of the network, which in the morning was I-405 Northbound and in the afternoon was the central business district, where there were no competitive alternate routes (on freeways). The top 1% of trips benefited more than 50% over non users of ATIS, a utility improvement of $7.15 per trip. This was much more than the set of all trips, which benefited $0.20 per trip. The top 1% of trips benefited 36 times more than the average trip ($7.15 vs. $0.20). These were generally longer trips, as expected.

5.1.5. Hypothesis #5: We will be able to identify the effective accuracy of the congestion map, and it will not be able to match accurate travel times.

Congestion map users realized benefit comparable to travel time-based ATIS users where travel times estimates had an error of 13% in uncongested conditions and 19% in congested conditions. In Los Angeles, this was adequate because day-to-day variability is high. In other cities where variability is not as high, better resolution may be required for the average trip to benefit.

6. Future Work

Future work on this project will include modeling of ATIS users unfamiliar with the web site. That is, users who apply consistent speeds to the colored dots rather than relying on experience. In addition, we will model the flexible departure archetype and identify whether such a traveler is able to save time by adjusting his departure time to avoid congestion. The feasibility of modeling trip chaining archetypes will also be considered in the future.

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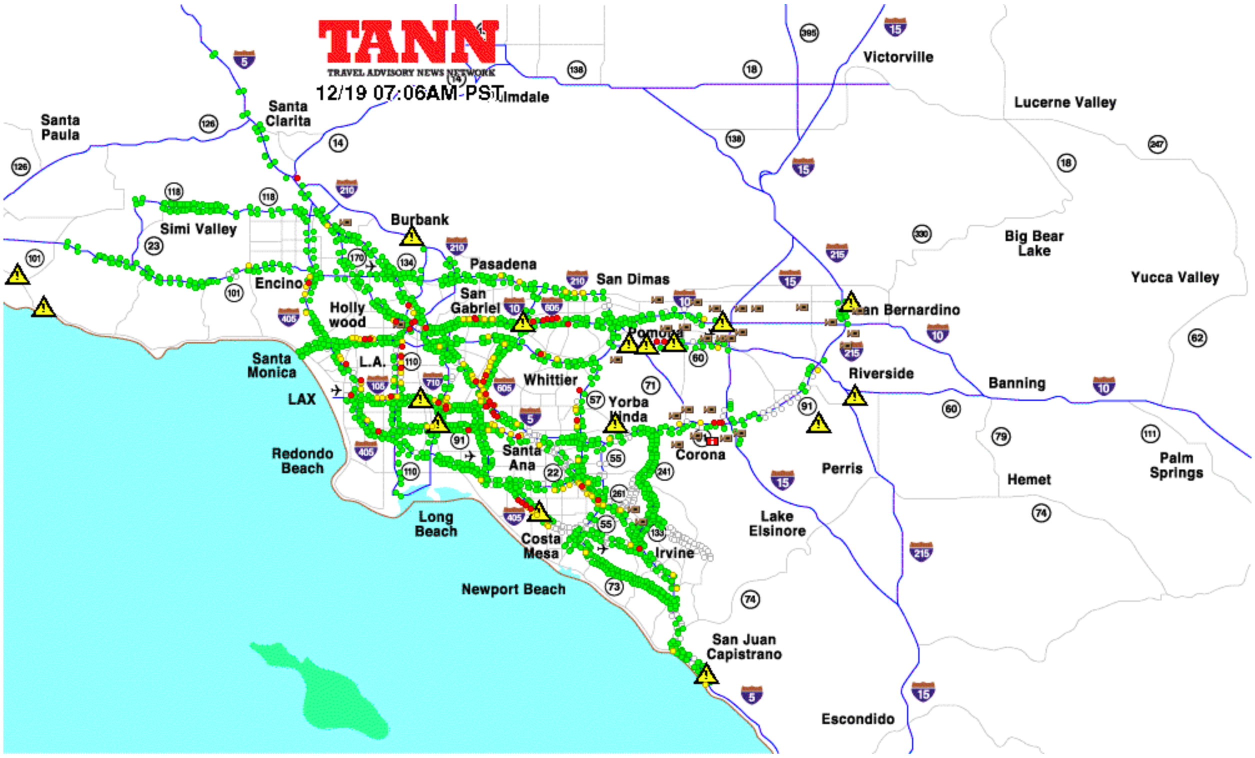

Figure 1. TANN Los Angeles Congestion Map

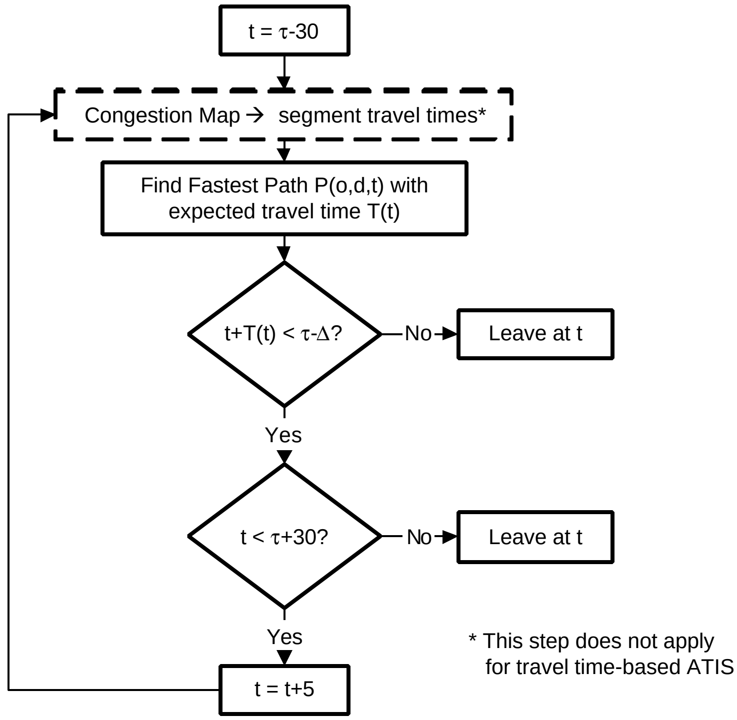

Figure 2. Fixed Arrival Mechanism Flowchart

Figure 3. Los Angeles Node-Link Network

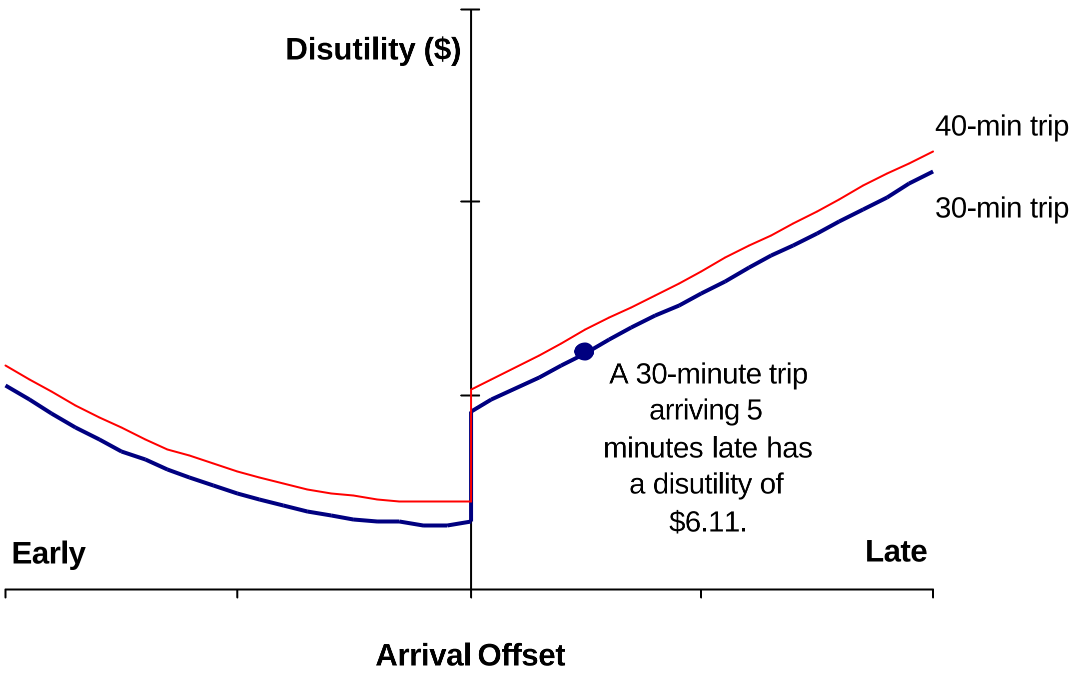

Figure 4. Disutility as a function of early and late schedule delay and trip travel time

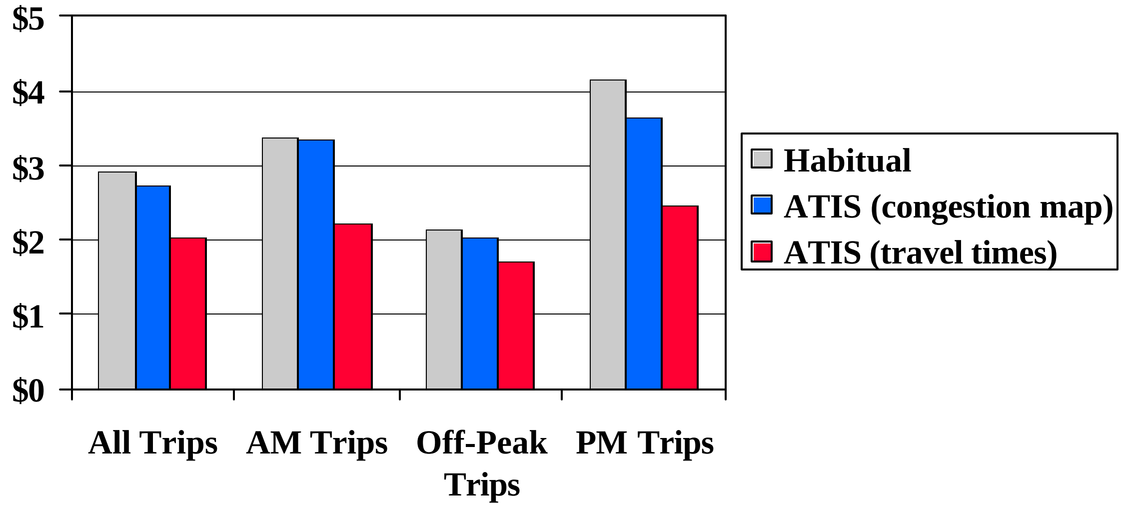

Figure 5. Trip Disutility for Fixed Arrival Archetype by Time of Day

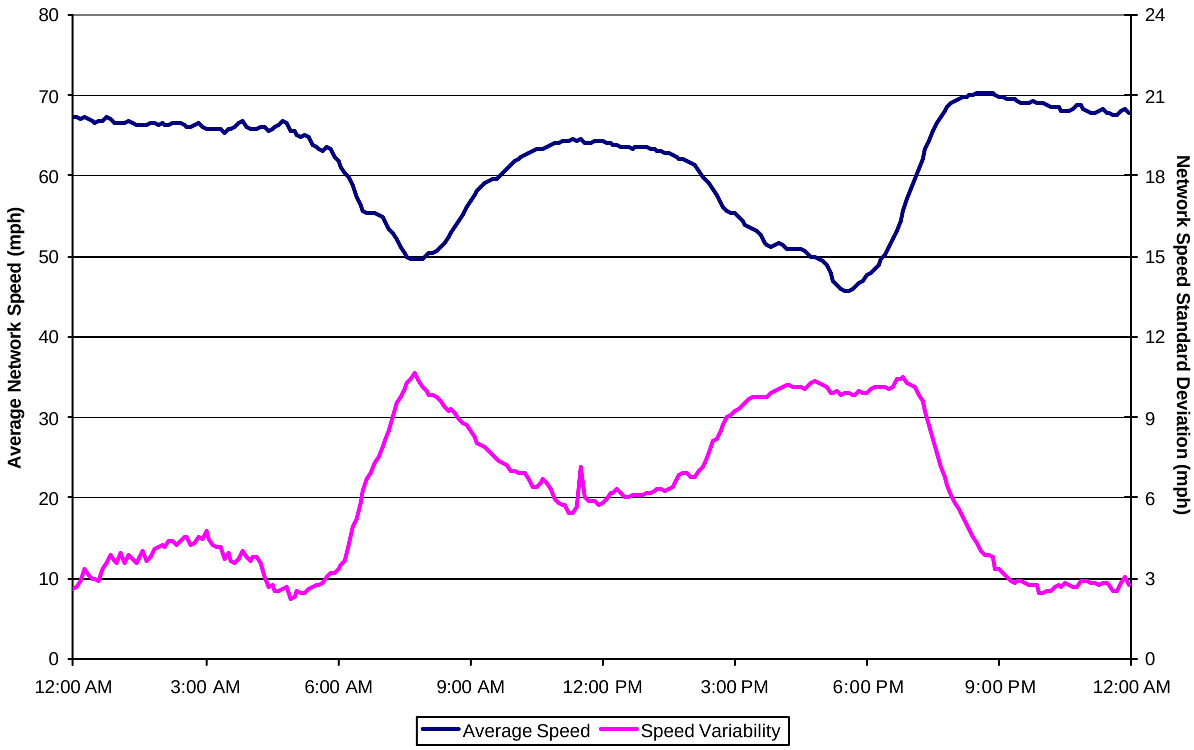

Figure 6. Average Speed and Day-to-Day Variability by Time of Day

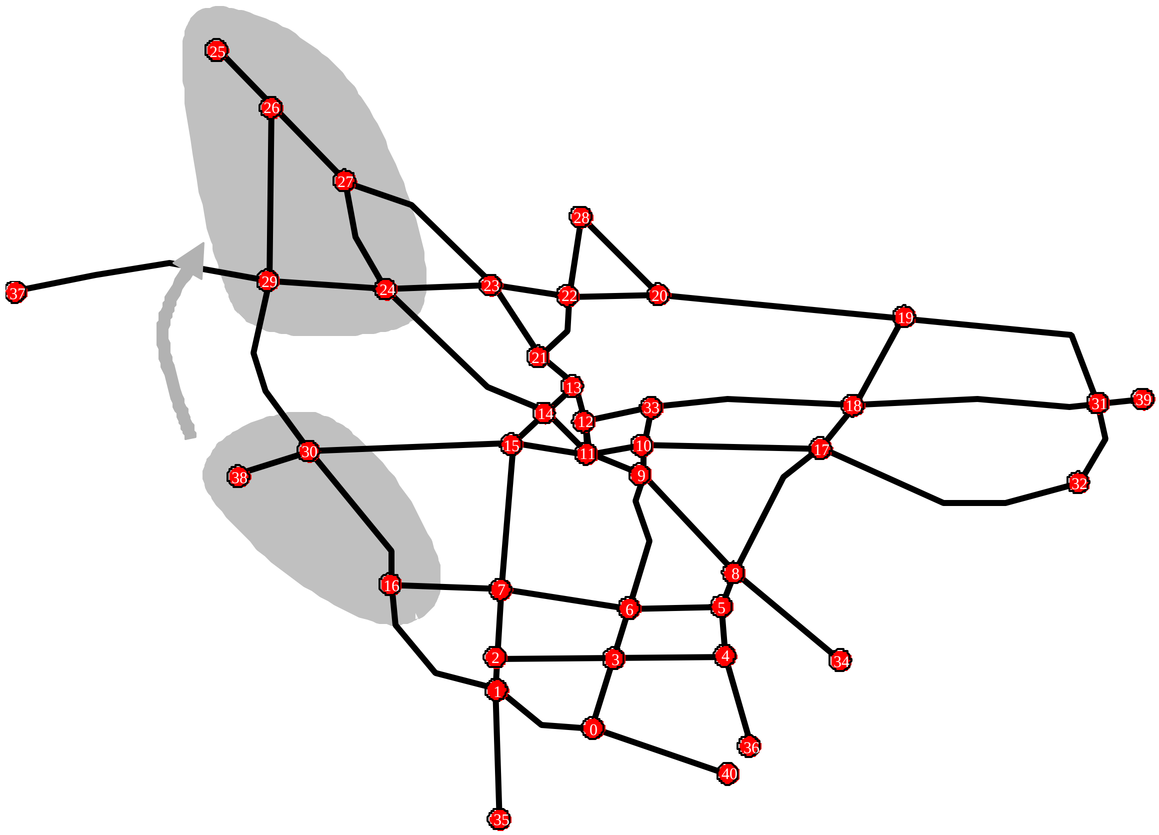

Figure 7. Trips for Which Congestion Map Users Realize Greatest Benefit in the AM Peak

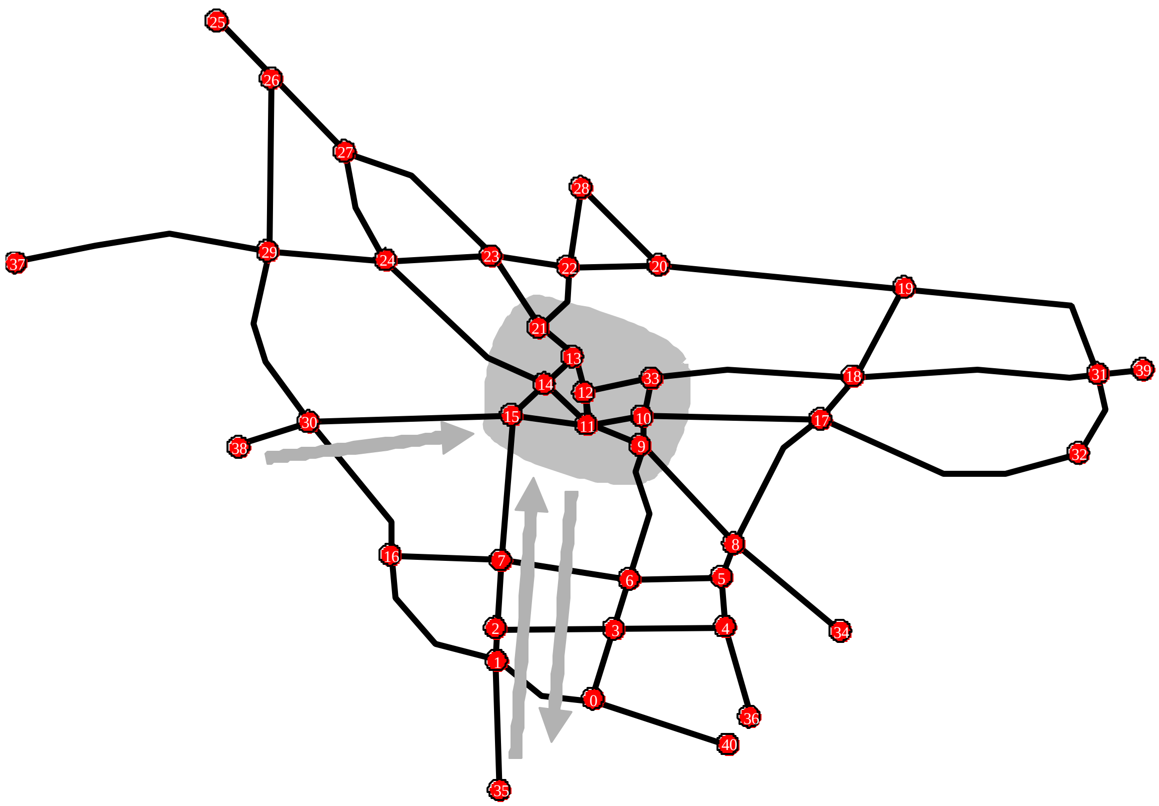

Figure 8. Trips for Which Congestion Map Users Realize Greatest Benefit in the PM Peak

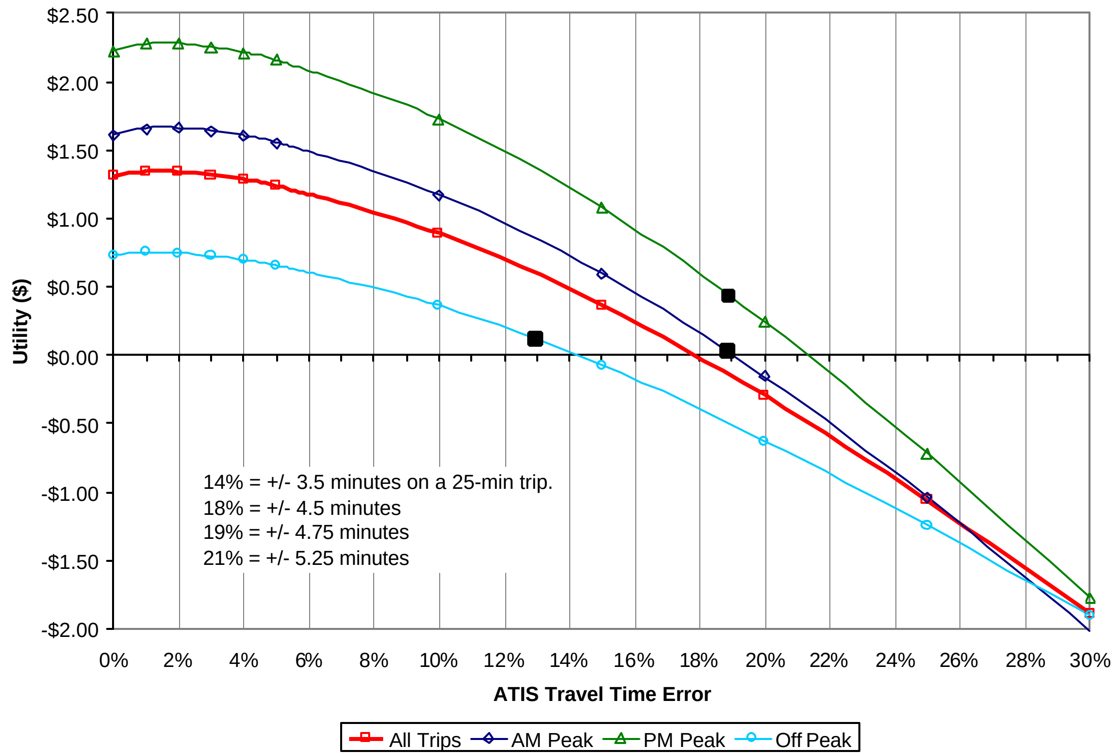

Figure 9. ATIS Benefit vs. Accuracy Relationship for Los Angeles