TECHNICAL REPORT

The Evaluation of Advanced Traveler Information Services (ATIS) Impacts on Truck Travel Time Reliability

Using the Simulated Yoked Study Concept

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ABSTRACT

The ability of Advanced Traveler Information Systems (ATIS) to improve the on-time reliability of urban truck movements is evaluated through the application of the Heuristic On-Line Web-Linked Arrival Time Estimation (HOWLATE) methodology. In HOWLATE, simulated paired driver trials are conducted based on archived roadway travel times to identify how ATIS use impacts trip outcomes. Previous research using this technique evaluated ATIS impacts on commuter trips in metropolitan areas and demonstrated that travelers who receive notification of current traffic conditions prior to departure can reduce dollar-valued disutility from improved on-time reliability as well as travel time savings. In this report, we expand the application of HOWLATE to investigate the ability of ATIS to improve on-time reliability of freight movements to intermodal terminals based on a case study of the Los Angeles metropolitan area.

We focus on how trucks using ATIS perform relative to their counterparts for both fixed departure and flexible departure time conditions. We analyzed the impacts of using ATIS for three types of truck drivers, classified by varying levels of familiarity with the regional roadway network and traffic characteristics and the desired level of on-time arrival. We also analyzed the effect of extending ATIS surveillance to include connector roadways linking freeways and intermodal terminals.

Our results indicate that for truck movements with stringent on-time requirements facing considerable variability in their trip travel times, ATIS is a useful and high-value service. In particular, unfamiliar truck drivers can reap significant benefit from ATIS (averaging between \$1.5 and \$13 per trip). The case study also shows that truck drivers with flexible departure times can accrue more benefit from using ATIS than truck drivers with fixed departure times (averaging between \$11 and \$41 per trip).

Further, accrued benefit varies by terminal location and the degree of connectivity. Trips destined for intermodal terminals located in the middle of the network benefit more significantly from ATIS than trips destined for intermodal terminals on the edge of the network. In addition, the provision of travel times on connector roadways between the freeway network and the intermodal terminals reduced late arrivals by up to half in some locations.

KEYWORDS: Intelligent Transportation System, HOWLATE, Advanced Traveler Information System, trucks, on-time reliability, simulated yoked trials, travel time, intermodal, Los Angeles.

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1. INTRODUCTION

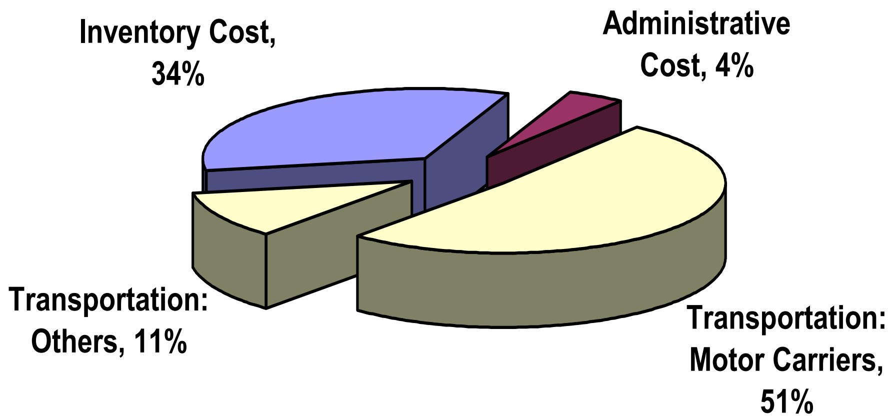
1.1 Background

Recent innovations in computer and Internet technologies have had significant impact on the freight industry. The industry has had to adapt to accommodate new business concepts such as business-to-business e-commerce and business-to-customer e-commerce. In addition, freight movement is becoming more complex and increasingly time critical due to Just-In-Time Delivery (JIT) and the globalization of the world economy.

As the globalization continues, manufacturing companies are consolidating production at lower cost locations and producing more multinational goods. Goods movements in our global economy are increasing longer and more complicated. The popularity of JIT inventory management requires more advanced freight service to satisfy small lot sizes and narrow delivery time windows. E-commerce is another force in the trend towards complicated goods movement and smaller package size as consumers or retailers now purchase directly from the factories or wholesalers. Moreover, by replacing individual consumer trips from/to retail shopping places with freight delivery, truck movements across the urban roadway system are increasing. These changes in the demand for freight service require very efficient, reliable, and seamless freight transportation -- while contending with increasingly congested urban roadways.

The demand for trucking services has grown rapidly in the last decade. In 1990, freight movement (ton-miles) by trucks was 23% of total national goods movement (3.19 trillion ton-miles); however, in 1998 it increased to 28%. The Freight Analysis Framework (FAF) estimated that the value of shipment by truck in 1998 was 80% of the total value of nationwide shipments. The FAF predicts that this figure will be 84% by 2010 (USDOT FHWA, 2002).

In 2001, transportation costs made up 62% of total business logistics costs (Figure 1-1). Logistics costs are defined as all costs associated with the "process that plans, implements, and controls the forward and reverse flow and storage of goods, services and related information between the point of origin and the point of consumption"(Council of Logistics Management), including inventory costs, administrative costs, and transportation costs. Motor carrier costs represented 82% of all transportation costs (Cass Information Systems and ProLogis, 2002). Therefore, over half of total logistics costs are driven by the movement of goods by trucks.

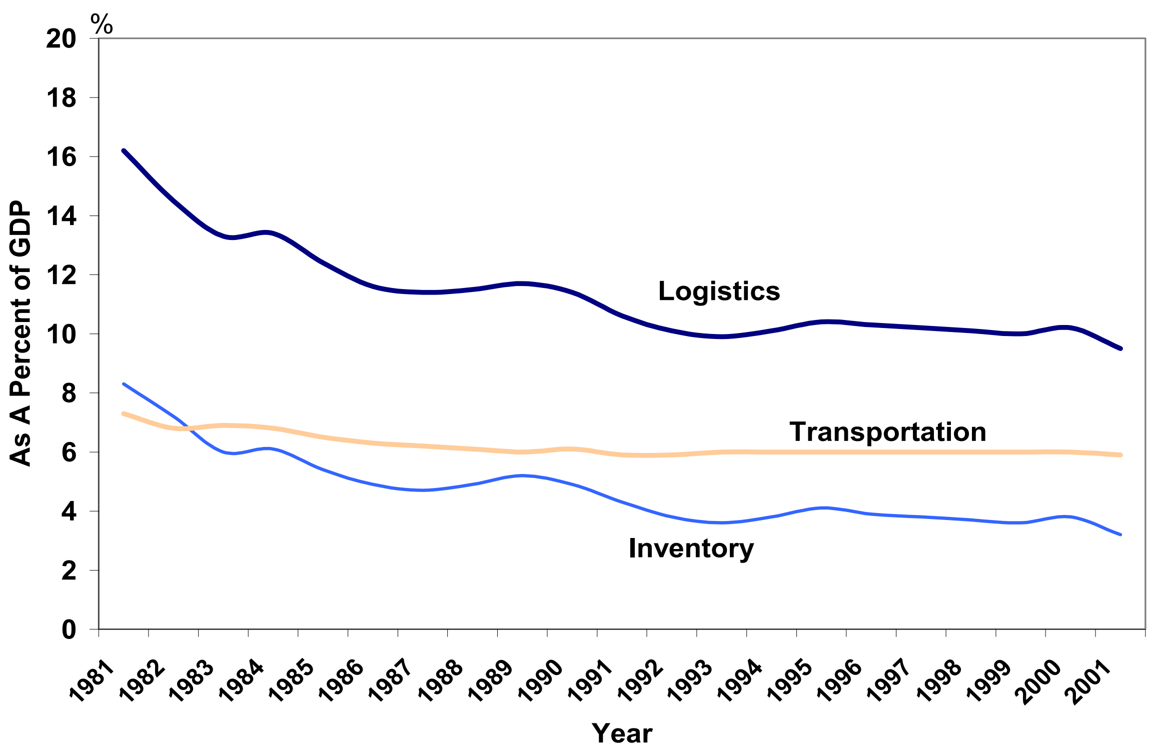


Source: Cass Information Systems and ProLogis, 13th Annual State of Logistics Report June 2002

Figure 1-1 U.S. Business Logistics Cost (2001)

Figure 1-2 shows the trend of logistics costs by its two primary components: inventory costs and transportation costs. Overall total logistics costs as a percent of GDP has been decreasing because of new techniques in inventory control. However, transportation costs have not declined in the last 20 years. For truck movements, one problematic factor is rising road congestion. Now more than ever, logistics costs are dependent on both travel time and travel time variability, both directly affected by congestion (ICF Consulting and HLB Decision-Economics, 2002). Consequently, domestic economic competitiveness will be significantly affected by the reliability of truck operations.

In truck operations arrival time reliability is critical because arriving late or even too early at a destination may incur a penalty. For example, if a truck arrives at an intermodal terminal later than its designated arrival time for the connecting transportation mode (train, ship, or airplane), the truck may miss its cargo's connection and require rescheduling or be forced to return to its origin still carrying the cargo. To avoid late arrival, a truck may depart from its origin with extra time resulting in an early arrival at the terminal. This early arrival may also create problems such as air pollution from increased idling time, increased traffic congestion in the vicinity of the terminal, traffic accidents as a result of congestion/illegal parking, and truck driver inefficiency. In most cases these actions incur additional cost borne only by the truck operator. Similarly, when a truck picks up a package from an urban location, early arrival at the pickup location may result in a parking fee or parking violation penalty due to extended idle time waiting for the package. In addition to penalties and fees, these inefficiencies increase truck operating costs due to poor fleet and driver productivity.



Source: Cass Information Systems and ProLogis, 13th Annual State of Logistics Report June 2002

Figure 1-2 U.S. Logistics Cost Trends

Intelligent Transportation System (ITS) technologies have a key role in the development of a more efficient and safer transportation system, while promoting reduced transport system cost and alleviating environmental degradation. Advanced Traveler Information Systems (ATIS) make up a class of ITS technologies used in passenger travel to improve travel reliability. In previous research (Jung *et al*., 2002), Mitretek found that ATIS could benefit commuters by improving their on-time reliability while at the same time reducing overall time allocated to travel. This research conducts a case study to determine if truck operations can accrue similar benefit from ATIS.

Clearly, congestion is a concern to truck operations. In 2001, Golob and Regan (2003) surveyed more than 700 trucking companies to assess opinions within the industry on traffic congestion and the use of automated routing and scheduling. In a question about the impact of traffic congestion, only 18% of the respondents said that congestion was not a serious problem. Of the remaining respondents, 64% answered that traffic congestion is a "somewhat serious" problem and 18% identified congestion as a "critically serious" problem to their business. In addition, 85% of respondents reported trucks missing scheduled deliveries due to traffic congestion.

Survey research also indicates that mainstream ATIS services targeted at commuters are not widely used by freight managers. In 1998, a survey was conducted of 1,177 managers at trucking companies in California regarding the perceived usefulness of different sources of traffic information to trucking operations. A majority of managers, 60%, were either unaware of congestion maps posted to the World Wide Web, or consider them "useless" (Golob and Regan, 2002). One key issue was the lack of relevance to freight operations of the web-based traffic information designed for commuters. Truck movements have restrictions both in terms of facility use options and time of travel within the day. In addition, web-based traffic information services are often limited to urban areas. However, most truck operations rely on intercity and interstate travel.

In this research, we evaluate the ATIS impact on truck operations by extending the Heuristic On-Line Web-Linked Arrival Time Estimation (HOWLATE) algorithm, a simulated yoked study, developed by Mitretek Systems in 1999, and applying it to a Los Angeles case study. This research is expected to quantify whether and how ATIS can contribute to improving truck travel time reliability. Benefits achieved by improving reliability results in both carrier cost savings through more efficient operations and shipper cost savings through reduced inventory costs. As the first step of our effort in this area, we will consider ATIS benefit only in terms of cost savings to motor carriers. Cost savings from improved truck movement reliability for the entire supply chain is left for future study.

1.2 Objective and Hypotheses

The objective of this research is to evaluate the ability of ATIS to improve the reliability of truck operations in an urban area. By using the HOWLATE model we can evaluate the performance of trips from each origin node within the network to each intermodal terminal, with disutility comparisons between trucks operated with and without ATIS. For simplicity, we define two terms that will be used throughout this report:

- ATIS truck: Trucks operated based on ATIS. Route and/or departure time for these trucks are influenced by travel time estimates provided by an ATIS service prior to trip departure. These simulated subjects form the experimental group.

- Non-ATIS truck: Trucks making freight movements without the aid of ATIS. Route and departure time for these trucks are decided prior to trip departure based on previous experience or a paper map. This class of simulated subjects forms the experimental control group.

In this research we seek to support or refute the following hypotheses:

Hypothesis 1 --- ATIS trucks will outperform non-ATIS trucks in terms of improved travel reliability and reduced disutility costs. The benefit from using ATIS will vary depending on the truck drivers' familiarity with geographical and traffic characteristics in the area, and on the desired frequency of on-time arrival.

Hypothesis 2 --- The benefit of using ATIS will depend on the location of the intermodal terminal. We expect that some locations have greater potential for ATIS benefit than others because some trips will have more variable travel times than others.

Hypothesis 3 --- ATIS trucks will accrue significantly reduced benefit from an ATIS system covering only urban freeways versus a system that also includes surveillance on key (non-freeway) intermodal terminal connector links.

Section 2 describes the HOWLATE methodology with only brief reference to trucking operations. Section 3 describes the experimental design for this research including a description of the roadway network model, truck driver behavior modeling, and trip performance measures. This section also presents a detailed description of the case study network. Section 4 presents a Los Angeles case study conducted to evaluate the ATIS impacts on truck reliability, which are traveling from a node in the network to intermodal terminal. Section 5 reviews implications of study findings and presents a set of conclusions we can draw from this study.

2. OVERVIEW OF HOWLATE

In 1999, in support of the ITS Joint Program Office (JPO) of the U.S. Department of Transportation, Mitretek Systems developed a new quantitative methodology for the evaluation of user impacts of ATIS based on archived roadway travel time data called HOWLATE. The HOWLATE code and software was initially developed for evaluation of ATIS as used by commuter travelers. In this section, we describe the general HOWLATE methodology. In Section 3, we present a detailed account of changes made to HOWLATE to reflect realistic truck operations and typical truck driver behavior. A strong point of the HOWLATE methodology is that it can easily accommodate different driving characteristics through the manipulation of model parameters. Additionally, Section 3 provides a description of the experiments used to evaluate ATIS impacts.

The HOWLATE methodology was documented and demonstrated using a small-scale test case in Volume I (Wunderlich *et al*., 2001). In Volume II (Jung *et al*., 2002), Mitretek applied HOWLATE in a large-scale evaluation of a prospective pre-trip notification-based ATIS in two cities over a 15-month period and found that ATIS can benefit routine users by improving their on-time reliability while only marginally reducing their in-vehicle travel time. Also in Volume II (Jung *et al*., 2002), Mitretek demonstrated how user savings in on-time reliability and in-vehicle travel time could be converted to a dollar-valued benefit. In Volume III (Shah *et al*., 2003), Mitretek Systems extended the HOWLATE methodology to investigate the impact of ATIS accuracy and geographic coverage levels on the value of the derived ATIS benefits. These HOWLATE research efforts focused on evaluating the effectiveness of ATIS on commuter trips.

HOWLATE is based on the concept of the simulated yoked study. A simulated yoked trial 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 one driver maintains a fixed route and departure time based on his previous experiences, while the other driver has various alternative travel routes and departure time based on real-time information he receives from an ATIS. The objective of both of these drivers (here they will be truck drivers) is to arrive at their destination on time.

The HOWLATE methodology consists of four modules (Figure 2-1), the first of which is the travel time archiver. The archiver is a software application that monitors ATIS link travel time reports via the Internet and stores these reports at five-minute intervals. The archiver compiles and saves a daily profile of link travel time by roadway, by time of day, and date, over a period of several months.

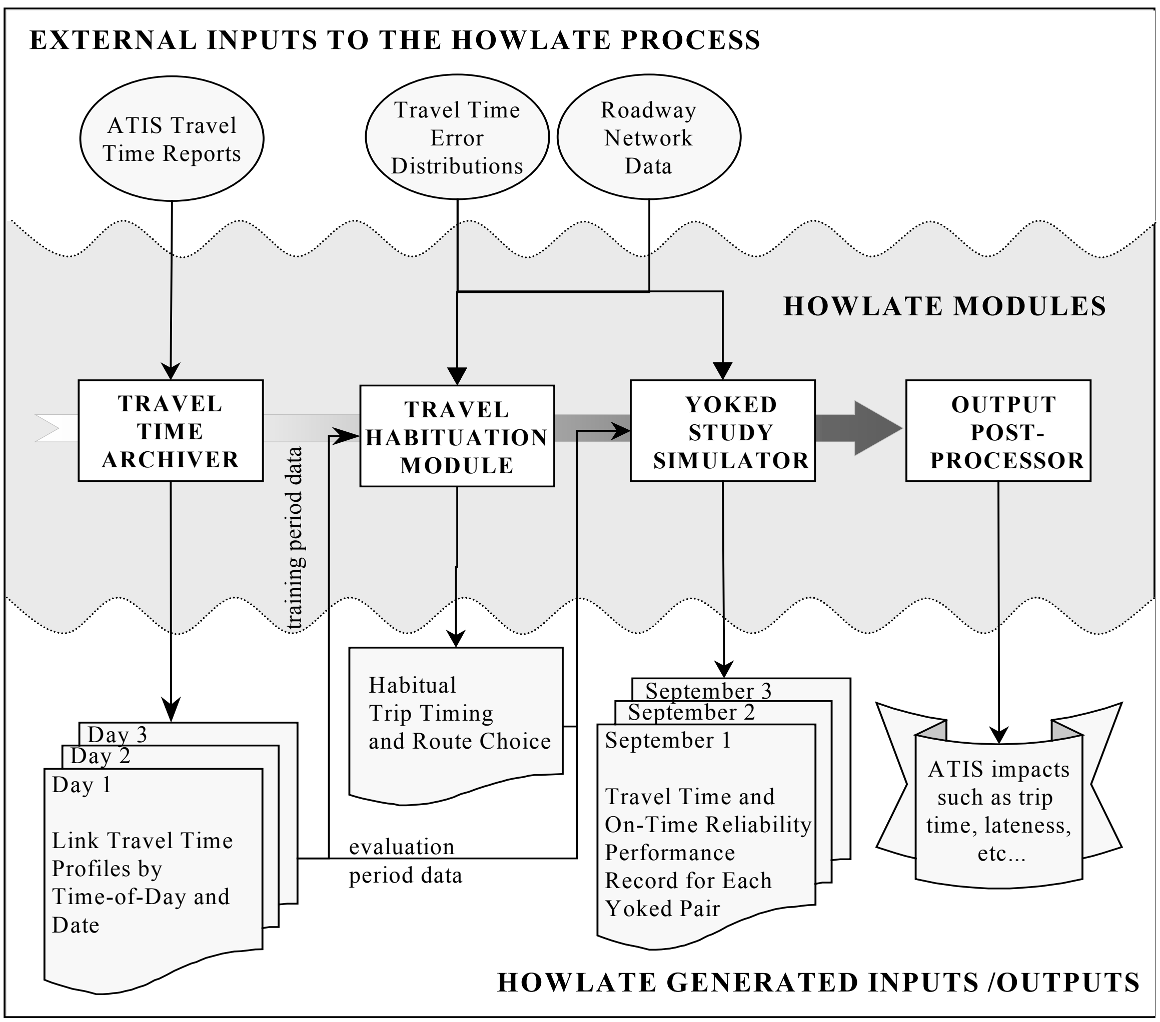


Figure 2-1 Overview of HOWLATE Methodology

A key input required for simulated yoked studies is the statistical distribution of error between the ATIS link travel time reports and true roadway travel times. The distributions of error, combined with the ATIS travel time report profiles collected by the travel time archiver, facilitates the construction of multiple "actual day" profiles through independent Monte Carlo trials. Since we cannot know precisely what the actual travel times were on the roadway links, we randomly sample from a set of likely values. Each random sample is analyzed as if it was the actual travel time, and is called a realization of the Monte Carlo trial. Multiple realizations are constructed from each day in the travel time archive and passed to the yoked study simulator.

In order to conduct a simulated yoked study trial, habitual time of trip start and route choice must be determined for the non-ATIS trucks. To facilitate the identification of habitual time of trip start and route choice, the ATIS travel time archive is separated into two periods: training and evaluation. The training period represents the time period in which non-ATIS trucks settle into habitual travel choices that meet a target on-time reliability threshold. This is modeled in the travel habituation module (Figure 2-1) by obtaining a single realization ("actual day profile") for each of the days in the training period data. Average link travel times at five-minute intervals are obtained across all days in the training period using the actual day profiles. Fastest time-variant paths and associated path travel times are then identified using the technique of Kaufman and Smith (1991) with respect to each origin-destination-target time of arrival. These fastest paths with respect to average travel times are selected as the habitual route for non-ATIS trucks.

We estimate travel time variability for each habitual path by computing the variability of its travel time over the days in the training period. To determine the time of habitual trip start we first subtract the average habitual path time from the target arrival time. We then subtract an additional time buffer proportional to the amount of travel time variability and level of on-time arrival confidence. The buffer size is computed under the assumption that day-to-day variation in travel times in the training period is normally distributed. Truck drivers who are very concerned about being late choose larger time buffers to produce a higher probability of being on-time.

After habitual routes and trip start timings are determined in the travel habituation module, one realization of travel congestion in each day of the evaluation period is generated. Details of the experimental (ATIS) and control (non-ATIS) travel behavior policies are set for all origin-destination-target time of arrival combinations in the network. Details include the on-time requirement for the non-ATIS trucks, as well as the flexibility of the ATIS trucks to adjust trip starts in real time. ATIS truck preference to remain on the habitual route is modeled using a travel time threshold. The ATIS service does not instruct the user to divert from the habitual path unless a faster alternative path is predicted to result in greater time savings than the threshold value.

Simulated yoked trials are conducted using a single Monte Carlo realization for each day in the evaluation period. The non-ATIS truck drivers depart from the origin at the habitual trip start time and traverse the network on the habitual path (no diversion). The ATIS service identifies a suggested trip start time by checking the travel time on the current fastest path. The first check is initiated at a set time (e.g., 30 minutes) prior to the habitual start time. The service postpones notifying the user about a trip start by five minutes if taking the current fastest path is projected to provide an arrival at the destination earlier than a set arrival window (e.g. 10 minutes) compared to the scheduled arrival time. When a trip can no longer be postponed, the service alerts the user of the projected trip start time and the fastest path (subject to the habitual route preference threshold). HOWLATE assumes that the ATIS truck drivers adopt the suggested trip start time and traverse the network on the suggested path. Note that the service may also contact the traveler to suggest trip start timing later than the habitual start time if congestion conditions are lighter than normal during that particular day. Although an en route guidance can also be modeled as a supplement to the basic pre-trip service, we postpone the analysis of the en route guidance impacts on truck reliability to future research.

In-vehicle travel time, arrival time, and other metrics are computed for both the ATIS trucks and the non-ATIS trucks by traversing the roadway network using the time-variant travel times associated with the actual day realizations.

These records of each simulated yoked trial are then analyzed in the output post-processor module. The post-processor accumulates performance measures such as on-time reliability, just-in-time reliability, in-vehicle travel time, and disutility for ATIS trucks and non-ATIS trucks.

3. EXPERIMENTAL DESIGN

In order to test the hypotheses proposed in Section 1.2 and to model more realistic truck operations, we make a set of assumptions defining the context of urban truck movement and driver behavior. We also define a set of performance measures. This section provides details on the key assumptions and parameters values chosen for truck operations modeling in HOWLATE.

We conducted two series of experiments:

1. We evaluated ATIS impacts based on varying levels of truck driver familiarity with regional roadway and traffic characteristics. As described in Section 2, we employed the HOWLATE methodology to conduct simulated yoked trials between paired ATIS trucks and non-ATIS trucks. In this experiment, we considered two types of drivers for each ATIS truck and non-ATIS truck: familiar and unfamiliar (discussed in detail in Section 3.2).

2. We evaluated the potential benefit of providing ATIS travel time coverage on connectors to intermodal terminal nodes. By comparing the ATIS-truck benefit on the hypothetical fully covered ATIS network and the current freeway-only ATIS network, we evaluated the value of providing travel time data on intermodal connection links (discussed in detail in Section 3.2).

Section 3.1 describes details of the case study city, Los Angeles, including ATIS travel time data and network characteristics. Section 3.2 introduces the baseline assumptions regarding key HOWLATE parameter settings as well as variations made to key parameters to incorporate more varied experiments. Performance measures are presented in Section 3.3.

3.1 Los Angeles Case Study

Los Angeles was selected for the case study because of the availability of travel time data by link, time of day, and across many days. Furthermore, Los Angeles experiences significant freight activity. In 2001, the Port of Los Angeles was the busiest port in the United States. In addition to the Port, there are six other important intermodal terminals for airport, train, and pipeline connections. These terminals are listed in Section 3.1.2.

3.1.1 Travel Time Data

The travel time data for the Los Angeles case study comes from PeMS, the California Freeway Performance Measurement System, which estimates segment travel times at 5-minute intervals in Los Angeles and Ventura Counties. These data are posted to the PeMS website (http://pems.eecs.berkeley.edu) in real-time from 5:30 to 21:00 and then archived. The analysis period for this study is reduced to 7:00 to 18:30 to reflect typical intermodal terminal working hours. Based on the cluster analysis of data by month, the AM peak is defined as 7:00 to 9:00, the PM peak is defined as 16:00 to 18:30, and the off peak is defined as all other times during the day.

The Los Angles roadway network defined by PeMS (Figure 3-1) is grid-shaped and consists of all freeways. The coverage area encompasses 734 directed miles. Roadway sections are subdivided into 61 links that are on average 11.9 miles long. These links are connected by 40 nodes. The training period for Los Angeles is comprised of 38 working days from March through April, 2002. The evaluation period is comprised of 110 working days from May through October, 2002.

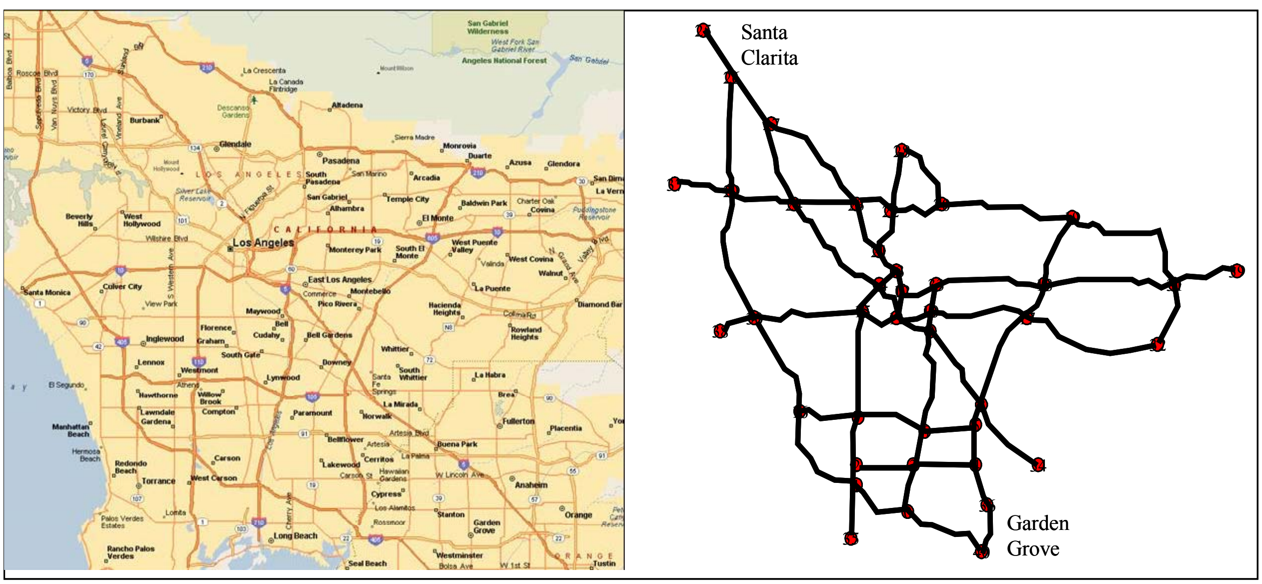


Figure 3-1 Map of Los Angeles ATIS Network

3.1.2 Intermodal Facility Location Modeling

As shown in Table 3-1, five intermodal terminals in Los Angeles case study area were identified from a report prepared by US DOT (2000), including 1 airport, 2 ports, and 2 truck/train terminals.

Intermodal Terminal Facility	Type
Los Angeles Internatinal Airport	Airport
Port of Long Beach	Port
Port of Los Angeles	Port
LA (NR.Union Station)	Truck/Rail
LA ATSF Rail Yard	Truck/Rail

Table 3-1 Intermodal Terminal Facility List and Types in Los Angeles

To address Hypothesis 1, we assume that an ATIS service is provided for the entire Los Angeles freeway currently under surveillance and that intermodal facilities can be accessed directly from the freeway network. In reality, intermodal terminals are not adjacent to the freeway grid in Los Angeles, and must be accessed via arterial and other facilities. For simplicity we model an intermodal terminal location at the nearest node (artificial location) on the Los Angeles ATIS network from the original location. Figure 3-2 presents the real locations of intermodal terminals and the corresponding artificial locations.

In a second set of experiments dealing with Hypothesis 3, we test the impact of adding surveillance to the connector facilities. A similar evaluation considering partial freeway deployments was considered in HOWLATE Vol. III (Shah *et al*., 2003). For each intermodal terminal, we create connector links and assume that the connector links are not covered by ATIS. The ATIS service assumes that these connectors have a travel time associated with the average travel time by time of day, presumably from some historic database. The ATIS service utilizes historical travel times on the connectors with real-time data on the freeway to report a total travel time to users.

Figure 3-2 Locations of Intermodal Terminals on Los Angeles ATIS Network

3.2 Key Parameters and Model Assumptions

On-Time Arrival Requirement: Many truck drivers must strictly observe time windows for delivery or pick-up to/from intermodal terminals - failure to comply with time windows may incur additional cost. For this reason, we consider a 99% on-time arrival requirement (time critical truck movements) for the familiar set of truck drivers to reflect situations where just-in-time arrival is critical. We also test the ATIS impact with 95% on-time arrival requirement (time sensitive truck movements) to reflect trucking operations with less critical on-time arrival demands.

Departure Time: In the original HOWLATE model for the purpose of evaluating the ATIS impacts on commuter trips, we considered flexible departure times for all our experiments. As described in Section 2, the ATIS service identifies a suggested trip start time by checking the travel time on the current fastest path. The first check is initiated at a set time (e.g., 30 minutes) prior to the habitual start time. The departure time of trucks may not be as flexible as that of commuters because it is influenced by other factors such as loading or unloading conditions. In this research, a fixed truck driver departure time is assumed as the base case scenario. For this case, the departure times of ATIS trucks are the same as those of the non-ATIS trucks and the benefit from using ATIS stems from more efficient route choice through the network. In a separate sensitivity test, the assumption of a fixed driver departure time is relaxed so that a comparative analysis could be made regarding ATIS benefit under both fixed and flexible departure time conditions.

ATIS-Truck Driver and Non-ATIS Truck Driver Behavior: To evaluate ATIS impact based on the truck drivers' familiarity with regional roadway and traffic characteristics, we conduct simulated yoked trials between paired ATIS trucks and non-ATIS trucks. Drivers are classified into three groups: drivers who are familiar with the driving environment (e.g., congestion location and intensity pattern) and require a 99% level of on-time arrivals, drivers who are familiar with the driving environment and require a 95% level of on-time arrivals, and drivers who are unfamiliar with the driving environment (no a *priori* knowledge of congestion patterns).

Familiar non-ATIS truck drivers rely on habitual routes and times of departure established over a month of travel in the training period. They are classified into two groups based on their on-time arrival requirement – one adopting a more conservative approach to arrive before the designated time (F99 having time critical truck movements), the other a less conservative approach (F95 having time sensitive truck movements). The F99 simulated control subject is a familiar non-ATIS truck with 99% on-time arrival requirement. The F95 simulated control subject is a familiar non-ATIS truck with 95% on time arrival requirement. Similarly, the familiar ATIS truck driver (ASV99 or ASV95) discounts or inflates the estimates of travel time provided by the ATIS service based on the observed accuracy of those reports in the training period. For example, if reports during the early morning periods frequently underestimated the experienced travel time during the training period, that driver would likely begin to adopt the position of "when they say it's going to be 45 minutes, I know that it's really going to be 60 minutes." For each origin-destination and time of arrival, a discounting/inflating factor is computed based on experience in the training period.

Truck drivers often operate in a wide geographic area and may frequently need to drive in unfamiliar places. Non-ATIS trucks with an unfamiliar driver (UNF) are considered to have a good map (e.g., they don't get lost), but must decide trip timing and route selection without any first-hand knowledge of congestion conditions. Route choice for these simulated control subjects are made based on link times associated with the fastest route under free-flow conditions. Unfamiliar ATIS truck drivers (ASV), however, follow a route and departure time suggested by the ATIS service.

Trip Description: Although a truck could potentially depart from a location outside the network, in this study, we examine the effect of ATIS only after the truck enters the network. Hence, we assume that pre-trip ATIS information is available once the truck joins the network. In this research, we analyze ATIS impacts on trips from all nodes in Los Angeles network to five nodes designated as intermodal terminals, described in Section 3.1. Therefore 40 nodes in the network, including five intermodal terminal nodes, have been used as origins. A unique trip in this research is defined by a trip date, an origin node, a destination node (which can only be an intermodal terminal), and a scheduled arrival time. Given that we have 35 nodes that are not intermodal terminals, there can be 175 trips (35 origin nodes x 5 intermodal terminal destinations) for each trip date and scheduled arrival time. In addition, there can be 20 trips originating from the intermodal terminals to other intermodal terminals for each trip date and scheduled arrival time. Thus, for each date and scheduled arrival time, there can be a total of 195 trips (35 origin nodes x 5 intermodal terminal destinations +5 intermodal terminal origins x 4 intermodal terminal destinations). The scheduled arrival times are at 15-minute intervals from 7:00 to 18:30. Hence, there are 47 different scheduled arrival times in a day. For each experiment, 110 days are evaluated; thus the total number of unique trips for each experiment is 1008150 (110 days x195 origin-destination pairs x 47 scheduled arrival times).

Method for Incorporating Partial ATIS Coverage: In order to test ATIS impact when connectors to the intermodal terminals are not covered by ATIS, we hypothesize that truck drivers will use past experience to fill in data gaps to arrive at a full trip travel-time estimate.

Conversely, our modeled ATIS service must resort to historic time-variant travel times where no surveillance information exists to derive an entire-trip travel time. Unmonitored links are assumed to have the average travel time by time of day that occurred during the training period. The modeled ATIS service aggregates links with and without information and reports a total trip time to users. Note that in the case of trips containing links with no surveillance, the average travel time during training is used in notifying users when to depart.

3.3 Performance Measurements

In our experiments, we apply four core measures of effectiveness: on-time reliability, just-in-time reliability, schedule delay, and dollar-valued disutility. We apply all of them unchanged from previous HOWLATE studies, except for the disutility calculation (see below):

On-time reliability is defined as the proportion of simulated yoked trials wherein a truck arrives at the destination node at or prior to the target arrival time. *Just-in-time reliability* is defined as the proportion of simulated yoked trials wherein a truck arrives at the destination node both on-time and no more than 10 minutes early. *Schedule delay* is defined as the difference between the actual arrival at the destination and the target time of arrival. If schedule delay is negative, it is called *early schedule delay*. If it is positive it is termed *late schedule delay*.

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 a driver reaches a destination based on the work of Small *et al*., 1999. We use a disutility function consisting of four variables: travel time, early schedule delay, late schedule delay, and late arrival penalty. For the first three variables, linear costs are applied. The last variable is one step cost when a truck arrives late. In Small's research, the disutility of in-vehicle travel time varies between $144.22-192.83/hour. In this research we set the disutility of in-vehicle travel time to $144.22/hour.

The costs incurred by early or late arrival are dependent upon situation and cargo type. When a truck arrives late, the cargo may be loaded or unloaded without any extra cost, or the cargo might wait for the next shipment opportunity in a warehouse at the intermodal terminal. Even in this situation, the warehouse storage cost is dependent upon cargo type. For example, some cargo needs refrigeration. If the cargo is perishable, its value will decrease while it is in the warehouse.

In the worst case, the cargo has to be returned to the origin because the terminal can not accept the cargo. For these reasons, we assume a range of values for late and early arrival penalties.

When a truck arrives early, we assume that the truck has to wait until its designated arrival time. We were unable to identify values for early arrival penalties in our literature review. Therefore, we consider waiting time with the same cost as travel time and set it at \$144.22/hour.

We consider two types of penalties for late arrival. Type 1 defines the cost of late arrival as a linear function of the magnitude of late arrival plus a one-step penalty for arriving late. Type 2, on the other hand, is defined as only a one-step penalty. The linear cost of late arrival is set as \$371.33/hr based on the research of Small *et al*. We apply a late arrival penalty in a range from \$0-\$1,000.

The disutility function is defined functionally as:

$$C = \alpha T + \beta SDE + \gamma SDL + \theta D_L$$

T: Travel Time

SDE: Schedule delay early

SDL: Schedule delay late

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

α: \$144.22/hr (linear cost of in-vehicle travel time)

β: \$144.22/hr (linear cost of early arrival)

γ: \$371.33/hr (linear cost of late arrival)

θ: \$0 - \$1,000 (one-step penalty for arriving late)

	Disutility Cost Type 1				Disutility Cost Type2				
Case	Penalty for Witing Time	Linear Cost of Late Arrival	One-Step Penalty for Arriving Late	Linear Cost of in-Vehicle Travel Time	Case	Penalty for Witing Time	Linear Cost of Late Arrival	One-Step Penalty for Arriving Late	Linear Cost of in-Vehicle Travel Time
C11	$144.22/Hr	$371.33/Hr	None	$144.22/Hr	C21	$144.22/Hr	None	None	$144.22/Hr
C12	$144.22/Hr	$371.33/Hr	$50	$144.22/Hr	C22	$144.22/Hr	None	$50	$144.22/Hr
C13	$144.22/Hr	$371.33/Hr	$100	$144.22/Hr	C23	$144.22/Hr	None	$100	$144.22/Hr
C14	$144.22/Hr	$371.33/Hr	$200	$144.22/Hr	C24	$144.22/Hr	None	$200	$144.22/Hr
C15	$144.22/Hr	$371.33/Hr	$300	$144.22/Hr	C25	$144.22/Hr	None	$300	$144.22/Hr
C16	$144.22/Hr	$371.33/Hr	$500	$144.22/Hr	C26	$144.22/Hr	None	$500	$144.22/Hr
C17	$144.22/Hr	$371.33/Hr	$1,000	$144.22/Hr	C27	$144.22/Hr	None	$1,000	$144.22/Hr

Table 3-2 Disutility Cost Types

Figures 3-3 and 3-4 illustrate the shapes of the dollar-valued disutility function for a 60-minute trip.

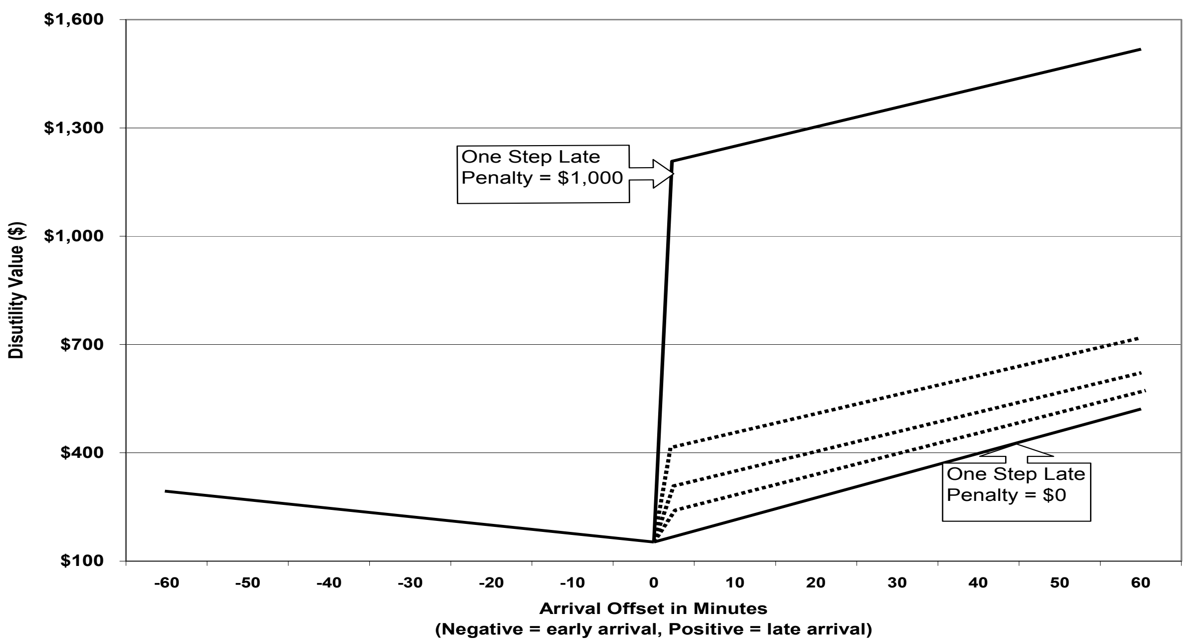


Figure 3-3 Dollar-Valued Disutility Type 1.
(Function with Linear and One-Step Late Costs)

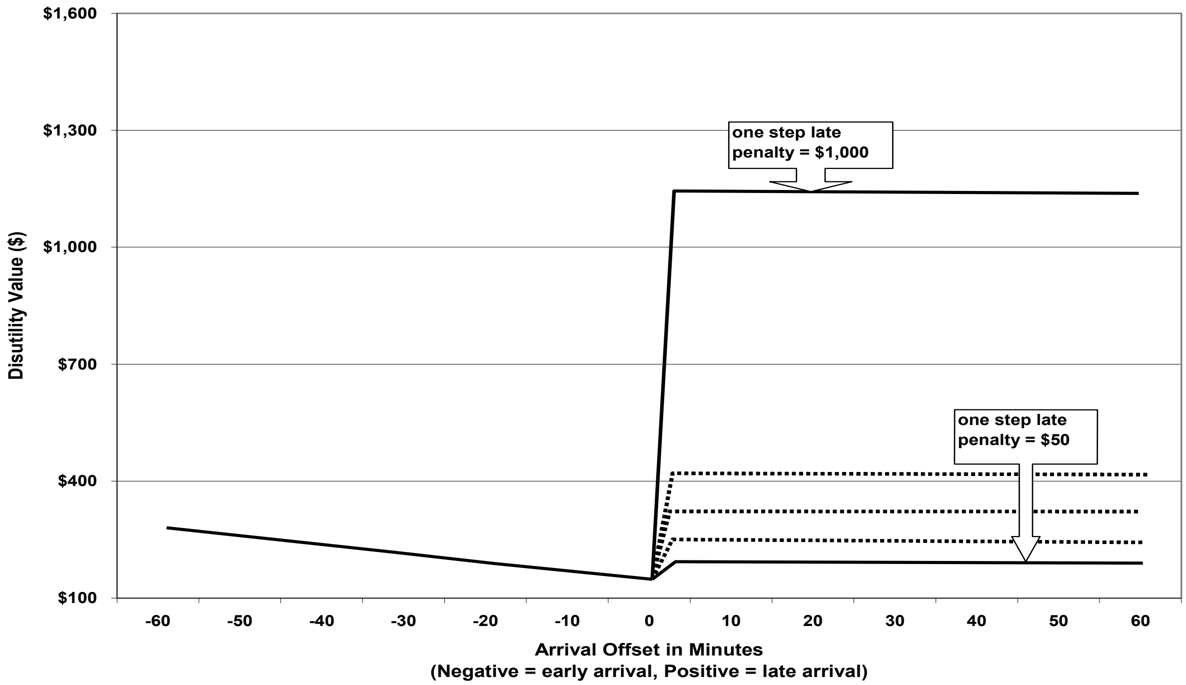


Figure 3-4 Dollar-Valued Disutility Type 2.
(Function with One-Step Late Costs)

4 LOS ANGELES CASE STUDY RESULTS

In this section, we describe the experimental results from the Los Angeles case study. Section 4.1 presents the ATIS impact according to the three types of truck drivers described in Section 3.2, under the assumption that the network is fully instrumented by ATIS. Section 4.2 examines the ATIS impact for each intermodal location. Section 4.3 describes the ATIS impact when the urban network is not fully instrumented by ATIS. Finally, Section 4.4 closes Chapter 4 with summary of experimental results.

4.1 ATIS Impacts Comparison by the Types of Truck Driver Behavior

This section describes the ATIS impact on truck operations according to various types of truck driver behavior, under the assumption that the whole network is covered by ATIS. As the base case (Section 4.1.1), we perform the ATIS impact evaluation for each type of truck driver with fixed departure times. As an alternative (Section 4.1.2), we also address ATIS impact under an assumption of flexible departure times.

4.1.1 Trip Outcomes

<u>Time Critical Truck Movements: Familiar Non-ATIS Trucks (F99) vs. ATIS-Trucks (ASV99) Experiment</u>

Tables 4-1 (a-b) present trip outcomes for familiar non-ATIS and ATIS trucks having time critical movements with fixed departure times. We define *time critical* movements as truck movements needing to be on-time in 99% or more of all cases. The results indicate that ATIS trucks with time critical movements have significantly reduced late arrivals, including a 53% decrease in late trips as well as a 3% reduction in trip time.

For trips having time critical movements, the trip outcomes of ATIS trucks compared to non-ATIS trucks are broken down in Table 4-1(a) by time of day. On average, ATIS trucks are early more often than non-ATIS trucks (66.8% compared to 64.9%) and late less often (0.8% compared to 1.7%); implying that the ATIS trucks are just-in-time less often (32.4% compared to 33.4%). ATIS trucks experience a 2.9% increase in early arrival and a 52.9% reduction in late arrival compared to their non-ATIS counterparts.

When non-ATIS trucks arrive early or late, they are on average 18.8 minutes early and 3.9 minutes late. Comparatively, ATIS trucks average early and late times of 19.4 and 1.7 minutes, respectively. These values constitute a 3% increase and a 57.4% reduction in the magnitude of early and late schedule delay, respectively. In addition, ATIS truck drivers are able to reduce trip time from 25.4 minutes to 24.6 minutes on average over all trips in the evaluation period by changing route pre-trip.

Over the 118 days simulated between May 2002 and October 2002, ATIS trucks modified their routes on 10.8% of trips. The number of ATIS trucks that change their route compared to their non-ATIS counterparts varies significantly by time of day. The percent of ATIS trips with route changes in the AM peak is 9%, drops to 7.4% for the off peak, and then increases to 20.6% for the PM peak.

Table 4-1 (a-b) present the trip outcomes by time of day categories as well as for the entire day. As described in Section 3.1.1, the AM peak is defined as 8:00 am to 9:00 am, the PM peak is defined as 4:00 pm to 6:30 pm, and the off peak is defined as the remaining time during the day. Trip outcomes vary significantly by time of day. ATIS trucks experience positive impacts throughout the day from ATIS use, although benefits are greatest in the off-peak period.

TRIP OUTCOMES COMPARISON HAVING TIME CRITICAL TRUCK MOVEMENTS: ATIS TRUCKS (ASV99) vs. NON-ATIS TRUCKS (F99) (MAY 2002 -OCTOBER 2002)								
Aggregate Trip Metrics	ALL DAY		AM PEAK		OFF PEAK		PM PEAK	
	F99	ASV99	F99	ASV99	F99	ASV99	F99	ASV99
% of Trips Early	64.9%	66.8%	76.0%	77.3%	56.7%	58.4%	75.9%	78.6%
% of Trips Just in Time	33.4%	32.4%	22.9%	22.1%	41.4%	40.7%	22.4%	20.6%
% of Trips Late	1.7%	0.8%	1.1%	0.6%	1.9%	0.9%	1.7%	0.8%
When Early, Avg. Min. Early	18.8	19.4	19.2	19.7	14.9	15.2	28.2	29.5
When Late, Avg. Min Late	3.9	1.7	3.0	1.5	4.4	1.7	3.4	1.7
% of Route Change		10.8%		9.0%		7.4%		20.6%
Trip Time (min.)	25.4	24.6	27.7	27.2	22.8	22.2	29.7	28.2

Table 4-1 (a) Time Critical Truck Movements: ATIS (ASV99) and non-ATIS (F99) Trip Outcomes

% CHANGE FROM F99 TO ASV99: MAY 2002 -OCTOBER 2002				
Aggregate Trip Metrics	ALL DAY	AM PEAK	OFF PEAK	PM PEAK
Frequency of Early Arrival	2.9% ↑	1.7% ↑	3.0% ↑	3.6% ↑
Frequency of Late Arrival	53.7% ↓	44.9% ↓	53.0% ↓	49.1% ↓
When Early, Avg. Min. Early	3.0% ↑	2.4% ↑	2.1% ↑	4.6% ↑
When Late, Avg. Min Late	57.4% ↓	51.2% ↓	60.8% ↓	51.0% ↓
Trip Time (min.)	3.0% ↓	2.0% ↓	2.3% ↓	5.2% ↓

Table 4-1 (b) Time Critical Truck Movements: Percent Change from non-ATIS Trips (F99) to ATIS Trips (ASV99)

<u>Time Sensitive Truck Movements: Familiar Non-ATIS Trucks (F95) vs. ATIS-Trucks (ASV95) Experiment</u>

In this section, we define a somewhat lower level of time criticality, *time sensitive*, for trips with a 95% on time arrival requirement. Tables 4-2 (a-b) summarize the trip outcomes for non-ATIS and ATIS trucks having time sensitive movements and the performance summary showing the relative improvement from using ATIS. Similar to the time critical case, ATIS trucks significantly reduce late arrivals (a 40.5% decrease), as well as a 3% reduction in trip time.

The trip outcomes of ATIS trucks compared to non-ATIS trucks are broken down in Table 4-2(a) by period of day. On average, non-ATIS trucks having time sensitive movements are early 36.5%, just-in-time 57.9%, and late 5.6% of all trips simulated. Their ATIS counterparts having time sensitive movements are early 38.7%, just-in-time 58%, and late 3.3% of all trips. ATIS trucks experience a 6% increase in percent of trips early and a 40.5% reduction in percent of trips late respectively compared to their non-ATIS counterparts having time sensitive movements.

When non-ATIS trucks do arrive early or late, they are on average 10.7 minutes early and 5.7 minutes late. Comparatively, the ATIS trucks' averages, when early or late, are 11 and 3.6 minutes, respectively. These values constitute a 3% increase and a 37.4% reduction in the magnitude of early and late schedule delay, respectively. In addition, ATIS trucks are able to reduce trip time from 25.7 minutes to 24.9 minutes, on average, over all trips in the evaluation period. ATIS trucks having time sensitive movements see benefit throughout the day with the highest benefit in the off-peak period. Similar to ATIS trucks having time critical movements, ATIS trucks having time sensitive movements change route about one out of every ten trips (11.1%). Route changes are more frequent in the PM peak (20.9%) and least frequent in the off peak (7.5%).

TRIP OUTCOMES COMPARISON HAVING TIME SENSITIVE TRUCK MOVEMENTS: ATIS TRUCKS (ASV95) vs. NON-ATIS TRUCKS (F95) (MAY 2002 -OCTOBER 2002)								
Aggregate Trip Metrics	ALL DAY		AM PEAK		OFF PEAK		PM PEAK	
	F95	ASV95	F95	ASV95	F95	ASV95	F95	ASV95
% of Trips Early	36.5%	38.7%	40.7%	43.0%	28.9%	30.3%	51.6%	56.0%
% of Trips Just in Time	57.9%	58.0%	54.2%	53.4%	65.9%	66.8%	41.3%	40.0%
% of Trips Late	5.6%	3.3%	5.1%	3.6%	5.2%	2.9%	7.1%	4.0%
When Early, Avg. Min. Early	10.7	11.0	10.4	10.7	8.8	8.9	15.5	16.3
When Late, Avg. Min Late	5.7	3.6	5.5	4.2	5.6	3.0	6.1	4.4
% of Route Change		11.1%		9.9%		7.5%		20.9%
Trip Time (min.)	25.7	24.9	28.5	27.9	22.8	22.3	30.5	29.0

Table 4-2 (a) Time Sensitive Truck Movements: ATIS (ASV95) and non-ATIS (F95) Trip Outcomes

% CHANGE FROM F95 TO ASV95: MAY 2002 -OCTOBER 2002				
Aggregate Trip Metrics	ALL DAY	AM PEAK	OFF PEAK	PM PEAK
Frequency of Early Arrival	6.0%↑	5.6%↑	4.8%↑	8.5%↑
Frequency of Late Arrival	40.5%↓	30.2%↓	43.8%↓	43.8%↓
When Early, Avg. Min. Early	3.0%↑	3.1%↑	1.3%↑	5.4%↑
When Late, Avg. Min Late	37.4%↓	23.6%↓	46.2%↓	27.8%↓
Trip Time (min.)	3.0%↓	2.0%↓	2.3%↓	5.1%↓

Table 4-2 (b) Time Sensitive Truck Movements: Percent Change from non-ATIS Trips (F95) to ATIS Trips (ASV95)

<u>Unfamiliar Truck Driver Experiments: Non-ATIS Trucks (UNF) vs. ATIS Trucks (ANV)</u>

Tables 4-3 (a-b) present the aggregate trip outcomes for drivers unfamiliar with local congestion patterns. Here, we compare the trip outcomes of simulated drivers making deliveries with the assistance of an ATIS service (ATIS trucks) or relying only on a paper map (non-ATIS trucks).

On average for unfamiliar drivers, ATIS trucks are early more often than non-ATIS trucks 15.8% compared to 13.68%) and late less often (29.2% compared to 33.9%) and as a result, just-in-time more often (55% compared to 52.5%). ATIS trucks experience a 16.4% increase in early arrival and a 14% reduction in late arrival compared to their non-ATIS counterparts.

When non-ATIS trucks with unfamiliar drivers do arrive early or late, they are on average 4.8 minutes early and 6.4 minute late. Comparatively, ATIS trucks averages when early or late are 5.0 and 4.5 minutes, respectively. These values constitute a 4.1% increase and a 30.4% decrease in the magnitude of early and late schedule delays, respectively. In addition, ATIS trucks are able to reduce trip time from 26.8 minutes to 25.4 minutes on average by changing their route pre-trip. As an example, Appendix includes the average travel time and travel distance of ATIS and non-ATIS trucks with unfamiliar drivers for each OD pair.

In this experiment departure times are considered fixed. Trucks using ATIS can improve their trip by changing route pre-trip. In 16.9% of all trips, ATIS trucks with unfamiliar drivers took different routes than their non-ATIS counterparts. The number of ATIS trucks that change their route varies significantly by time of day. The percent of ATIS trucks that change their route ranges between 12.5-28.1% by time of day, with most frequent route changes occurring in the PM peak. ATIS trucks with unfamiliar drivers benefit most in the PM peak period, excluding average minutes late when arriving late. Benefits in terms of average minutes late when arriving late are greatest in the off peak period.

TRIP OUTCOMES COMPARISON HAVING UNFAMILIAR TRUCK DRIVERS: ATIS TRUCKS (ANV) vs. NON-ATIS TRUCKS (UNF) (MAY 2002 -OCTOBER 2002)								
Aggregate Trip Metrics	ALL DAY		AM PEAK		OFF PEAK		PM PEAK	
	UNF	ANV	UNF	ANV	UNF	ANV	UNF	ANV
% of Trips Early	13.6%	15.8%	28.6%	31.9%	1.1%	1.3%	31.7%	38.0%
% of Trips Just in Time	52.5%	55.0%	47.2%	48.9%	61.0%	63.9%	35.9%	38.3%
% of Trips Late	33.9%	29.2%	24.2%	19.2%	37.9%	34.8%	32.4%	23.7%
When Early, Avg. Min. Early	4.8	5.0	7.9	8.2	2.0	2.0	9.2	9.7
When Late, Avg. Min Late	6.4	4.5	5.8	4.5	5.7	3.8	8.6	6.1
% of Route Change		16.9%		16.6%		12.5%		28.1%
Trip Time (min.)	26.84	25.38	29.85	28.63	23.53	22.52	32.51	29.74

Table 4-3 (a) Unfamiliar Drivers: ATIS (ANV) and Non-ATIS (UNF) Trip Outcomes

% CHANGE FROM UNF TO ANV: MAY 2002 -OCTOBER 2002				
Aggregate Trip Metrics	ALL DAY	AM PEAK	OFF PEAK	PM PEAK
Frequency of Early Arrival	16.4% ↑	11.5% ↑	18.2% ↑	19.9% ↑
Frequency of Late Arrival	14.0% ↓	20.7% ↓	8.2% ↓	26.6% ↓
When Early, Avg. Min. Early	4.1% ↑	4.9% ↑	0.5% ↑	5.4% ↑
When Late, Avg. Min Late	30.4% ↓	22.2% ↓	33.8% ↓	29.4% ↓
Trip Time (min.)	5.4% ↓	4.1% ↓	4.3% ↓	8.5% ↓

Table 4-3 (b) Unfamiliar Drivers: Percent Change from Non-ATIS Trips to ATIS Trips

Comparison of the Trip Outcomes of Three types of Truck Drivers using ATIS

Table 4-4 summarizes the trip outcomes for the three types of ATIS trucks with fixed departures that we analyzed. Unfamiliar drivers make the most frequent use of ATIS though route changes, but realize more modest improvement in on-time reliability than familiar drivers.

TRIP OUTCOMES COMPARISONS WITH FIXED DEPARTURE TIME (MAY 2002 -OCTOBER 2002)									
Aggregate Trip Metrics	Familiar Truck Drivers with						Unfamiliar Truck Drivers		
	Time Critical Truck Movements			Time Sensitive Truck Movements					
	Non-ATIS (F99)	ATIS (ASV99)	% of Change	Non-ATIS (F95)	ATIS (ASV95)	% of Change	Non-ATIS (UNF)	ATIS (ANV)	% of Change
% of Trips Early	64.9%	66.8%	2.9%	36.5%	38.7%	6.0%	13.6%	15.8%	16.4%
% of Trips Just in Time	33.4%	32.4%	-3.0%	57.9%	58.0%	0.1%	52.5%	55.0%	4.8%
% of Trips Late	1.7%	0.8%	-53.7%	5.6%	3.3%	-40.5%	33.9%	29.2%	-14.0%
When Early, Avg. Min. Early	18.8	19.4	3.0%	10.7	11.0	3.0%	4.8	5.0	4.1%
When Late, Avg. Min Late	3.9	1.7	-57.4%	5.7	3.6	-37.4%	6.4	4.5	-30.4%
% of Route Change		10.8%			11.1%			16.9%	
Trip Time (min.)	25.4	24.6	-3.0%	25.7	24.9	-3.0%	26.8	25.4	-5.4%

Table 4-4 Fixed Departure Time Condition: Trip Outcomes Comparison by ATIS Truck Types

4.1.2 Disutility Cost with Fixed Departure Time

This section describes the dollar-valued disutility cost by using two types of disutility functions. As described in Section 3.3, the difference between disutility Types 1 and 2 is the calculation method used for the cost of a late arrival. In the disutility function Type 1, the cost of a late arrival is a linear cost function of the magnitude of a late arrival plus a one-step penalty for arriving late. In the disutility function Type 2, the cost of a late arrival is simply a one-step penalty for arriving late. Therefore, disutility costs calculated by Type 2 are slightly lower than those calculated by Type 1.

Tables 4-5 (a-c) present the dollar-valued disutility results for the three simulated yoked trials pairing ATIS and non-ATIS trucks. When the one-step penalty for arriving late is $0, the unfamiliar driver has the lowest disutility and the familiar driver set with time sensitive truck movements has the highest disutility. This is because the non-ATIS truck drivers having time critical movements (F99) are so concerned about being late, they accept higher early arrival costs. As the one-step late penalty increases, the unfamiliar drivers' disutility steeply increases, because they arrive late more frequently than other drivers.

As the one-step late penalty increases from $0 to $1,000, the value of ATIS increases for all three types of truck drivers. ATIS trucks having time critical truck movements (ASV99) reduce disutility cost 0.6%-7.7% under disutility Type 1 where the one-step late penalty ranges from $0 to $1,000. Under disutility Type 2, the benefits range is similar, 0.2%-7.4%. ATIS trucks having time sensitive movements (ASV95) are able to reduce disutility cost from 2.0% up to 17.4% under disutility Type 1 and from 0.6% up to 16.8% in disutility Type 2. ATIS trucks with unfamiliar drivers (ANV) are able to reduce disutility cost by 9.5% up to 13% and by 3.3% up to 12.1% for disutility functions type 1 and type 2, respectively.

		One-Step Penalty for Arriving Late						
		$0	$50	$100	$200	$300	$500	$1,000
Disutility Type 1	F99	$ 106.4	$ 107.2	$ 108.1	$ 109.8	$ 111.5	$ 114.8	$ 123.3
	ASV99	$ 105.8	$ 106.2	$ 106.6	$ 107.4	$ 108.2	$ 109.8	$ 113.7
	% of Change	-0.6%	-1.0%	-1.4%	-2.2%	-3.0%	-4.4%	-7.7%
Disutility Type 2	F99	$ 105.7	$ 106.6	$ 107.4	$ 109.1	$ 110.8	$ 114.2	$ 122.6
	ASV99	$ 105.6	$ 106.0	$ 106.4	$ 107.2	$ 108.0	$ 109.5	$ 113.5
	% of Change	-0.2%	-0.6%	-1.0%	-1.8%	-2.6%	-4.1%	-7.4%

Table 4-5 (a) Disutility Costs for Non-ATIS (F99) and ATIS (ASV99) Trucks with Time Critical Movements

		One-Step Penalty for Arriving Late						
		$0	$50	$100	$200	$300	$500	$1,000
Disutility Type 1	F95	$ 88.2	$ 91.0	$ 93.8	$ 99.5	$ 105.2	$ 116.5	$ 144.8
	ASV95	$ 86.5	$ 88.1	$ 89.8	$ 93.1	$ 96.4	$ 103.0	$ 119.6
	% of Change	-2.0%	-3.2%	-4.3%	-6.4%	-8.3%	-11.5%	-17.4%
Disutility Type 2	F95	$ 86.0	$ 88.9	$ 91.7	$ 97.4	$ 103.0	$ 114.3	$ 142.6
	ASV95	$ 85.6	$ 87.2	$ 88.9	$ 92.2	$ 95.5	$ 102.1	$ 118.7
	% of Change	-0.6%	-1.9%	-3.1%	-5.3%	-7.3%	-10.7%	-16.8%

Table 4-5 (b) Disutility Costs for Non-ATIS (F95) and ATIS (ASV95) Trucks with Time Sensitive Movements

		One-Step Penalty for Arriving Late						
		$0	$50	$100	$200	$300	$500	$1,000
Disutility Type 1	UNF	$ 90.6	$ 107.6	$ 124.5	$ 158.5	$ 192.4	$ 260.3	$ 430.0
	ANV	$ 82.0	$ 96.6	$ 111.2	$ 140.4	$ 169.6	$ 228.0	$ 374.0
	% of Change	-9.5%	-10.2%	-10.7%	-11.4%	-11.9%	-12.4%	-13.0%
Disutility Type 2	UNF	$ 73.7	$ 90.7	$ 107.7	$ 141.6	$ 175.6	$ 242.5	$ 413.2
	ANV	$ 71.3	$ 85.9	$ 100.5	$ 129.7	$ 158.9	$ 217.3	$ 363.3
	% of Change	-3.3%	-5.3%	-6.6%	-8.4%	-9.5%	-10.4%	-12.1%

Table 4-5 (c) Disutility Costs for Unfamiliar Non-ATIS (UNF) and ATIS (ANV) Trucks

Figure 4-1 shows the percentage of reduced disutility from ATIS usage on the y-axis with the one-step penalty options on the x-axis. For both types of disutility functions, ATIS trucks with unfamiliar drivers (ANV) realize the largest reduction in disutility (up to $500). When the one-step penalty for arriving late is more than $500, ATIS trucks with time sensitive movements (ASV95) have the highest percent change in disutility from ATIS.

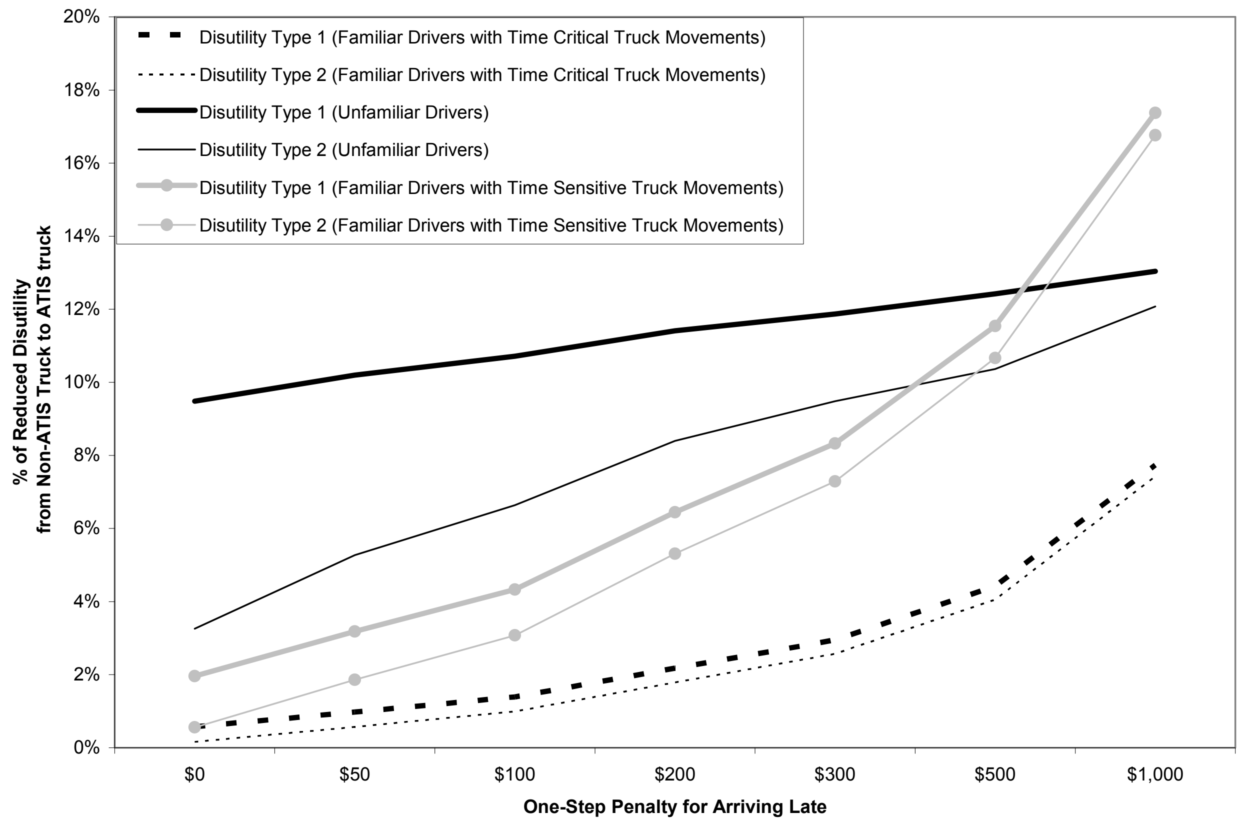


Figure 4-1 Percentage Reduction in Disutility, ATIS Truck versus Non-ATIS Truck

4.1.3 Truck Trips with Flexible Departure Time

In this experiment, we allow drivers of ATIS trucks the ability to adjust their departure time based on congestion conditions. In Sections 4.1.1 and 4.1.2, ATIS trucks were assumed to have fixed departure times. In this section, we evaluate ATIS benefit when ATIS trucks can change both their departure time and route based on traffic conditions. Because a flexible departure time does not impact the trip outcomes of non-ATIS trucks, we only compare trip outcomes between the two types of ATIS trucks (fixed departure time or with flexible departure time).

Comparison of Trip Outcomes with Fixed Departure: Table 4-6 summarizes the trip outcomes from ATIS trucks with fixed and flexible departure time conditions. When ATIS truck drivers can adjust their departure time, they generally increase the percent of just-in-time trips and reduce early and late schedule delay while incurring small increases in trip time. For all types of trucks, trip time increases by 0.3%-2.3%. One exception to this can be seen in the case of ATIS trucks with time critical movements where late trips rise by 64% to 1.3% of all trips. One other exception was unfamiliar ATIS trucks where average early schedule delay when early increases by 44% to 7.2 minutes from 5 minutes.

In terms of improved just-in-time performance, ATIS trucks with time critical movements experience the most significant benefit from flexible departure, notching a 148.5% increase to 80.6% from 32.4%. In terms of improved on-time reliability, unfamiliar ATIS trucks experience the most significant improvement, reducing late trips from 29.2% to 3.5%.

When flexible departure is allowed, ATIS trucks can accrue more benefit by adjusting departure time as well as finding the time dependent shortest path. When flexible departure is allowed, the percent of trips of ATIS trucks with time critical movements that depart earlier compared to their non-ATIS counterparts is 11.7% and the percent of trips where ATIS trucks with time critical movements depart later is 57.6%. The percentages of trips of ATIS trucks with time sensitive movements and unfamiliar ATIS trucks that depart earlier compared to their counterparts are 25% and 33%, respectively. The percentages of trips of ATIS trucks with time sensitive movements and unfamiliar ATIS trucks that depart later compared to their counterparts are 61% and 13%, respectively.

TRIP OUTCOMES COMPARISONS BETWEEN FIXED DEPARTURE TIME AND FLEXIBLE DEPARTURE TIME MAY 2002 -OCTOBER 2002									
Aggregate Trip Metrics	Fixed Departure Time			Flexible Departure Time			% of Change		
	ASV99	ASV95	ANV	ASV99	ASV95	ANV	ASV99	ASV95	ANV
% of Trips Early	66.8%	38.7%	15.8%	18.1%	11.6%	7.9%	-72.9%	-70.1%	-49.7%
% of Trips Just in Time	32.4%	58.0%	55.0%	80.6%	86.1%	88.6%	148.5%	48.7%	61.0%
% of Trips Late	0.8%	3.3%	29.2%	1.3%	2.3%	3.5%	64.4%	-31.9%	-88.0%
When Early, Avg. Min. Early	19.4	11.0	5.0	9.4	7.7	7.2	-51.4%	-29.4%	44.0%
When Late, Avg. Min Late	1.7	3.6	5.0	1.9	2.1	2.2	12.7%	-42.7%	-55.6%
% of Route Change	10.8%	11.1%	16.9%	11.1%	11.1%	16.6%	2.8%	0.2%	-1.7%
% of Early Departure				11.7%	25.3%	60.9%			
% of Late Departure				57.6%	33.0%	12.6%			
Trip Time (min.)	24.6	24.9	25.4	25.1	25.3	25.4	2.3%	1.6%	0.3%

*) ASV99: ATIS trucks with time critical movements
ASV95: ATIS trucks with time sensitive movements
ANV: ATIS trucks with unfamiliar drivers

Table 4-6 Trip Outcomes from ATIS-Trucks with Fixed or Flexible Departure Time

Disutility Costs: Dollar-valued disutility for all three types of trucks was calculated using the disutility function Type 1 and compared with those from fixed departure condition. For all types of trucks and all late penalties, the flexible departure contributes to the reduction of dollar valued disutility, except for unfamiliar ATIS trucks with a $0 one-step late arrival penalty.

Figure 4-2 presents the dollar valued disutility for the three types of drivers using our Type 1 function. The x-axis is one-step late arrival penalty and the y-axis is the dollar valued disutility. As in Figure 4-1, unfamiliar driver's disutility cost with fixed departure is most sensitive to the increase of one-step late penalty. When allowing flexible departure, unfamiliar ATIS trucks can reduce the percent of late trips and average late minutes, and as a result, their disutility is less sensitive to the one-step late penalty.

When flexible departure is allowed for ATIS trucks with time critical movements (ASV99), the range of trip disutility is $83-$96 (compared to $106-$114 with fixed departure). The disutility ranges of ATIS trucks with time sensitive movements (ASV95) and unfamiliar ATIS trucks (ANV) with flexible departures are $80-$103 and $80-$114 (compared to $87-$120 and $82-$374 with fixed departure). As the one-step late arrival penalty increases, the percent reduction in disutility for ATIS trucks with time critical movements decreases from 21% to 16%, while those of ATIS trucks with time sensitive movements and unfamiliar ATIS trucks increase from 8% to 14% and 3% to 69% respectively.

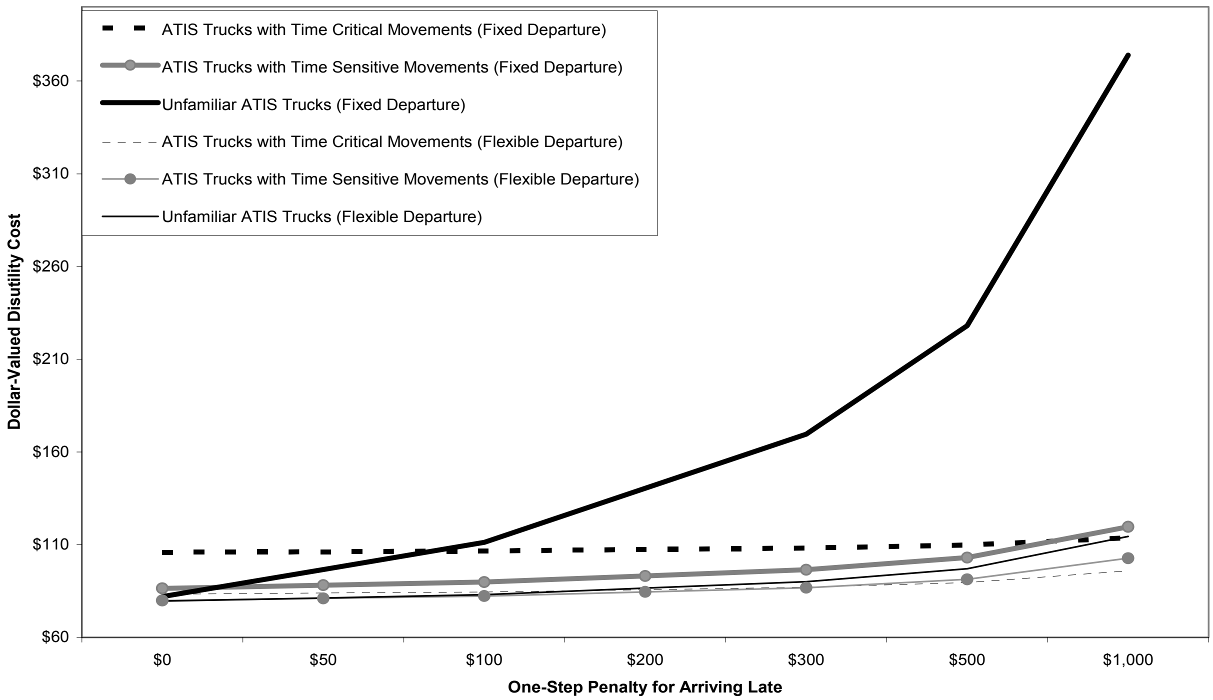


Figure 4-2 Disutility Cost for ATIS Trucks with Fixed and Flexible Departure Time by Type 1

4.2 ATIS Impacts by Intermodal Terminal Location

In this section, we analyze the trip outcomes for each intermodal terminal under our base case fixed departure time assumption.

Among the five terminals, the Port of Los Angeles is the most difficult destination to reach reliably, with the lowest percent of just-in-time trips and the highest percent of early arriving trips for all types of truck drivers. For example, the percent of just-in-time trips for ATIS trucks with time critical movements is only 14.4%. This compares with a just-in-time arrival rate of 35-43% at other terminals for ATIS trucks with time critical movements. The performance of trips to the Port of Los Angeles can be explained by both location and travel time variability of the connector link. The port is located on an isolated node, connected by only one link to the rest of case study network. The link length is 8.7 miles. Compared to an average trip length in our network of less than 30 miles, the impact of the connector link cannot be ignored. Moreover, this link has high travel time variability.

The four other intermodal terminals (excluding the Port of Los Angeles) considered in this research can be classified into two categories by location. Two of them (ATSF Rail Yard and NR Union Station) are located in the middle of the network and two of them (Los Angeles International Airport and Port of Long Beach) are on nodes on the exterior of the network. Trips to the ATSF rail yard and NR Union Station located in the middle of the network have similar trip characteristics and ATIS benefit. Trips to these two intermodal terminals have shorter travel times, lower trip time variability, and less dollar-valued disutility than those of others (as measured by their percent of change in disutility from non-ATIS to ATIS trucks with time critical movements) ATIS benefit is smaller for these interior network locations than intermodal terminals on the edge of network (Table 4-7).

Intermodal Terminal	Aggregate Trip Metrics	F99	ASV99	% of Change
Port of Long Beach	% of Trips Just in Time	36.6%	35.2%	-3.7%
	% of Trips Late	2.0%	0.9%	-54.0%
	When Late, Avg. Min. Late	4.9	1.9	-62.6%
	Trip Time (Min.)	26.6	25.7	-3.3%
	Disutility Cost*)	$105.4	$103.5	-1.7%
LA ATSF Rail Yard	% of Trips Just in Time	36.1%	35.1%	-2.8%
	% of Trips Late	1.8%	0.9%	-51.5%
	When Late, Avg. Min. Late	4.1	1.6	-60.5%
	Trip Time (Min.)	19.8	19.1	-3.4%
	Disutility Cost*)	$87.7	$86.1	-1.8%
LA NR. Union Station	% of Trips Just in Time	35.7%	34.9%	-2.2%
	% of Trips Late	1.8%	0.9%	-51.1%
	When Late, Avg. Min. Late	3.5	1.5	-56.4%
	Trip Time (Min.)	19.6	19.1	-2.8%
	Disutility Cost*)	$86.2	$84.6	-1.8%
Los Angeles International Airport	% of Trips Just in Time	43.8%	42.5%	-3.0%
	% of Trips Late	1.9%	0.7%	-60.5%
	When Late, Avg. Min. Late	3.8	1.4	-62.5%
	Trip Time (Min.)	26.4	25.5	-3.3%
	Disutility Cost*)	$104.1	$102.2	-1.8%
Port of Los Angeles	% of Trips Just in Time	15.0%	14.4%	-3.7%
	% of Trips Late	0.9%	0.5%	-41.7%
	When Late, Avg. Min. Late	3.2	1.9	-40.7%
	Trip Time (Min.)	34.4	33.5	-2.5%
	Disutility Cost*)	$157.0	$156.3	-0.4%

*)Disutility type 1 with $100 one-step arrival late penalty

Table 4-7 Trip Outcomes of Intermodal Terminals for ATIS (ASV99) and Non-ATIS (F99) Trucks with Time Critical Movements

4.3 ATIS Impacts under Partial Roadway Network Surveillance

In Sections 4.1 and 4.2, we assumed that an ATIS service is provided for the entire Los Angeles freeway network. However, in this section, we limit ATIS information for adjacent links from intermodal terminal to test the hypothesis 4 in Section 1.2. We analyze ATIS impacts for the trucks with time critical movements on partially-covered networks. Non-ATIS trucks are not affected by the loss of travel time information because they do not rely on ATIS information for their trip decisions.

Table 4-8 summarizes the trip outcomes of ATIS trips with time critical movements to each intermodal terminal when an ATIS service is provided for the entire network (complete network) and a partial network. Percent of late trips and average minutes late when late are shown in Table 4-8, because these are the most significant metrics influencing disutility cost.

Under the partial ATIS network, benefits for ATIS-trucks are reduced for all intermodal terminals, compared to the benefits on the entire network. The differences vary according to the intermodal terminal location and although small in magnitude, are statistically significant.

Intermodal Terminal	Trip Metrics	ATIS Trips with Fixed Departure			ATIS Trips with Flexible Departure		
		Partial Network (PN)	Complete network (WN)	% Change from WN to PN	Partial Network (PN)	Complete network (WN)	% Change from WN to PN
Port of Long Beach	% of Trips Late	0.90%	0.90%	0.01%	1.71%	1.40%	22.03%
	When Late, Avg. Min. Late	1.85	1.85	0.00%	2.61	2.30	13.34%
	Disutility Cost*)	$103.65	$103.54	0.11%	$85.11	$84.62	0.58%
LA ATSF Rail Yard	% of Trips Late	0.90%	0.89%	0.70%	0.94%	0.86%	8.80%
	When Late, Avg. Min. Late	1.69	1.61	4.57%	1.49	1.30	14.59%
	Disutility Cost*)	$86.17	$86.14	0.03%	$67.14	$67.03	0.17%
LA NR. Union Station	% of Trips Late	0.90%	0.89%	1.42%	0.57%	0.54%	5.67%
	When Late, Avg. Min. Late	1.58	1.53	3.48%	0.95	0.88	8.77%
	Disutility Cost*)	$84.61	$84.61	0.00%	$66.15	$66.10	0.08%
Los Angeles International Airport	% of Trips Late	0.84%	0.75%	12.62%	1.57%	0.85%	83.59%
	When Late, Avg. Min. Late	1.70	1.44	18.39%	1.67	1.38	21.32%
	Disutility Cost*)	$102.37	$102.23	0.14%	$86.14	$85.05	1.28%
Port of Los Angeles	% of Trips Late	0.55%	0.54%	1.79%	2.82%	1.27%	122.91%
	When Late, Avg. Min. Late	1.93	1.91	1.38%	3.63	1.88	93.07%
	Disutility Cost*)	$156.37	$156.34	0.02%	$119.97	$119.70	0.23%

*)Disutility type 1 with $100 one-step arrival late penalty

Table 4-8 Trip Outcomes under Complete and Partial Roadway Network Surveillance (ATIS Trucks with Time Critical Movements)

The loss of coverage on connector links has the most significant impact on Los Angeles International Airport. The reason is that Los Angeles International Airport has the longest connector. Two rail/truck intermodal terminals, ATSF Rail yard and NR Union station located middle of the network, have no significant impact from loss of connector coverage.

4.4 Summary of Case Study

In Section 4, we explored trip metrics and dollar-valued disutility for trucks traveling from each node to intermodal terminals in Los Angeles area considering a 38 day training period and a 110 day evaluation period. We focused on how trucks using ATIS perform relative to their counterparts for both fixed departure and flexible departure time conditions. We also analyzed the effect of ATIS surveillance on the connectors to intermodal terminals by comparing trip performance with both complete ATIS network coverage and partial ATIS network coverage for each intermodal terminal.

- Under the fixed departure time condition, ATIS benefits truck operations by finding the time-dependent shortest path. ATIS trucks make pre-route changes on 10.8-16.9% of days, reducing late arrivals by 14-54%.

- Among of three types of truck drivers, familiar drivers with time critical truck movements show the largest percentage reduction in late trips. In terms of dollar-valued disutility, unfamiliar drivers realize the most benefit from using ATIS.

- When flexible departure times are allowed, truck drivers can accrue more benefits from using ATIS. The value of improved reliability rose to \$8.3-\$316 per trip from \$0.6-\$56 per trip compared to trucks with fixed departure times.

- The accrued benefit from ATIS varied by terminal location and connectivity.

  - With ATIS covering the whole network, trucks coming to or from Port of Los Angeles had the highest disutility savings from using ATIS, because of variable congestion on a critical connector link.

- When the links adjacent to intermodal terminals were excluded from ATIS coverage, trips destined for intermodal terminals located on the edge of the network had significantly worsened reliability performance.

5 KEY FINDINGS AND FUTURE WORK

In this section, we revisit the hypotheses of the study first presented in Section 1.2 and provide a summary of key findings from the Los Angeles case study in Section 5.1. Implications of these findings are presented in Section 5.2. Conclusions and future work are presented in Section 5.3

5.1 Hypotheses and Key Findings

***Hypothesis 1*:** ATIS trucks will outperform non-ATIS trucks in terms of improved travel reliability and reduced operating costs. The benefit from using ATIS will vary depend on truck drivers' familiarity with geographical and traffic characteristics in the area and desired level of on-time arrival.

Findings: Even with fixed trip starts, trucks realize significant on-time reliability benefits from ATIS across of all types of truck drivers considered in our experiments (shown in the highlighted row in Table 5-1). These benefits are realized from more efficient route choice decisions. ATIS trucks reduce their risk of late arrival by more than half when they are familiar to the area and are strongly motivated to be on-time for time critical truck movements (target on-time arrival rate 99%). Truck drivers who are unfamiliar with local congestion patterns can also cut their risk of late arrival. The benefits of ATIS for trucks can be valued between \$1.5-\$13.3 per trip depending on how time critical the truck movement is and the familiarity of the driver with congestion conditions in the network. Higher values (\$13.3) are associated with trips made by unfamiliar drivers.

TRIP OUTCOMES FOR ALL DAY WITH FIXED DEPARTURE (MAY 2002 -OCTOBER 2002)									
Aggregate Trip Metrics	Familiar Drivers with Time Critical Truck Movements			Familiar Drivers with Time Sensitive Truck Movements			Unfamiliar Drivers		
	non-ATIS	ATIS	% change	non-ATIS	ATIS	% change	non-ATIS	ATIS	% change
On-Time Reliability	98.3%	99.2%	0.9%	94.3%	96.7%	2.5%	66.1%	70.8%	7.1%
% of Trips Late	1.7%	0.8%	-52.9%	5.7%	3.3%	-42.1%	33.9%	29.2%	-13.9%
Dollar -Valued Disutility*	$ 108.1	$ 106.6	-1.4%	$ 93.8	$ 89.8	-4.3%	$ 124.5	$ 111.2	-10.7%
Trip Time (min.)	25.4	24.6	-3.1%	25.7	24.9	-3.1%	26.8	25.4	-5.4%

*)Disutility type 1 with $100 one-step late penalty

Table 5-1 ATIS Impacts for Trucks Having Fixed Departure Time

Truck trips with flexible start times realize even higher benefits from ATIS use. Trucks with this flexibility improved their reliability by both changing the time of trip start and route choice. When flexible departure time was allowed for ATIS trucks, travel time increased slightly (0.3%-2.3%) compare to fixed departures. As shown in the highlighted row in the Table 5-2, however the value of improved reliability raised to $7.6-$28.2 per trip depending on how time critical the trip and the level of driver familiarity with congestion patterns. When flexible trip timing is allowed, the value of ATIS is more than fifteen times that of fixed departure time trips for time critical deliveries.

TRIP OUTCOMES COMPARISONS BETWEEN FIXED DEPARTURE TIME AND FLEXIBLE DEPARTURE TIME MAY 2002 -OCTOBER 2002									
Aggregate Trip Metrics	Fixed Departure Time			Flexible Departure Time			% of Change		
	Familiar		Un-familiar	Familiar		Un-familiar	Familiar		Un-familiar
	Time Critical	Time Sensitive		Time Critical	Time Sensitive		Time Critical	Time Sensitive	
On-Time reliability	99.2%	96.7%	70.8%	98.7%	97.7%	96.5%	-0.5%	1.1%	36.3%
% of Trips Late	0.8%	3.3%	29.2%	1.3%	2.3%	3.5%	64.4%	-31.9%	-88.0%
Dollar-Valued Disutility*	$106.6	$89.8	$111.2	$84.5	$82.2	$83.0	-20.7%	-8.5%	-25.4%
Trip Time (min.)	24.6	24.9	25.4	25.1	25.3	25.4	2.3%	1.6%	0.3%

*)Disutility type 1 with $100 one-step late penalty

Table 5-2 ATIS Impacts Comparison between Fixed and Flexible Departure Time

> ***Hypothesis 2***: The benefit from using ATIS will depend on the location of the intermodal terminal. We expect that some locations have more ATIS benefit than others because some trips will have more variable travel times than others.

Findings: The benefit from using ATIS varied by the location of the terminals. Table 5-3 shows the percent change of trip metrics from non-ATIS trucks to ATIS trucks. Generally, trips destined to intermodal terminals located in the middle of the network had significantly less dollar-valued disutility than trips destined to terminals located on the edge of the network, regardless of whether ATIS is used. Trip outcomes from terminals located on the edge of the network had slightly more benefit than the terminals located in the middle of the network. Trucks traveling to Port of Los Angeles have the smallest benefit among the five intermodal terminals. This result is related to how trucks must access the facility. The Port of Los Angles is connected to the freeway system by one long link (8.7miles) with high travel time variability. With no good alternative access route ATIS trucks cannot find better paths around this frequently congested link.

Intermodal Terminal	Aggregate Trip Metrics	Non-ATIS Trucks	ATIS Trucks	% of Change
Port of Long Beach	% of Trips Late	2.0%	0.9%	-54.0%
	When Late, Avg. Min. Late	4.9	1.9	-62.6%
	Disutility Cost*)	$105.4	$103.5	-1.7%
LA ATSF Rail Yard	% of Trips Late	1.8%	0.9%	-51.5%
	When Late, Avg. Min. Late	4.1	1.6	-60.5%
	Disutility Cost*)	$87.7	$86.1	-1.8%
LA NR. Union Station	% of Trips Late	1.8%	0.9%	-51.1%
	When Late, Avg. Min. Late	3.5	1.5	-56.4%
	Disutility Cost*)	$86.2	$84.6	-1.8%
Los Angeles International Airport	% of Trips Late	1.9%	0.7%	-60.5%
	When Late, Avg. Min. Late	3.8	1.4	-62.5%
	Disutility Cost*)	$104.1	$102.2	-1.8%
Port of Los Angeles	% of Trips Late	0.9%	0.5%	-41.7%
	When Late, Avg. Min. Late	3.2	1.9	-40.7%
	Disutility Cost*)	$157.0	$156.3	-0.4%

*)Disutility type 1 with $100 one-step arrival late penalty

Table 5-3 ATIS Impacts on Trips with Time Critical Trips by Intermodal Terminal Locations

Hypothesis 3: ATIS trucks will accrue significantly reduced benefit from an ATIS system covering only urban freeways versus a system including surveillance on key (non-freeway) intermodal terminal connector links.

Findings: ATIS benefit dropped by as much as 1.3% in terms of disutility cost when connector links were not assumed to be under surveillance. When flexible departure time was allowed, trips arriving at the Port of Los Angeles had the most serious impact under limited ATIS information, because of its long and frequently congested connector link. Impacts of partial coverage for terminals in the interior of the network (such as ATSF railyard and NR Union Station) were less significant.

Intermodal Terminal	Trip Metrics	ATIS Trips with Fixed Departure			ATIS Trips with Flexible Departure		
		Partial Network (PN)	Complete network (WN)	% Change from WN to PN	Partial Network (PN)	Complete network (WN)	% Change from WN to PN
Port of Long Beach	% of Trips Late	0.90%	0.90%	0.01%	1.71%	1.40%	22.03%
	When Late, Avg. Min. Late	1.85	1.85	0.00%	2.61	2.30	13.34%
	Disutility Cost*)	$103.65	$103.54	0.11%	$85.11	$84.62	0.58%
LA ATSF Rail Yard	% of Trips Late	0.90%	0.89%	0.70%	0.94%	0.86%	8.80%
	When Late, Avg. Min. Late	1.69	1.61	4.57%	1.49	1.30	14.59%
	Disutility Cost*)	$86.17	$86.14	0.03%	$67.14	$67.03	0.17%
LA NR. Union Station	% of Trips Late	0.90%	0.89%	1.42%	0.57%	0.54%	5.67%
	When Late, Avg. Min. Late	1.58	1.53	3.48%	0.95	0.88	8.77%
	Disutility Cost*)	$84.61	$84.61	0.00%	$66.15	$66.10	0.08%
Los Angeles International Airport	% of Trips Late	0.84%	0.75%	12.62%	1.57%	0.85%	83.59%
	When Late, Avg. Min. Late	1.70	1.44	18.39%	1.67	1.38	21.32%
	Disutility Cost*)	$102.37	$102.23	0.14%	$86.14	$85.05	1.28%
Port of Los Angeles	% of Trips Late	0.55%	0.54%	1.79%	2.82%	1.27%	122.91%
	When Late, Avg. Min. Late	1.93	1.91	1.38%	3.63	1.88	93.07%
	Disutility Cost*)	$156.37	$156.34	0.02%	$119.97	$119.70	0.23%

*)Disutility type 1 with $100 one-step arrival late penalty

Table 5-4 ATIS Impacts under Complete and Partial ATIS Roadway Network Surveillance (with Time Critical Truck Movements)

5.2 Implications of the Research

As results in Chapter 4 showed, ATIS benefit was greater for drivers who are not familiar with the area in terms of dollar-valued disutility. Because of the nature of truck operations, it is likely that drivers covering long distances to reach intermodal terminals may be unfamiliar with local congestion patterns. For more efficient freight movement, web sites catering to truck operations may benefit from including congestion information. For example, the Commercial Vehicle Information Systems and Network (CVISN) program sponsored by Federal Motor Carrier Safety Administration (FMCSA) is tasked to identify, develop, and deploy a specific set of organizational and technical capabilities associated with CVO-related information systems and communications networks. Currently, Washington State road work (work zones), traffic conditions, and weather information is provided on the CVISN website. Average link travel time and current link travel time is also posted. Based on our research efforts such as the one in CVISN are likely to have significant benefits for drivers who have time critical shipments.

To date, ATIS deployment priority has been focused on passenger travel and on freeways rather than arterials. Also, freeways located between urban areas have lower priority than center-city freeways. Since May 2002, Mitretek has measured urban congestion and mobility in ten cities (Boston MA, Cincinnati OH, Miami FL, Seattle WA, Los Angeles CA, Houston TX, Chicago IL, San Antonio TX, Pittsburgh PA, and Philadelphia PA) based on "real-time" traffic information on various web sites. Facilities covered by ATIS are all freeways, except in Boston and Cincinnati where arterial coverage compared to the total network is 15% and 17%, respectively (Jung, 2003). Given the importance of arterial connector links to intermodal terminals, these ATIS deployments may have been different if the value for freight operations had been considered.

The estimated ATIS benefit on commuter trips in Los Angeles was $0.85/trip using the same network in a previous study (Shah et al., 2003). Our study of truck movements indicate the range of estimated value of disutility reduction per truck trip was $8-$316, when flexible departure is allowed for trucks. Depending upon the cargo and time criticality of shipments, ATIS provides more than 10 times the value for a truck trip than for a commuter trip. Therefore, significant benefits may be overlooked if only commuters are considered in the deployment of ATIS. That said, the ATIS needs of the freight operation and the commuter are not identical. Some arterials, which have an important role as connectors to intermodal terminals, may warrant surveillance instrumentation equivalent to freeway deployments.

5.3 Conclusions and Future Work

By modifying the HOWLATE methodology parameters to accommodate representation of realistic truck operations, we successfully evaluated ATIS impacts on truck operations in terms of on-time reliability and trip disutility reduction. The study included trucks with varying needs for on-time arrival and varying familiarity with the regional roadway network and traffic conditions. The case study was performed using the Los Angeles region network.

Clearly the case study indicated that for trucks that need to be on time and face considerable variability in their trip travel times, ATIS was a useful and high-value service. In particular, drivers not familiar with the regional roadway network and congestion can reap significant benefit from ATIS.

A valuable extension of this research would be to examine the benefits of ATIS for more to complex truck operations, such as fleet routing and scheduling. However, a key obstacle to this extension is the current coverage of the ATIS network - predominantly limited to highways. This more realistic application would require data on the arterial network, not just the freeway network.

Additional extensions of this study include an assessment of the benefit of en-route information on truck operations. This research was performed based on the pre-trip decisions. After departure from the origin the simulated truck did not receive updated information on traffic conditions. Therefore, the truck may be late because of unexpected traffic conditions occurring on the selected route after departure from the origin. Clearly, the en-route ATIS impact depends upon the shape of the network. Even with updated information an en-route service will not be helpful unless alternative routes are available.

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Appendix: Average travel time and travel distance for unfamiliar trucks with fixed departure time

Origin Node	Destination Node	Average of non-ATIS Truck Travel Time (min)	Average of ATIS Truck Travel Time (min)	Average of Optimal Travel Time (min)	Average of non-ATIS Truck Trip Distance (mile)	Average of ATIS Truck Trip Distance (mile)
0	9	16.31	16.11	15.99	14.50	14.68
	12	24.96	22.17	21.55	19.50	20.04
	16	15.26	14.75	14.49	13.40	13.64
	35	17.02	16.96	16.88	14.10	14.15
1	0	6.66	6.57	6.53	5.40	5.45
	9	19.47	18.69	18.43	16.40	16.71
	12	24.52	22.69	22.21	17.90	19.05
	16	9.65	9.26	9.04	8.00	8.13
	35	11.41	11.41	11.36	8.80	8.80
2	0	7.90	7.76	7.69	6.30	6.37
	9	18.63	17.83	17.56	15.50	15.78
	12	23.67	21.79	21.32	17.00	18.15
	16	10.92	9.69	9.18	8.90	8.97
	35	12.64	12.64	12.57	9.70	9.70
3	0	4.53	4.49	4.48	4.30	4.34
	9	12.06	11.90	11.83	10.20	10.33
	12	20.72	18.02	17.48	15.20	15.72
	16	15.47	14.50	14.16	14.01	14.07
	35	17.98	17.96	17.89	15.00	15.01
4	0	9.96	9.90	9.84	9.30	9.36
	9	15.73	14.60	14.32	11.30	11.91
	12	24.34	20.60	20.00	16.30	17.60
	16	20.31	19.54	19.13	18.61	18.71
	35	23.39	23.34	23.26	20.00	20.03
5	0	11.84	11.74	11.63	11.61	11.65
	9	12.49	11.67	11.41	8.70	9.14
	12	21.11	17.63	17.09	13.70	14.81
	16	17.03	16.94	16.83	15.90	15.99
	35	25.23	25.16	25.05	22.30	22.31
6	0	7.09	7.05	7.03	7.00	7.04
	9	8.88	8.82	8.78	7.50	7.56
	12	17.50	14.90	14.44	12.50	12.92
	16	12.29	12.22	12.14	11.30	11.36
	35	20.50	20.47	20.43	17.70	17.70
7	0	12.18	11.85	11.71	10.30	10.47
	9	20.59	16.20	15.70	13.41	13.61
	12	19.74	18.54	18.20	13.00	14.08
	16	5.47	5.47	5.47	5.20	5.20
	35	16.82	16.81	16.72	13.70	13.72
8	0	13.92	13.82	13.71	13.61	13.65
	9	9.04	8.85	8.80	6.70	6.91
	12	17.65	14.89	14.47	11.70	12.44
	16	19.13	19.04	18.91	17.90	17.89
	35	27.29	27.22	27.12	24.20	24.21

Origin Node	Destination Node	Average of non-ATIS Truck Travel Time (min)	Average of ATIS Truck Travel Time (min)	Average of Optimal Travel Time (min)	Average of non-ATIS Truck Trip Distance (mile)	Average of ATIS Truck Trip Distance (mile)
9	0	15.65	15.59	15.52	14.50	14.58
	12	8.63	6.02	5.67	5.00	5.35
	16	24.20	20.82	20.25	18.61	18.82
	35	29.06	28.93	28.78	25.20	25.27
10	0	17.19	17.13	17.02	15.70	15.79
	9	1.53	1.53	1.53	1.20	1.20
	12	5.04	4.92	4.89	5.00	5.01
	16	24.01	21.56	21.13	19.00	19.43
	35	30.57	30.29	30.10	26.40	26.46
11	0	20.62	19.57	19.30	17.20	17.62
	9	5.13	4.18	4.01	2.70	2.98
	12	3.83	3.77	3.72	2.30	2.38
	16	19.62	19.16	19.00	15.90	16.24
	35	30.75	29.93	29.63	24.40	24.89
12	0	24.85	22.37	21.95	19.50	20.01
	9	9.46	6.96	6.66	5.00	5.36
	16	23.83	22.76	22.41	18.20	18.76
	35	34.96	33.40	32.83	26.70	27.52
13	0	28.04	24.72	24.18	21.51	21.89
	9	12.53	9.61	9.26	7.00	7.40
	12	3.12	3.11	3.10	2.00	2.01
	16	23.18	22.22	21.95	16.90	17.55
	35	34.52	33.35	32.79	25.40	26.27
14	0	26.31	24.12	23.45	20.32	20.71
	9	10.73	9.55	9.17	5.80	6.33
	12	5.51	5.42	5.35	3.40	3.45
	16	20.16	19.79	19.59	15.50	15.86
	35	31.39	30.92	30.56	24.00	24.49
15	0	21.89	20.73	20.41	17.90	18.41
	9	8.64	7.73	7.55	5.80	6.06
	12	7.39	7.30	7.17	5.40	5.47
	16	15.26	15.17	15.12	12.80	12.87
	35	26.55	26.48	26.26	21.30	21.40
16	0	16.60	15.75	15.55	13.44	13.81
	9	26.25	22.01	21.34	18.61	18.84
	12	25.41	24.31	23.85	18.20	19.25
	35	21.34	20.67	20.50	16.80	16.97
17	0	24.18	23.44	23.09	20.91	21.30
	9	10.65	10.60	10.56	9.70	9.73
	12	14.18	13.97	13.90	13.50	13.54
	16	29.33	28.47	28.04	25.20	25.72
	35	37.55	36.85	36.45	31.60	31.97
18	0	27.39	26.64	26.25	23.81	24.23
	9	14.04	13.74	13.62	12.63	12.64
	12	15.16	14.37	14.22	12.70	13.14
	16	32.57	31.70	31.19	28.10	28.63
	35	40.71	40.01	39.61	34.50	34.89

Origin Node	Destination Node	Average of non-ATIS Truck Travel Time (min)	Average of ATIS Truck Travel Time (min)	Average of Optimal Travel Time (min)	Average of non-ATIS Truck Trip Distance (mile)	Average of ATIS Truck Trip Distance (mile)
19	0	33.29	32.59	32.11	29.81	30.25
	9	19.92	19.63	19.49	18.63	18.67
	12	21.07	20.27	20.05	18.70	19.17
	16	38.49	37.70	37.02	34.10	34.66
	35	46.56	45.93	45.45	40.50	40.91
20	0	39.32	36.26	35.44	31.81	32.37
	9	23.92	21.21	20.60	17.30	17.75
	12	14.52	14.49	14.44	12.30	12.33
	16	34.53	33.74	33.23	27.10	27.81
	35	45.71	44.77	44.06	35.60	36.46
21	0	30.98	27.82	27.15	23.61	23.98
	9	15.56	12.68	12.23	9.10	9.50
	12	6.10	6.10	6.06	4.10	4.11
	16	26.22	25.31	24.93	18.90	19.57
	35	37.47	36.39	35.76	27.40	28.26
22	0	35.09	32.04	31.33	27.51	27.92
	9	19.76	16.95	16.43	13.00	13.42
	12	10.31	10.30	10.26	8.00	8.02
	16	30.36	29.47	29.06	22.90	23.51
	35	41.55	40.51	39.90	31.40	32.17
23	0	36.71	33.05	32.25	27.81	28.64
	9	21.36	17.92	17.36	13.30	14.14
	12	11.89	11.32	11.20	8.30	8.61
	16	32.00	30.35	29.82	23.10	24.28
	35	43.31	41.59	40.82	31.60	32.95
24	0	42.98	37.61	36.63	30.66	32.55
	9	27.80	22.63	21.97	16.10	18.09
	12	17.66	16.69	16.51	13.31	13.63
	16	35.71	31.29	30.87	23.40	24.93
	35	47.95	45.36	44.50	34.20	36.01
25	0	59.38	50.89	49.43	43.94	45.96
	9	43.57	36.55	35.27	31.33	32.53
	12	30.55	29.74	29.41	26.70	27.12
	16	42.90	40.91	40.04	30.50	32.88
	35	64.28	58.39	56.75	47.30	49.34
26	0	55.57	46.94	45.63	39.94	41.96
	9	39.72	32.51	31.47	27.33	28.55
	12	26.74	25.90	25.61	22.70	23.13
	16	39.06	36.97	36.24	26.50	28.88
	35	60.43	54.31	52.96	43.30	45.40
27	0	49.99	42.47	41.32	36.94	38.10
	9	34.76	27.27	26.48	22.43	23.63
	12	21.70	20.82	20.61	17.80	18.21
	16	43.03	37.31	36.51	29.70	31.38
	35	55.14	50.86	49.59	40.54	42.17
28	0	38.38	35.38	34.54	30.91	31.37
	9	22.95	20.24	19.64	16.40	16.81

Origin Node	Destination Node	Average of non-ATIS Truck Travel Time (min)	Average of ATIS Truck Travel Time (min)	Average of Optimal Travel Time (min)	Average of non-ATIS Truck Trip Distance (mile)	Average of ATIS Truck Trip Distance (mile)
28	12	13.54	13.52	13.47	11.40	11.43
	16	33.61	32.81	32.27	26.30	26.90
	35	44.73	43.80	43.11	34.80	35.62
29	0	44.78	40.92	40.02	31.54	33.52
	9	35.50	30.38	29.52	21.30	23.53
	12	25.44	24.48	24.27	18.61	19.02
	16	28.17	27.39	27.05	18.10	19.33
	35	49.46	46.61	45.86	34.90	36.42
30	0	27.06	26.24	25.87	21.84	22.29
	9	23.35	22.20	21.72	15.30	16.13
	12	22.04	21.85	21.63	14.90	15.24
	16	10.57	10.57	10.53	8.40	8.40
	35	31.85	31.21	30.81	25.10	25.33
31	0	41.64	39.77	38.94	34.81	35.85
	9	28.18	26.70	26.29	23.63	24.13
	12	29.31	27.40	27.05	23.70	24.96
	16	46.80	45.00	43.88	39.10	40.32
	35	55.05	53.21	52.27	45.58	46.54
32	0	40.42	39.19	38.51	33.21	34.15
	9	26.94	26.17	25.96	22.00	22.59
	12	30.39	29.03	28.70	25.80	26.25
	16	45.49	44.23	43.41	37.50	38.55
	35	53.67	52.48	51.79	43.90	44.77
33	0	19.97	19.87	19.74	17.90	18.05
	9	4.35	4.32	4.30	3.40	3.43
	12	2.84	2.82	2.81	2.80	2.82
	16	26.67	24.14	23.50	21.00	21.42
	35	33.45	32.86	32.65	28.64	28.72
34	0	25.98	25.93	25.72	20.61	20.56
	9	21.00	20.86	20.76	13.70	13.90
	12	29.74	27.14	26.48	18.70	19.43
	16	31.19	31.14	30.91	24.90	24.89
	35	39.53	39.48	39.18	31.20	31.21
35	0	15.30	15.22	15.16	14.10	14.15
	9	28.20	27.51	27.04	25.20	25.49
	12	33.13	31.52	30.82	26.70	27.79
	16	18.30	17.95	17.66	16.80	16.92
36	0	15.42	15.35	15.26	14.50	14.56
	9	21.18	20.14	19.75	16.40	17.00
	12	29.86	26.23	25.43	21.40	22.69
	16	25.75	25.04	24.56	23.71	23.81
	35	28.81	28.77	28.67	25.10	25.13
37	0	80.81	77.93	75.46	64.85	66.66
	9	71.62	68.06	65.22	54.70	56.68
	12	61.53	61.04	60.11	52.01	52.37
	16	64.50	64.07	62.75	51.50	52.69
	35	85.53	83.43	81.07	68.20	69.60

Origin Node	Destination Node	Average of non-ATIS Truck Travel Time (min)	Average of ATIS Truck Travel Time (min)	Average of Optimal Travel Time (min)	Average of non-ATIS Truck Trip Distance (mile)	Average of ATIS Truck Trip Distance (mile)
38	0	33.88	33.16	32.49	27.04	27.48
	9	30.07	29.01	28.34	20.50	21.32
	12	28.75	28.60	28.24	20.10	20.44
	16	17.52	17.52	17.39	13.60	13.60
	35	38.48	37.94	37.30	30.40	30.61
39	0	50.76	49.10	47.80	41.01	42.04
	9	37.37	35.97	35.27	29.83	30.32
	12	38.54	36.68	36.02	29.90	31.17
	16	55.96	54.38	52.70	45.30	46.50
	35	64.20	62.59	61.02	51.78	52.71
40	0	8.21	8.21	8.20	7.60	7.60
	9	24.57	24.41	24.22	22.10	22.29
	12	33.18	30.57	29.78	27.10	27.62
	16	23.52	23.08	22.72	21.00	21.24
	35	25.19	25.14	25.11	21.80	21.85