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Stated And Reported Route Diversion Behavior: Implications On The Benefits Of ATIS

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### Authors

Khattak, Asad  
Kanafani, Adib  
Le Colletter, Emmanuel

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CALIFORNIA PATH PROGRAM  
INSTITUTE OF TRANSPORTATION STUDIES  
UNIVERSITY OF CALIFORNIA, BERKELEY

# **Stated and Reported Route Diversion Behavior: Implication on the Benefits of ATIS**

**Asad Khattak  
Adib Kanafani  
Emmanuel Le Colletter**

**California PATH Research Report  
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Institute of Transportation Studies  
California PATH Program  
University of California at Berkeley

**STATED AND REPORTED ROUTE DIVERSION BEHAVIOR:  
IMPLICATIONS ON THE BENEFITS OF ATIS**

Research Report

**Asad Khattak**

Adib Kanafani

Emmanuel Le Colletter

January 1994

Berkeley, California

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## **ABSTRACT**

Advanced Traveler Information Systems (**ATIS**) user benefits are estimated from a survey of commuting behavior undertaken in the San Francisco Bay Area in 1993. Both reported and stated response to unexpected congestion are used to determine the commuters who would directly benefit from qualitative, quantitative and predictive, as well as prescriptive **ATIS** information. Under incident conditions, **ATIS** quantitative delay information may induce about 40% of the commuters to change their route to work, mostly the people with greater diversion opportunities, knowledge of more alternate routes, and lower congestion levels on their best alternate route. The travel time savings achieved by **ATIS**-induced route diversion (with quantitative information) are calculated from the survey and translated into monetary benefits. The value of time used is a function of personal income and of the time savings. The frequency of annual diversion is estimated from the time elapsed since the last incident. The potential annual benefits from **ATIS** route diversion, applicable to about 40% of commuters in the Golden Gate Bridge corridor, range from \$124 to \$324 per person, depending on the weight assumed for delay.

## **I.INTRODUCTION**

Advanced Traveler Information Systems (**ATIS**), an element of the general IVHS (Intelligent Vehicle-Highway Systems) effort, are intended to help drivers make more informed travel decisions. Computerized in-vehicle information systems could support pre-trip decisions such as departure time, destination choice, and trip chaining sequence, as well as route selection and diversion while en route.

The successful introduction of **ATIS** in the market is conditional on the net benefits that users can gain from the system. Time savings achieved when changing route to avoid incident-induced bottlenecks will probably be among the most tangible user benefits of **ATIS**. This study intends to evaluate the extent of such benefits, using the results of a

survey about commuting behavior. The survey is used to determine who would divert when prompted to do so by an **ATIS** device, how these people value their time, how much time they would save by diverting, and consequently, how much they would benefit from a route change.

This paper first summarizes the conceptual framework used as a basis for the research. It covers the issues of reported and stated preferences, user and system benefits of **ATIS**, the propensity of commuters to divert under incident conditions, and finally the notion of a monetary value of time. The design of the survey and the main characteristics of the sample are presented. The commuting behavior of the participants is detailed, along with the relationships between reported and stated preferences about diversion propensity. Then, a profile of the people who stated they would divert under **ATIS** is given. The core of the text details the calculations made to obtain the value of time of each respondent and the total benefits brought by **ATIS**-induced diversion.

## **2. CONCEPTUAL STRUCTURE AND SYNTHESIS OF LITERATURE**

### **2.1 Reported behavior and stated preferences**

Reported behavior is used to quantify responses only when it is difficult or impossible to observe directly the behavior of a large number of individuals in a given situation. Because of perceptual errors, omissions, or memory loss, there might be a discrepancy between true behavior and what is reported by individuals. Reported behavior is often, however, the best estimate available for the true behavior. In this study it was used as such, without correction.

Stated preference analysis, on the other hand, can be used to forecast the response of individuals to the introduction of new systems or technologies before they are actually implemented. Respondents are placed in a hypothetical context and asked how they would



behave. Stated preferences may not reflect true behavior because people are not necessarily fully aware of how they would react. Furthermore, the hypothetical context may not truly reflect the situation they would face in the future. There might also be other biases in the response introduced by questionnaire design or by a tendency to please the interviewer.

In this study, stated preference analysis was used to estimate the response to a future in-vehicle **ATIS** device. To increase the validity of the technique, the stated preference questions were tied to a situation previously experienced by the respondents.

## **2.2 Benefits of ATIS**

This study evaluates the benefits of route diversion from **ATIS** under incident conditions. **ATIS** benefits can accrue to the users (and non-users) of the device, and also to the transportation system as a whole.

### 2.2.1 User benefits

The main user benefits of **ATIS** will be travel time savings from reduced errors when driving in unfamiliar areas, and from avoiding unexpected congestion through changes in travel decisions such as destination, mode, departure time, route, en route diversion, parking, and trip chaining. There are also a large number of less tangible, but nonetheless important, benefits:

- Increased knowledge of travel options (e.g. “yellow pages” information);
- Reduced anxiety - even if travelers do not change their travel decisions;
- Increased reliability to arrive on time at destination;
- Enhanced ability to avoid congestion; travelers may be able to avoid queuing by taking a longer distance route with the same travel time.
- Improved ability to communicate during emergencies; and
- Reduced possibility of getting lost.

### 2.2.2 System benefits

Transportation system benefits of **ATIS** may include reductions in trip time, air pollution, and energy consumption, as well as safer traveling. System benefits are more than the aggregation of user benefits. Indeed, certain impacts such as reduced energy consumption, less air pollution, and lower probability of getting involved in **an** accident might be too small to be perceived at the user level, but become very important at the system scale.

This study focuses on the user benefits of route diversion. Although a wider definition of **ATIS** user benefits is possible, only time savings to people with access to **ATIS** devices are considered.

## 2.3 Propensity to divert

The extent to which both user and system benefits of **ATIS** can be achieved is a function of how travelers respond to information. Relevant literature on route diversion behavior is summarized below.

Researchers have found that drivers are willing to divert in response to prescriptive and descriptive traffic information and that this propensity increases with delays and/or congestion (1-7). In addition, longer trip length, lower number of traffic stops on **alternate** routes, and familiarity with the alternate route encourage diversion. Further, younger, male, and unmarried drivers are more likely to divert.

Studies on diversion behavior conducted so far are insightful, yet there is a need to quantify the effect of the type of information provided on drivers' diversion behavior. Is descriptive information enough? Are drivers willing to follow prescriptive information? Does information about future travel time increase the propensity to divert? These are some of the questions addressed in this paper.

## **2.4 Money value of time**

The value of travel time has been investigated extensively, both from the theoretical and empirical points of view. Hensher (8) provides a good summary of the issue. The most frequent methods to find out a value of travel time rely on econometric models of situations involving a trade-off between money and time. The value of time is generally accepted to be a function of income, although a wide range of values have been suggested for the ratio of the value of time to hourly wage (9,10). The monetary value of travel time is a function of the trip purpose: time spent for work trips, for example, is more onerous than time spent on social or recreational trips (11). It has also been accepted that the value of travel time savings depends on the amount of time freed for other purposes: a saving of a couple of minutes might not be important because it is too small to be used productively (12). These issues were considered when evaluating the time savings brought about by ATIS; specifically, the value of time was calculated as a function of both personal hourly income and the magnitude of the time savings.

## **3. SURVEY CONTEXT**

This paper is based on a survey about commuting behavior undertaken in the San Francisco Bay Area at the beginning of 1993 (13). The questionnaires were distributed to peak period commuters crossing the Golden Gate Bridge during both morning and afternoon rush hours. There might have been a self-selection bias among respondents, since they had to mail back the questionnaire. Money incentives conditional on the completion of the survey were successful in achieving a good response rate: more than a third of the 9000 copies distributed were returned (see Khattak (13) for the details of the questionnaire distribution). About half of the questionnaires were concerned with en route response to

unexpected congestion, while the other half looked at pre-trip response. The sections of the questionnaires relevant to this study are:

1. *Normal travel patterns.* This part elicits a day-to-day commuting behavior description such as work schedule, schedule flexibility, normal and best alternate routes to work, and the presence of recurrent congestion.

2. *En route response to unexpected congestion.* This part of the questionnaire inquires about how respondents recently modified their commuting behavior after being informed on the road of unexpected congestion on their usual route. Through a sequence of stated preference questions tied to the situation where the behavior was reported, the survey also explores how **ATIS** could affect the decision to divert to the best alternate route.

3. *Socioeconomic profile.* The last part of the questionnaire asks respondents about some socioeconomic characteristics such as gender, age, personal income, level of education, and household size.

### **3.1 General characteristics and representativeness of the sample**

Three fifths (63%) of the 1492 respondents to the questionnaire are male and the average age of the sample is 43 years. Seventy-three percent of the respondents have at least a college degree; their major occupational fields are professional/technical (36%) and management (30%). The average annual personal income is \$65,500 with 36% of the respondents earning more than \$80,000 a year. Sixteen percent of the sample live in **one-**person households, while 44% reported a two-person household. Most respondents live in Mar-in County and work in San Francisco; this single origin-destination pair accounts for 57% of the sampled individuals. The sample represents therefore a middle-aged, **well-**educated, and wealthy segment of the population.

To evaluate the representativeness of the sample, it was compared with both the census (14) and the Bay Area Travel Study (1990). Minor differences were found for the ratio of drive alone/carpool, the average trip time to work, and the number of cars or persons per household (15). The differences were expected, given the method chosen to distribute the questionnaires. It was concluded that the sample, although it does not reflect the whole population of the area, provides a clear picture of the population commuting by car in the Golden Gate Bridge corridor. Analysis, however, does not preclude biases in other attributes or contextual factors.

### **3.2 Commuting behavior of the respondents**

In the first part of the questionnaire, respondents were asked about their routes to work. Fifty-six percent stated that they select their route before getting in their car; the remaining 44% choose it while on the road. A large majority (97%) use at least some portion of a highway as their usual route. More than half of the respondents (53%) stated that they have at least one alternate route; for 37% of them, this route is an arterial. A third (33%) of those who have an alternate route did not use it in the past month, 19% used it once due to traffic congestion, 16% used it twice, and the remaining third (32%) used it three times or more.

Respondents were asked to report their most recent unexpected congestion on their usual route. This part was filled out by three quarters (74%) of the respondents, i.e. those who stated that they did experience unusual congestion on their route in the past three months. These people constitute our sample for the rest of this study. The length and cause of delay, the weather at that time, and the way they learned about this congestion were obtained. Only 17% of the people could not give the cause of the delay; the percentage of commuters who knew the cause of the delay when they first learned about the congestion is, however, unknown. Forty-eight percent of the respondents learned about

the incident by observing the congestion, and 11% through radio reports only. Twenty-four percent first observed the congestion and then received a confirmation from the radio, while 23% obtained the information in the opposite sequence. Respondents were asked how much they thought the congestion would add to their trip when they first learned about it (expected delay), and how much it actually added (experienced delay). Respondents on average expected a delay of 21.1 minutes but actually were delayed for 25.6 minutes. There is nevertheless a wide discrepancy between the expected and actual delay for a given respondent: the difference between the two values ranges from -70 to +75 minutes, and only 52% of the respondents were able to correctly estimate their delay within plus or minus five minutes. This result suggests that an ATIS device giving the accurate length of incident-related delays might fulfill a need.

Respondents were then asked about how they responded to this unexpected congestion while on the road; results are shown in the following table, with the corresponding average delays:

TABLE I  
Response to unexpected congestion on the usual route  
and corresponding delays

<b>Response</b>	<b>Proportion of respondents?</b>	<b>Average expected delay (min.)</b>	<b>Average experienced delay (min.)</b>
Did not change travel plans	78.3%	20.3	24.9
Took alternate route	16.3%	22.8	24.4
Canceled intermediate stops	4.7%	18.8	26.5
Added unintended intermediate stops	4.0%	26.7	42.1 <sup>††</sup>
Used public transportation after parking the vehicle	0.5%	20.0	28.0

<sup>†</sup>The numbers do not sum up to 100% because more than one answer is possible.

<sup>††</sup>Including the extra stops

Only 21% of the respondents reported that they had an opportunity to divert.<sup>1</sup> Of these people, most (78%) did indeed divert.

Table I shows that about nine percent of the total respondents modified their trip chaining sequence by adding or canceling some intermediate stops as a response to the unexpected congestion. Thus, a significant portion of commuters facing unexpected events respond by changing their activity sequencing. ATIS may be able to support such decisions by providing drivers with information about relevant activities (e.g. shopping places in the vicinity). For the remainder of this paper, respondents were simply divided between two basic categories: those who stayed on their usual route and those who diverted to their best alternate route.

#### **4. REPORTED AND STATED PREFERENCES ABOUT DIVERSION PROPENSITY**

The questionnaire was designed to use reported diversion behavior as the basis of a sequence of stated preference (SP) questions about the propensity to divert under ATIS. This methodology increases the validity of the stated preferences technique, by relating the response to ATIS technology to a specific incident that was actually experienced by the respondent. The objective of the SP questions was to determine how incremental amounts of information provided by an ATIS device would influence the propensity to divert.

Travelers were asked to imagine starting once again, on the same day, the trip during which they experienced their most recent unexpected congestion. They were told not to be aware of any unexpected congestion before they got in their vehicle, until an in-vehicle ATIS device provided them with accurate traffic information. For each question, that is, for each level of information provided, respondents were asked if they would divert

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<sup>1</sup>The few respondents who reported no opportunity to divert but then said that they diverted were interpreted as actually having an opportunity to divert.

to their best alternate route. They had to report this on a 1-4 scale, where 1 meant “I definitely take my usual route” and 4 meant “I definitely take my best alternate route”. The results are shown in Table II; respondents who answered either 3 or 4 were taken as showing a preference for diversion.

TABLE II  
Route diversion behavior under ATIS

Question	Proportion of respondents showing a preference for route diversion
Reported diversion behavior with currently available information	16.3%
<b>QUALITATIVE INFORMATION</b>	
<i>The device knows your usual route and gives you the following message: &lt;&lt; Unexpected congestion on your usual route &gt;&gt; but does not tell you how much of a delay this congestion is causing</i>	<b>32.9%</b>
<b>QUANTITATIVE INFORMATION</b>	
Usual route, real-time <i>The device tells you the expected length of delay on your usual route at the present time (your initial estimate <b>of</b> delay)</i>	<b>57.4%</b>
Usual route, forecast <i>The device tells you the length <b>of</b> delay at the present time, and accurately predicts the length <b>of</b> delay it will cause 15 to 30 minutes into the future</i>	61.6%
Alternate route, real-time <i>The device tells you the length <b>of</b> delay at the present time, and provides information regarding present travel time on your best alternate route</i>	<b>69.3%</b>
<b>PRESCRIPTIVE INFORMATION</b>	
<i>The device tells you &lt;&lt; Unexpected congestion on your usual route &gt;&gt; and <b>suggests</b> that you take your best alternate route</i>	<b>67.5%</b>



In the qualitative information question, the device does not provide more details than what was available to the driver when he or she first learned about the congestion. Indeed, qualitative traffic information equivalent to <<*unexpected congestion on your usual route*>> is currently available in the Bay Area; it is gathered by the commercial media and disseminated almost in real-time through radio traffic reports. Since the context in the qualitative information question is comparable to the situation for which the behavior was reported, this question can be used to relate stated preferences to reported behavior (see Table III). The sample size here is 895 because only respondents who faced unexpected congestion are included, and missing responses are eliminated on a listwise basis.

**TABLE III**  
Stated preference vs. reported behavior

		<b>REPORTED BEHAVIOR</b>		
		does not divert	diverts	
<b>STATED PREFERENCE</b>	does not divert	<b>555</b> 62.0%	<b>46</b> 5.1%	<b>601</b> 67.2%
	diverts	<b>197</b> 22.0%	<b>97</b> 10.8%	<b>294</b> 32.8%
		<b>752</b> 84.0%	<b>143</b> 16.0%	<b>895</b> 100%

It appears that respondents overstate their propensity to divert when compared with reported behavior. One fifth (22%) of the respondents stated that they would divert even though they reported not having diverted. On the other hand, only 5% of the people stated that they would not divert even though they actually diverted when they faced the unexpected delay. The correlation between the two variables is 0.32 and, from these results, stated preferences can reduce by only 17% the error in determining the real behavior.<sup>2</sup> However, some of the difference might be explained by the fact that respondents had more opportunities to divert in the stated preference questions, since they

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<sup>2</sup>Using Goodman and Kruskal's lambda, a measure of the proportional reduction in error.

were asked to imagine that they were just starting their trip. Also, some respondents might have regretted not having diverted in the original trip, and therefore stated they would divert this time; their expectation of the delay is now influenced by hindsight.

As can be seen in Table II, the largest stated propensity to divert (69.3% of the respondents) is obtained when the ATIS device also gives real-time information about traffic conditions on the alternate route. This result suggests that some respondents might be currently restrained from diverting by not knowing the conditions on their alternate route. When the complete picture is given, respondents might be more confident and consequently more inclined to divert.

A high proportion of respondents (67.5%) also stated that they would divert when provided with simple prescriptive information, that is, when the device suggests taking the best alternate route. Prescriptive information may be interpreted differently than other forms of information because it implies that the alternate route is the best option. Consequently, it may appear surprising that less diversion is obtained with this type of information (67.5%) than with detailed quantitative information (69.3%). This may indicate that compliance rates differ for prescriptive and quantitative information. Nevertheless, the relatively high diversion rate for prescriptive information indicates that, under incident conditions, some drivers are responsive to clear directions about the route to take (although they might still like to know details regarding the incident). Surprisingly, the decision to comply to prescriptive information does not appear to be influenced by the potential time savings. Indeed, people who stated they would comply to the prescriptive information were expecting to save, on average, as much time as those who didn't.

The answers to the last four stated preference questions are closely correlated, indicating a consistency in driver behavior. Indeed, people stating a preference to divert or to stay on their usual route generally kept the same preference throughout the last four questions. However, the possible bias due to the ordering of the question is recognized.

To further explore the correlation between reported behavior and stated preferences, a linear regression model relating the answers to each question was developed. The 1-to-4 scale of the stated preference questions was used; 1 representing “*definitely take my usual route*” and 4 “*definitely take my best alternate route*”. Reported diversion behavior was recoded as 1 or 4 accordingly (no 2 or 3). All observations from the reported behavior and the five stated preference questions were stacked in a single column vector which thus contained six times the sample size. This vector was then related to a sequence of five dummy variables, flagging one when the observation was from the specific stated preference question. Reported preferences thus served as the base. The equation used is:

$$DP = a_0 + \sum_{i=1}^5 a_i SP_i$$

where:            DP = vector of observations on diversion propensity  
                        $a_0$  = constant  
                        $a_i$  = coefficient to be determined by regression  
                        $SP_i = 1$  when the observation in DP is obtained from  $i$ , and 0 otherwise.

The coefficients obtained reflect the influence of each stated preference variable in explaining the vector of observations, as well as the increase in the probability of diversion given the additional information provided. The coefficients obtained are shown on Table IV.

The constant reflects the “base” diversion propensity, that is, the diversion propensity from reported behavior. The value of  $a_1$  corresponds to an increased propensity of diversion with qualitative information. An even higher propensity of diversion is observed when drivers are provided with quantitative information ( $a_2$ ). However, additional details and prescriptive information do not induce significantly more diversion as reflected in the uniformity of coefficients  $a_2$  to  $a_5$ .

**TABLE IV**  
Coefficients of stated preferences model

<b>Coefficient</b>	<b>Value</b>	<b>t-stat. (p)</b>
<b>a<sub>0</sub></b> Constant term	1.36	44.6 (0.00)
<b>a<sub>1</sub></b> Qualitative information	0.70	14.2 (0.00)
<b>a<sub>2</sub></b> Quantitative information (usual route, real-time)	1.33	27.3 (0.00)
<b>a<sub>3</sub></b> Quantitative information (usual route, forecast)	1.44	29.4 (0.00)
<b>a<sub>4</sub></b> Quantitative information (alternate route, real-time)	1.58	31.6 (0.00)
<b>a<sub>5</sub></b> Prescriptive information	1.56	32.1 (0.00)
<b>Summary statistics:</b> sample size = 1492	$R^2 = 0.47$	

## 5. WHO WOULD DIVERT UNDER ATIS?

This section explores the personal and contextual characteristics determining diversion propensity, both to obtain a portrait of the potential diverters and to verify the consistency of the stated responses. Respondents were divided into four categories, according to their reported and stated diversion behavior (see Table V). The stated diversion response was taken from the question generating the highest diversion rate, that is, when the device provides the most complete quantitative information, including travel times on the alternate route.

**TABLE V**  
Categories of diversion behavior

<b>Category</b>	<b>Reported diversion</b>	<b>Stated diversion</b>	<b>Proportion</b>
1 Undivertable	NO	NO	29.3%
2 Could divert with ATIS	NO	YES	54.0%
3 Already diverts with current information	YES	YES	15.5%
4 No longer diverts with ATIS	YES	NO	1.3%

ATIS will benefit primarily the 54% of the sample who would change route once provided with the device. Recall that this figure applies only to the 74% of the sample who experienced unexpected delay; therefore, the proven percentage of the commuters in the corridor that would change route with ATIS under unexpected congestion is therefore actually around 40%.

To explore the characteristics distinguishing the first three groups (the fourth group is marginal and was ignored), discriminant analysis was performed by estimating the coefficients of two independent discriminant functions. These two functions assign separate discriminant scores to each observation; both scores are then used to classify observations. The sample size in that case is only 376 respondents because missing cases are deleted on a listwise basis. The five variables best characterizing diversion behavior are presented in Table VI; all of them are significant at the 5% level or better. Both the standardized coefficients assigned to each variable and their correlation with each function are indicated. Positive coefficients indicate a higher propensity to divert.

TABLE VI  
Characteristics determining diversion behavior

Variable	p value of F- statistic	Coeff. in 1 <sup>st</sup> funct.	Coeff. in 2 <sup>nd</sup> funct.	Corr.  with 1 <sup>st</sup> funct.	Corr.  with 2 <sup>nd</sup> funct.
Diversion opportunities (1 = yes, 0 = no)	0.00	<b>+1.00</b>	<b>-0.02</b>	<b>0.99</b>	<b>0.00</b>
Number of alternate routes known	0.00	<b>+0.02</b>	<b>0.69</b>	<b>0.07</b>	<b>0.71</b>
Frequency of recreational trips (times/week)	0.02	<b>-0.08</b>	<b>0.59</b>	<b>-0.03</b>	<b>0.62</b>
Weather (0 = good, 1 = bad (rain or fog))	0.01	0.01	<b>0.29</b>	<b>-0.08</b>	<b>0.23</b>
Congestion on best alternate route (1 = not congested, 2 = congested, 3 = heavily congested)	<b>0.03</b>	-0.11	<b>-0.24</b>	<b>-0.07</b>	<b>-0.32</b>
<b>Summary statistics:</b>					
Canonical correlation:		<b>0.86</b>	<b>0.21</b>		
% correctly classified: 65%					
sample size: 376					

The existence of diversion opportunities is obviously critical in determining diversion behavior, as confirmed by the high coefficient attributed to this variable in the first discriminant function. Furthermore, diversion propensity increases with the number of alternate routes known: undivertable respondents know on average only 1.50 routes; those who could divert with ATIS, 1.73; and those who currently divert, 1.94. The number of alternate routes known to drivers obviously increase their possibilities of diversion; however, drivers also know more alternate routes because they tend to divert often. In this case, causality can actually work in both directions. Another important variable, the frequency of recreational trips, was found in previous research (16,17) to be

a proxy measure of such personality characteristics as extroversion, achievement, and need for stimulus or adventure. The frequency of recreational trips does influence the propensity to divert with ATIS: “undivertable” respondents travel on average 1.63 times/week for recreational purposes, while the people who could divert with ATIS do so 2.08 times/week. More diversion is also observed under bad weather conditions, as can be concluded from the sign of the weather coefficient. Finally, the presence of congestion on the alternate route acts as a deterrent to diversion: undivertable respondents have more congestion on their alternate route (average congestion = 1.88<sup>3</sup>), followed by the people who would divert with ATIS (1.72), and by the people who already divert (1.51). Although not significant at the 5% level, the number of stops on the usual route was also found to decrease with the propensity to divert: as expected, people constrained to stop on their usual route have less flexibility in changing route.

All these findings are consistent with what was expected and increase our confidence in the validity of the stated preference technique.

## **6. CALCULATION OF ATIS BENEFITS FROM ROUTE DIVERSION**

### **6.1 Time savings**

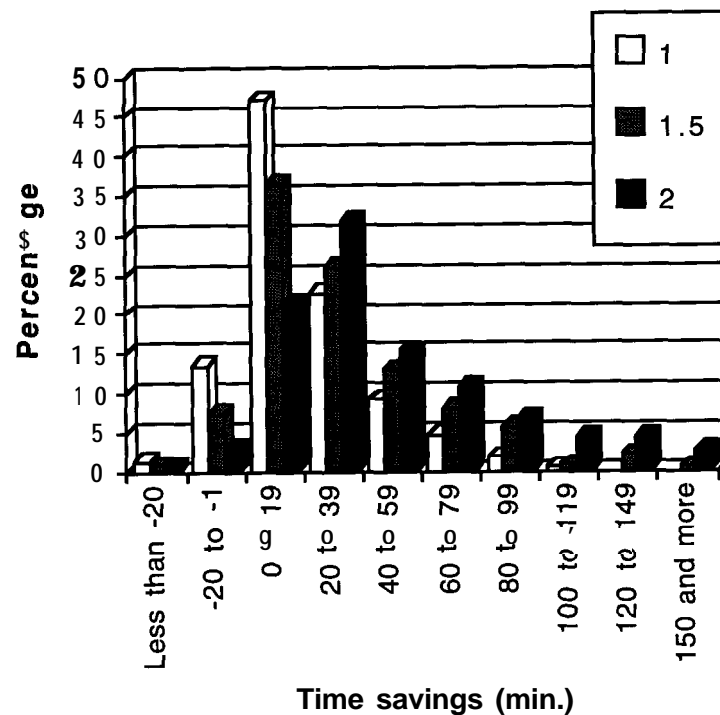
The potential time-saving benefits achieved by diverting under ATIS are calculated here, using again the case of the most complete quantitative information, (highest stated diversion rate). The calculation applies only to the 40% of respondents who would change their commuting behavior when provided with ATIS (n = 597). It does not include the potential time savings that other road users may experience, or the extra delay that may occur on alternate routes once a larger number of vehicles are diverted.

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<sup>3</sup>The following coding was used: 1 = not congested, 2 = congested, 3 = heavily congested.

The savings from route diversion are simply the delay minus the time difference between the alternate and usual routes. To account for the fact that time spent in a bottleneck is usually more onerous than normal in-vehicle travel time, a weight has been associated with delay. Because this weight is a subjective measure and has a direct influence on the final result, a sensitivity analysis was performed using weights ranging from 1.0 to 2.0.

Figure 1 presents the distribution of travel time savings that would accrue to people who stated they would divert to their alternate route. With a delay weight of 1, 14% of the diverters would actually lose time by taking their best alternate route, 9% would see no change in their total travel time, and 77% would save some time. The average time savings are summarized in Table VIII.

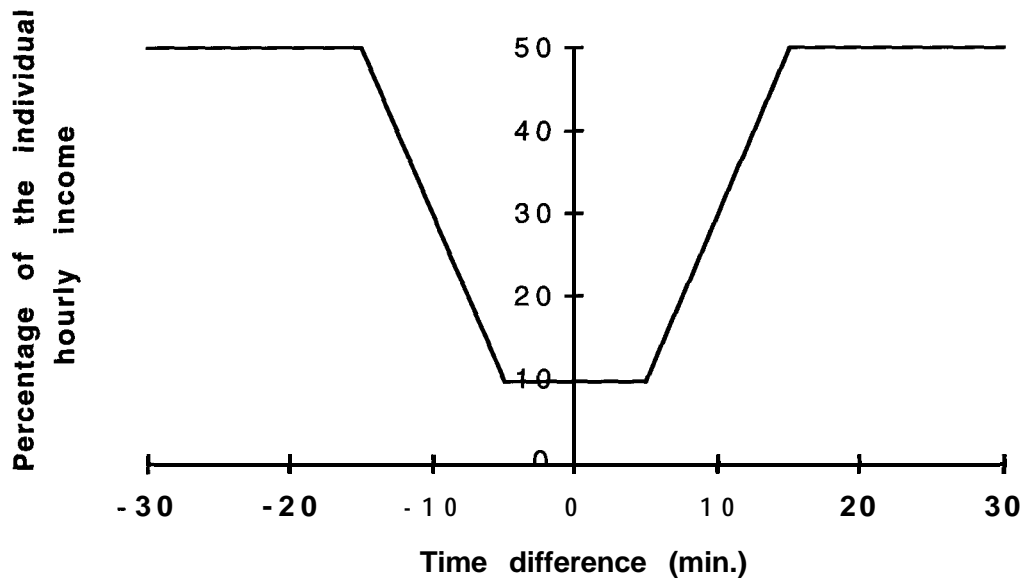


**Figure 1:** Distribution of travel time changes among the people who stated they would divert to their alternate route under ATIS, as a function of the weight of delay



## 6.2 Monetary value of time

To attach a monetary value to time savings, an estimate of the value of time for each respondent is needed. To avoid aggregating a large number of negligible time savings into a large amount of money, the value of time was assumed to increase with higher time savings. Furthermore, to account for personal differences in the valuation of time, the value for each respondent was taken as a fraction of the personal hourly income (8). The function used is presented in Figure 2; it is adapted from a method presented by AASHTO (12).



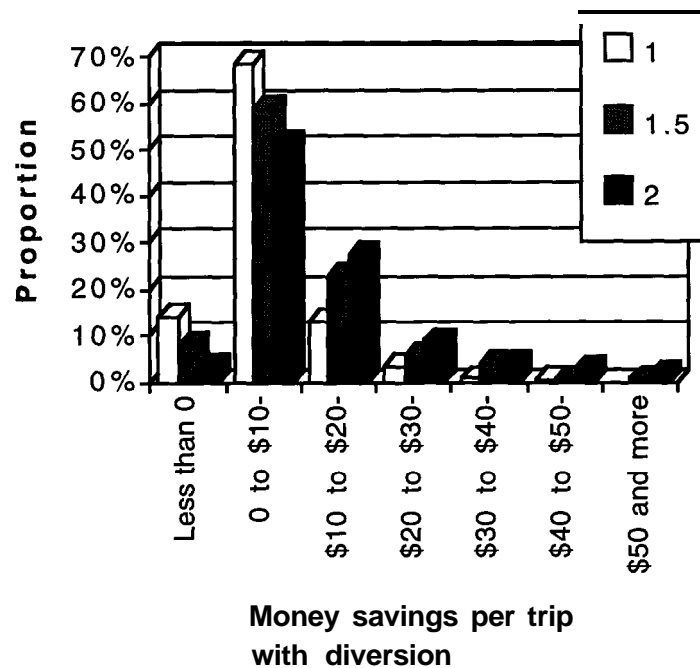
**Figure 2:** Function used for the monetary value of time

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As can be seen from the figure, travel time variations within plus or minus five minutes are valued at 10% of the personal hourly income. Those larger than 15 minutes are evaluated using a value of 50% of the hourly income. Increases in travel time are assumed to have the same weight as corresponding savings; that is, small increases in travel time have negligible impacts.

### 6.3 Money benefits of route diversion

Figure 3 presents the distribution of monetary savings that would be achieved through route diversion under unexpected congestion. This was calculated by combining the time savings with the values of time for every respondent. The average saving for the sample is \$4.80/trip; this value includes the 14% of people who lose time by diverting. These people have been kept in the average to reflect, first, that any ATIS will not be perfectly accurate and might advise a small proportion of travelers to take routes that are actually longer; and second, that some people are willing to lose travel time to avoid bottlenecks.



**Figure 3:** Distribution of monetary savings for people who stated they would divert to their best alternate route, as a function of delay weight

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## **6.4 Annual frequency of route diversion**

The values presented in the previous section apply for a single trip with route diversion. In order to evaluate the annual benefits of such diversions, it is necessary to estimate how frequently they would occur. A precise measure of diversion frequency could be obtained using traffic and incident data in the corridor. For every O-D pair and time-of-day combination, it would be necessary to estimate how often an incident on the usual route would induce a route switch. However, all respondents differ in the minimum length of unexpected delay (threshold) that justifies a modification to the intended travel plans. The calculation would thus have to account for these different (and unknown) threshold values, and for the fact that potential diverters are not on the road daily. All these obstacles make it difficult, if not impossible, to know how often each respondent would divert to his or her best alternate route.

To overcome these difficulties, a proxy variable was used for the potential frequency of route diversion. When asked to report specifics of their recent unexpected congestion, respondents mentioned how long ago the incident occurred. If it is assumed that the occurrence of incidents follow a Poisson process, the time elapsed since the last incident is actually just the mathematical expectation of the time period between two incidents of at least the same size (see calculations in Appendix). The number of weeks between two incidents can then be translated into an annual frequency of incidents experienced, assuming that respondents work about 48 weeks a year. Table VII presents the results and the corresponding frequencies of route diversion.

TABLE VII  
 Potential frequency of route diversion  
 using the time since the most recent incident

<i>How long ago did the most recent unexpected congestion occur?</i>	<b>Corresp. frequency of incidents experienced</b>	<b>Potential annual frequency of route diversion</b>	<b>Proportion of potential diverters</b>	<b>Average expected delay (min.)</b>
Less than one week	Twice a week	<b>96</b>	15.7%	19
1-2 weeks	Every 1.5 week	32	22.6%	18
2+-4 weeks	Every 3 weeks	16	28.6%	22
1-2 months	Every 6 weeks	8	26.2%	24
More than 2 months	Every 12 weeks	<b>4</b>	<b>6.9%</b>	29

The weighted average frequency of diversion is 29 times a year. As seen from the table, the vast majority (77.4%) of respondents would divert between 8 and 32 times a year. About one sixth (15.7%) of respondents would divert as often as twice a week (out of 10 possible trips). These people might have a high variability in their route choice decision and are likely to divert as soon as traffic conditions deteriorate on their usual route.

The measure used for the frequency of route diversion, in spite of its approximate nature<sup>4</sup> and of its possible seasonal bias, has two important advantages. First, it incorporates the threshold value of all respondents, since they are free to report the most recent unexpected delay they find worth mentioning. It is unlikely that smaller unexpected delays would be considered for route diversion. Respondents who faced their incident relatively longer ago apparently have larger threshold values, since they experienced longer delays (Table VII); they were accordingly assigned a smaller frequency of diversion. Second, commuters who are not on the road daily, because they also use transit or car-pool,

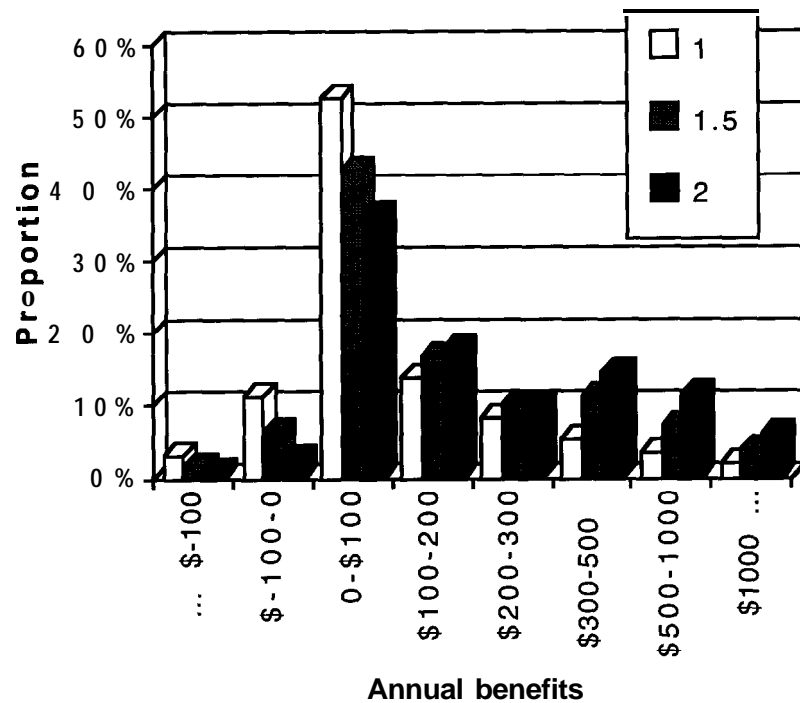
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<sup>4</sup>Its correlation with the monthly frequency of diversion without ATIS is only 0.14.

are less likely to face unexpected delays than others and are thus less likely to divert. The proxy measure used takes this into account by assigning these people a smaller annual frequency of diversion.

### 6.5 Annual benefits of route diversion

Combining the annual frequency of unexpected delays and the monetary savings achieved by trip, it is possible to calculate the annual benefits of route diversion under incident conditions (see Figure 4).



**Figure 4:** Annual monetary benefits of ATIS-induced route diversion, as a function of delay weight

The average annual benefit of ATIS-induced route diversion is \$124 per year per diverter, when the weight of delay is one. Table VIII summarizes the results of the calculation for different weights of delay and shows the average time savings under each assumption. It is interesting to note that the percentage of people with negative savings (i.e. with an alternate route longer than the travel time plus the delay on the usual route) dwindles as the weight attached to delay increases. This suggests that the apparently irrational behavior of longer diversion time could be partly explained by a high cost associated with queuing delays.

TABLE VIII  
Route diversion benefits of **ATIS** under incident conditions

<b>Weight of delay compared to travel time</b>	<b>Average time savings achieved by diverting (min.)</b>	<b>Proportion of people with negative savings</b>	<b>Monetary savings per trip with diversion</b>	<b>Potential annual benefits of ATIS -induced route diversion</b>
1.00	17	14.4%	\$4.80	\$124
1.25	24	12.9%	\$6.60	\$174
1.50	30	8.1%	\$8.40	\$224
1.75	37	6.3%	\$10.20	\$274
2.00	43	3.7%	\$12.00	\$324

For our subset of the population, the annual benefits of route diversion through **ATIS** under incident conditions range from \$124 to \$324 per person, depending on the weight of delay. Recall that this value applies to about 40% of the auto commuters in the corridor, and that high values of time were used because of the large average income of the sample. It therefore appears that the time-savings benefits of **ATIS** from route diversion under incident conditions are limited.

## 7. SUMMARY AND CONCLUSION

This paper estimated route diversion benefits of **ATIS** under unexpected congestion from reported and stated diversion behavior. Three quarters of the respondents reported that they faced unexpected congestion on their usual route to work at least once in the past three months. Twenty-one percent of them reported that they then had an opportunity to divert, and 16% did divert. Thirty-three percent stated they would divert if provided with **ATIS** qualitative information (roughly equivalent to currently available information) at the beginning of their trip. More diversion is obtained in the stated preference case, partly because respondents had the benefit of hindsight and had more opportunities to divert since they were starting over their trip. There might also be a tendency to overstate diversion behavior.

The stated preference questions showed that the more complete the travel information, the higher the proportion of commuters diverting under unexpected congestion. Close to 70% of the people stated they would divert when the device provided quantitative real-time information on their usual route plus travel times on their alternate route. It was found that, under incident conditions, prescriptive information might be sufficient to achieve high diversion rates. However, driver compliance with prescriptive information will be conditional on the effectiveness (reliability and accuracy) of the system in suggesting better routes.

Route diversion propensity under **ATIS** depends primarily on the presence of opportunities to divert, increases with the number of alternate routes known, and decreases with higher levels of congestion on the best alternate route. Personality characteristics and weather also significantly influence the propensity to divert.

The travel time savings achieved by **ATIS**-induced route diversion were calculated from the survey and translated into monetary benefits. The value of time used was a function of personal income and the extent of time savings. The frequency of annual

diversion was estimated from the time elapsed since the last incident. The potential annual monetary benefits from ATIS-induced diversion in the Golden Gate Bridge corridor ranged from \$124 to \$324 per person, varying linearly with the weight assumed for delay. These figures apply to about 40% of the commuting population in the corridor.

The estimate of benefits is only preliminary and a more reliable frequency of diversion under ATIS is needed from field operational tests currently underway. Because the Golden Gate corridor offers limited route diversion opportunities and has a relatively high income population, research should also be performed in other corridors to obtain more generalizable estimates.

This project has demonstrated that, even in a corridor with limited opportunities to divert, ATIS could bring about significant time savings to a certain portion of commuters by inducing route changes. Although the calculated benefits per driver may appear limited when translated into annual dollar figures, they account for only a subset of total ATIS benefits. Changes in other travel decisions such as departure time and mode may allow commuters to save time as well. Research is currently underway to estimate the extent of pre-trip ATIS benefits. Other less tangible benefits such as easier wayfinding, increased confidence in unfamiliar areas, increased ability to modify trip chaining, and the availability of general traveler information will also have to be summed up in the final analysis. Finally, greater benefits may be achieved by broadening the scope of ATIS through the development of an Advanced Activity and Travel Information System (AATIS). Such a system is a logical extension: it would provide information to support not only travel decisions but also activity participation.

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## APPENDIX

This appendix details the calculation of the expectation of the time period between two incidents. Consider a time period made up of intervals between incidents. The probability of making an observation (distributing a questionnaire) during an interval of length  $x$  is:

$$\frac{x p(x)}{\int_0^{\infty} x p(x)} = \frac{x}{\mu} p(x)$$

where:  $p(x)$  is the probability that the interval length is  $x$ ;  
 $\mu$  is the average length of intervals.

Now, given that the observation is made during an interval of length  $x$ , the expected time since the last incident is  $x/2$ . This is because observation points are uniformly distributed over the whole interval. Therefore, the expected value of time since the last incident ( $t$ ) is:

$$\begin{aligned} E(t) &= \int_0^{\infty} \frac{x}{\mu} p(x) \frac{x}{2} dx \\ &= \frac{1}{2\mu} \int_0^{\infty} x^2 p(x) dx \\ &= \frac{1}{2\mu} (\sigma^2 + \mu^2) \quad \text{Because } \text{VAR}(X) = E(X^2) - (E(X))^2 \\ &= \frac{\mu}{2} \left( \frac{\sigma^2}{\mu^2} + \frac{\mu^2}{\mu^2} \right) \\ &= \frac{\mu}{2} (k^2 + 1) \end{aligned}$$

where:  $\sigma^2$  is the variance of the length of interval;  
 $k$  is the coefficient of variation.

Now, assume that incidents **occurrence** follows a Poisson process of rate  $\lambda$ . It implies that interval length has an exponential distribution. Therefore,

$$E(X) = \mu = \frac{1}{\lambda}$$
$$\text{VAR}(X) = \sigma^2 = \frac{1}{\lambda^2}$$

And:

$$E(t) = \frac{\mu}{2} \left( \frac{1}{\lambda^2} \frac{\lambda^2}{1} + 1 \right)$$
$$= \mu$$
$$= E(X)$$

In our case, since  $t_0$  (the time since the last incident) is taken as an estimator of  $E(t)$ , it is also an estimator of  $E(X)$ . Therefore, the average time lag between two incidents can be estimated from the time since the last incident was observed,