

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

Modeling the Behavior of Traffic Information Providers

**Matthew Malchow
Adib Kanafani
Pravin Varaiya**

**California PATH Working Paper
UCB-ITS-PWP-97-5**

This work was performed as part of the California PATH Program of the University of California, in cooperation with the State of California Business, Transportation, and Housing Agency, Department of Transportation; and the United States Department Transportation, Federal Highway Administration.

The contents of this report reflect the views of the authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the State of California. This report does not constitute a standard, specification, or regulation.

February 1997

ISSN 1055-1417

Modeling the Behavior of Traffic Information Providers

Matthew Malchow

Adib Kanafani

Pravin Varaiya

Institute of Transportation Studies
University of California at Berkeley

March 1997

Abstract:

This working paper discusses two models used to represent the locational behavior of traffic information providers. The characteristics which make traffic information unique as a service good are discussed and exploited in the models to show how the behavior of information providers might differ from that of firms in a traditional market. Questions are addressed regarding the clustering of competing providers and the efficiency of the resulting output. The purpose of this paper is to contribute to the study of the economics of the traffic information industry and of the role of public financing versus private competition.

Keywords: Information Providers, ATIS

Executive Summary

Because the market for traffic information is so different than that for more traditional goods, the behavior of information suppliers appears very different from the traditional behavior of suppliers. Traffic information is different from traditional goods in that:

- in most cases it is not marketed directly to the consumer; instead it is sent through a media such as a radio station. This prevents direct pricing, removes the transportation cost traditionally incurred by the consumer, and shifts a provider's focus to the number of customers rather than the value (willingness-to-pay) placed in the good.
- the area in which the information is collected is of more importance to the individual than the point from which it is distributed.
- individuals, as well as broadcast stations, are unable to consume traffic reports in multiple quantities; that is, if the quality of the report improves, an individual can still only use it once.

In this paper we will attempt to exploit these and other characteristics as we describe models to represent the spatial element of the demand for information. We will describe two models, one using an aggregate measure of traffic and one involving the disaggregate behavior of individuals, and describe how each changes with respect to location. With each model we will explain the advantages which can be drawn, as well as the economic properties which are difficult to represent. We will also mention our preliminary findings from the survey presently being conducted of the traffic information providers and adjustments which might be necessary for the models as a result of these findings. The results from this survey will be available in a following report, and with these findings we will then reexamine the models proposed herein.

1. Introduction

Many characteristics of traffic information distinguish it from other goods. For example, traffic information is not marketed at a common destination such as the grocery store and thus bears no transportation cost to the user; instead all forms of information are immediately available to all drivers (e.g. radio broadcasts or Internet connection, etc.). As a result, the methods by which competing firms in the traffic information industry might position themselves differ from the methods by which suppliers of more common goods would locate their operations.

The positioning of providers should be of interest because multiple providers are often producing the same good. From our early observation of the information providers in the Bay Area, as well as unscientific sampling of each provider's reports, the content of reports is essentially identical. This might be expected because the procedures used by each provider to collect information are very similar, as each uses aircraft, cellular phone calls, the CHP's computer-aided dispatch, etc. In addition, each provider has access to the reports broadcast by the others. The only differences result not from the accuracy or the amount of information collected by each, but from the manner in which the providers choose to package their product for their customers.

A competing information provider which covers a common area thus provides decreasing marginal benefits to society in the gathering of his information (because most relevant information could be gathered by the first provider). Because the second provider's costs are independent, his net benefit to society is significantly less. Other indirect benefits, such as the improved accuracy resulting from competition, will be addressed in later reports.

The objective of this research paper is to describe two simple models, and extensions of these, by which one might represent the economic behavior of information providers, with particular focus on their positioning. A clearer understanding of the decisions made by information providers will be useful in the later phases of the research, in which we will talk with the providers to develop economic models of the supply and demand for traffic information.

2. Modeling the Aggregate Demand

With each of the demand models, our objective is to find one which effectively represents the dimensions of the market which an information provider would try to capture. An information provider's assumed objective is to maximize his profit, because it is a private firm. This can be accomplished by signing more radio stations to distribute the product. More radio stations can be contracted by gathering information for more listeners. Thus, the models must somehow be related to the number of drivers, which is a function of the time and location of the different points for which information could be collected.

For the first model consider a corridor represented by a segment $[0,1]$ as in Figure 1.

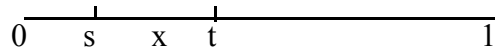


Figure 1. A segment along which all trips are made, in the $0 \rightarrow 1$ direction.

All trips are assumed to be in the direction from 0 to 1, and a formula $n(s,t)$ represents the number of trips from origin s to destination t . Thus, all trips would pass through all locations $\{x : s \leq x \leq t\}$ between s and t . An information provider might “capture” a driver following this path as a customer if he gathers information regarding any segment of that trip.

The total number of trips passing any one point, s , can be represented by the total number of trips beginning upstream of s $\{x : 0 \leq x \leq s\}$ and ending downstream of s $\{y : s \leq y \leq 1\}$. These intervals can be represented by the integral:

$$\int_s^1 \int_0^s n(x,y) dy dx$$

The distribution of vehicles along the segment might be represented as in Figure 2.

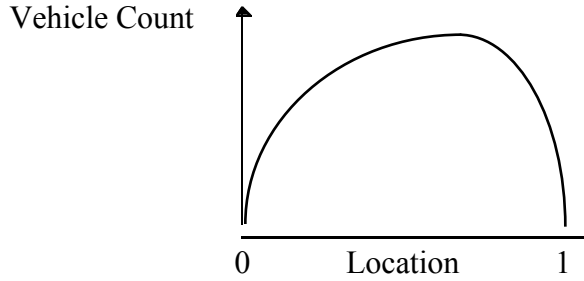


Figure 2. A distribution of vehicles along a segment

To avoid initial difficulties with the redundancy of vehicles (and listeners), we might use the model to represent the number of new vehicles along a segment. One method for overcoming this might be to count the number of vehicles originating at certain locations. This could be used in combination with a measure such as the average trip length (and its distribution) to estimate the number of “new” drivers in an area. An information provider could then estimate the number of “new” customers passing a location (and thus the incentive to incur the costs of covering a new location).

A simple way to deal with this would be to assume that all trips continue to one location (e.g. the CBD, at the end of the segment). This distribution might be represented by a curve similar to either of the two curves shown in Figure 3.

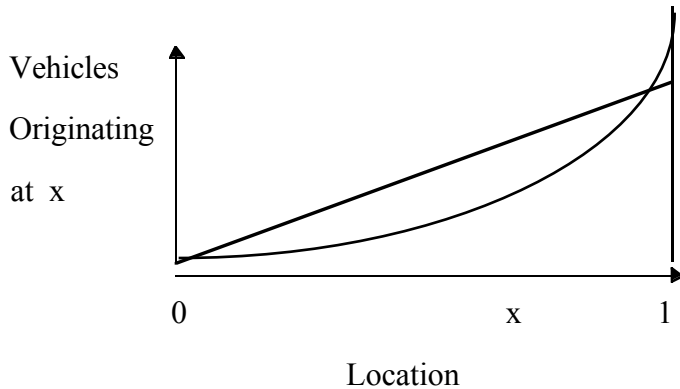


Figure 3. Sample distribution of vehicles with a common destination.

Technically, a number of other factors would affect the total value of information at a particular location, in addition to the volume of traffic. Information economics has consistently

shown that the value of information is proportional to the number of times information will be used (number of incidents) and the expected payoff from using the information (related to the alternate routes available). Each of these characteristics will be explored later when using the model of an individual trajectory; for now, we can proceed as though these characteristics are included in our estimate of the demand.

The most interesting observation to be made from this model regards the optimal positioning of competing information providers. To capture the largest number of vehicles, a provider would cover a section as close to the CBD as possible, because all drivers pass through the segment nearest the CBD. Thus, a single information service could capture all drivers if it covered a section of the drivers' trips long enough at the end of this segment (long enough, implying that the average individual benefits, in terms of time saved and in proportion to the length of the segment covered, exceed the individual's perceived costs of having to access this information). More importantly, a second competing provider, assuming that all providers face the same cost function, would position himself alongside the first provider. Because all providers would produce the same information, providers would share equally all trips which originated upstream of their market. The size of each provider's market is maximized if each positions himself as far downstream as possible.

Because a traffic report cannot be sold to each customer more than once, it would make little economic sense for an information provider to increase his service (i.e. cover more area or provide more accurate reports) once all potential customers have been captured. The only factor which might encourage more extensive coverage, in terms of area or frequency, would be the competition between providers if profit could still be gained, i.e. if marginal revenues exceeded the marginal costs of information collection.

In an extension of this model, the behavior of information providers can also be affected by the length of trips if they do not all continue to a common destination, as shown in Figure 4.

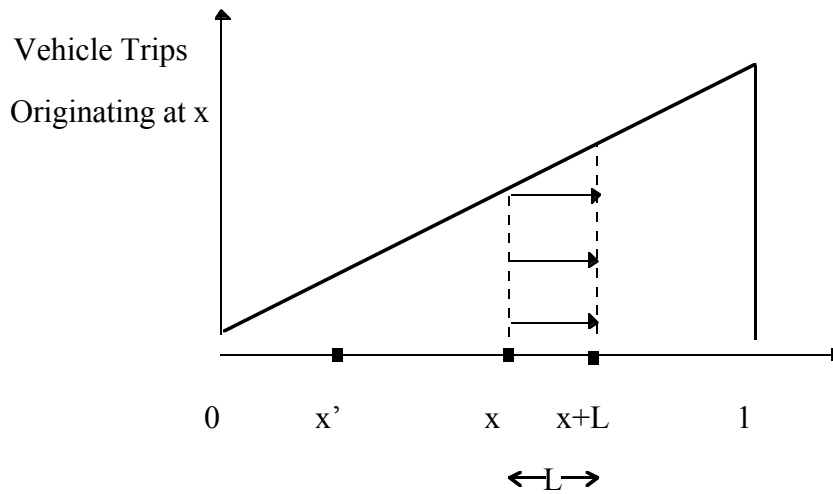


Figure 4. The distribution of trips without a common destination.

Assume that all drivers have a trip of length L . Clearly, for a driver originating at location x to receive any benefit from the traffic information, the information must be relevant to his itinerary $[x, x+L]$. Similarly, for a driver originating at x' , the information must be relevant to his itinerary $[x', x'+L]$. The objective of the information provider would then be understood as covering the portion(s) of the segment $[0,1]$ which would contain the largest number of listeners. In the case of a single traffic information provider, this would again be the segment furthest to the right (or closest to 1, where traffic is greatest).

For a single provider, simple economics (profit maximization) can show that the provider will cover all areas to the left of $x=1$ until the marginal revenues no longer exceed the marginal costs of gathering information for that section. Ideas about the precise location of this we hope to address in a later report as we explore the costs of providing information.

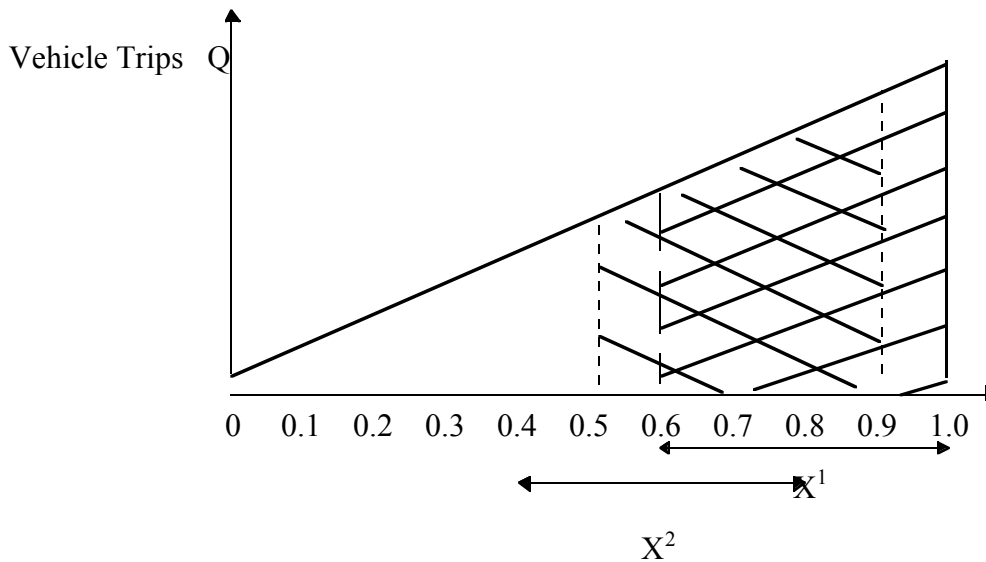


Figure 5. The positioning of two providers in a competitive environment

In a situation involving two competing providers (Figure 5), the first would again position himself as close to the end as possible (e.g. location X^1). However, the second provider, to maximize his profits, would not necessarily position himself alongside the first provider. Again assuming that all vehicles whose trips are covered equally by both providers are shared equally between the providers, the second provider would choose to capture all drivers at certain locations rather than one-half of those in the section which he would share. In one instance, the positioning of providers might correspond to X_1 and X_2 as shown in Figure 5. (Note that the demand captured by provider #2 at the left extreme would equal one-half that at the right extreme.) A similar relationship would ensue regardless of the length of the area to be covered by each provider.

Furthermore, the center of the area covered by the second provider might be estimated with the following rules, where L is the average trip length and D the length of the segment covered. (Though this assumes that both providers will cover a segment of equal size, it still shows that some clustering will exist between providers.)

If $(L + D) \leq 1/3$	then	$x_2 = 1 - 3D/2 - L$
$(L + D) > 1/3$ and $D < 1/3$	then	$x_2 = 1/3 + D/2 + L$
$D > 1/3$	then	$x_2 = 3D/2 + L$

$$(2D + L) > 1 \quad \text{then} \quad x_2 = 1 - D/2$$

The derivation of these rules can be found in the appendix.

Another scenario exists in which the second provider can choose any portions of the segment to cover, i.e. the areas covered do not have to be adjacent. This is simpler, as the provider would prioritize areas as such:

1. Cover all areas not covered by the first information provider in which the demand exceeds one-half the maximum demand, starting as near to the highest demand as possible. With the linear distribution shown in Figure 5, this is $\{x: 0.5 < x < 1\}$

2. Move left from this region and from the location of highest demand simultaneously. With the linear distribution shown in Figure 5, move left from $x = 0.5$ at $1/2$ the rate from $x = 1$.

As one can see from these models, the areas which have the largest number of vehicles will attract a number of competing providers. The outlying regions will receive no coverage at all. This results because an information provider would choose to share a higher demand in one area with his competition (and capture a fraction of the market) rather than cover an outlying region.

Questions Remaining

Because we do not yet have a clear understanding of the traffic information industry, many issues remain that could affect these models and the conclusions we might extract. In particular, it appears that many of the information-gathering processes are not fixed-location. Information providers upon initial observation have shown a tendency to cover an entire metropolitan area as requested by most radio stations. This is convenient because of the use of aircraft, cellular phones, etc., which are not fixed-location. The main applications of these models, alternatively, might be to optimize the distribution of fixed resources, such as closed-circuit cameras or loop detectors. If an information provider had a fixed investment, it would be wisest to position this near the areas of highest demand. A similar issue arises when a provider must choose one of many incidents to report on.

In addition, it remains uncertain what percentage (or portion) of an individual's trip an information provider would have to cover to "capture" a driver as a listener. Clearly, as the length of the segment covered increased, the benefits received from information would increase.

However, the length of coverage at which the individual benefits exceed the individual costs, and thus the level of coverage required to capture an individual as a listener, remains uncertain.

Finally, different models of demand would be necessary for different time periods, because the number of trips made during the peak periods is much greater and much more concentrated in terms of the origin or the destination. An interesting sidenote is the effect of the decentralization of the workplace and the resulting spread of the demand for traffic information. Because of this, less competition would exist between information providers, and each provider would have to cover a larger area to capture the same number of listeners. In nearly all cases, however, one can expect that clustering will still exist to some degree.

3. A Disaggregate Model

In our second model, our initial focus is on its application to an individual driver and the visualization it allows toward his path of travel. After this we will discuss the adjustments necessary to apply this to multiple drivers.

An individual (as shown in Figure 6) begins a trip at location $x = x_0$ at time $t = t_0$. The speed of his vehicle determines the slope of his trajectory ($v = dx/dt$). Any point along the trajectory will represent the driver's location at the corresponding time.

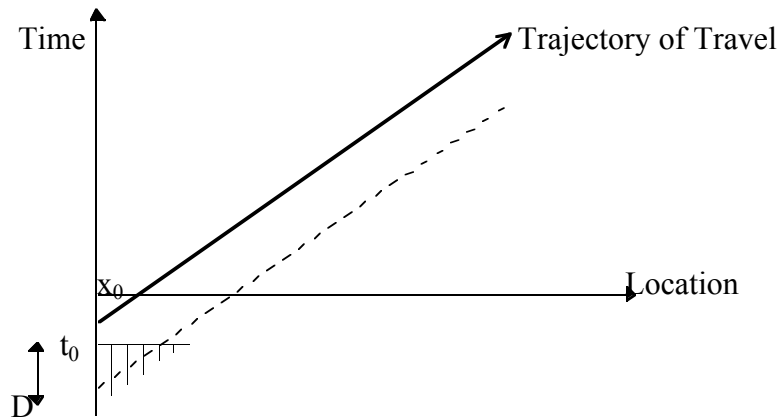


Figure 6. A representative model of an individual's trip and area of concern

The dotted line below the driver's trajectory encloses the space-time region for which the driver would have interest for information. The dotted line parallels the trajectory at a measure D below it, where D represents the duration of an incident (typically defined as the time required for an incident to be removed and for traffic to return to its previous state). One occurring outside of this area would not be of interest because it either would be removed before the individual arrived or it occurs in the future and is impossible to predict.

Since drivers tend to make decisions only at certain locations, the model can be extended to focus on areas of concern. Imagine a node-link diagram as shown in Figure 7.

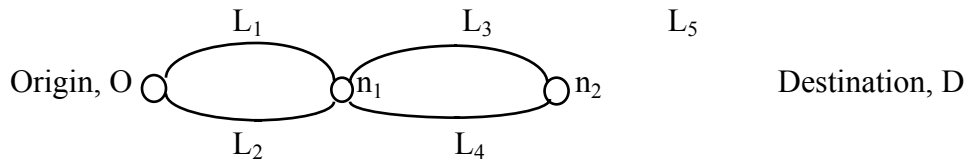


Figure 7. A sample network faced by an individual decision-maker

A driver who begins his trip at origin O and ends his trip at destination D would face two decision points along his trip. Specifically, his first decision point occurs before departure, when he must decide whether to travel on link L_1 or L_2 . The second decision would come as he approaches node 1, when he decides between links L_3 and L_4 . When the driver reaches node 2, he faces no decision because there is only one route between node 2 and his destination. Thus, information regarding this link will be of lesser value.

Significant works in decision theory have shown that the value of information is proportional to the probability that one's action will change (Marschak, 1974; Hirshleifer et al. 1992). Although there is always the option to terminate the trip or turn around, the probability of the driver's action changing because of an incident along L_5 is much less than the probability of his action changing because of an incident along links 1-4. Thus, Figure 8 might represent the space-time regions of particular interest to the driver.

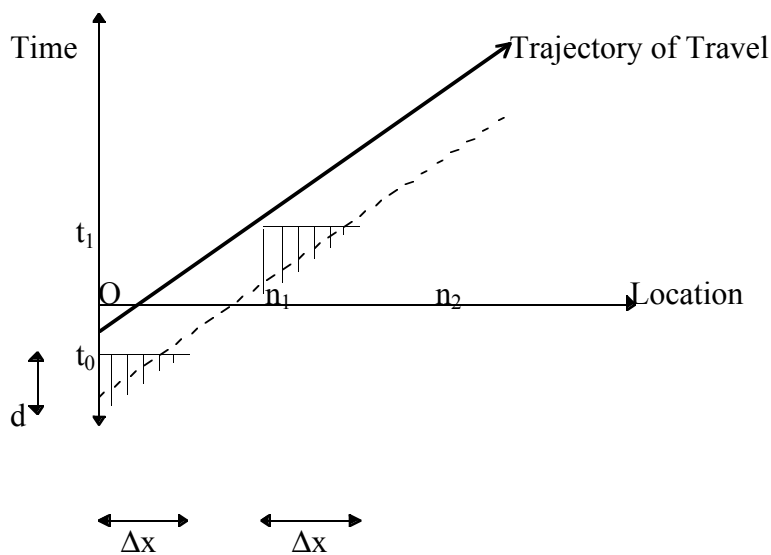


Figure 8. The areas of concern to an individual driver

The first shaded region represents the decision faced by the driver as he approaches his departure time at the origin, O, the second shaded region as he approaches node 1. The implication that this has on traffic information is that information gathered outside of this triangle will not be of interest to this particular driver. Thus the information provider would have no incentive to gather information outside of this triangle if his sole objective is to maximize revenue, which is done by capturing listeners.

In the following sections we will address a number of issues which might affect the actual shape of this shaded area, such as its length (the duration of incidents), the aggregation of individual drivers, and the valuation placed on the information by individuals.

Effect of Incident Duration

The duration of an incident can vary widely depending on its severity, the response of the incident management system, and the level of traffic surrounding the incident. Two studies (Giuliano 1989; Skabardonis 1997) have analyzed data regarding incidents and found the duration to have a distribution similar to that shown in Figure 9.

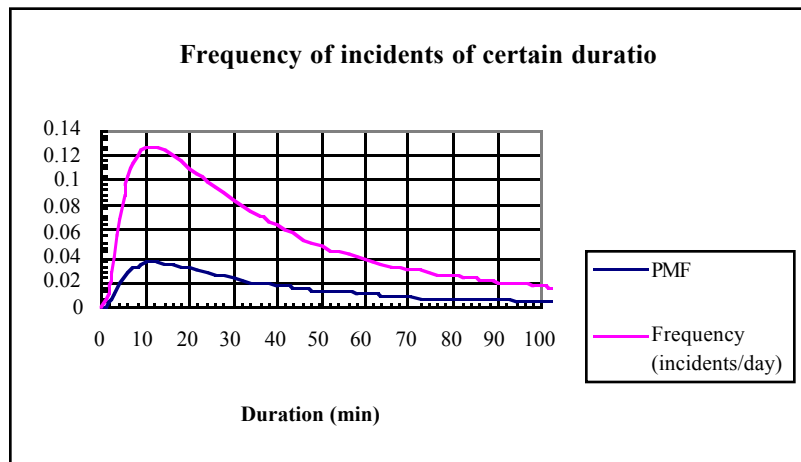


Figure 9. A representation of the probability and frequency of incident durations
(Source: Giuliano 1989)

In one study, approximately 75% of the incidents had a duration of 18 minutes or greater, and 50% had a duration of 36 minutes or greater.

In many cases, the distance between two decision points is significantly less than the distance which could be traveled in 36 minutes. Thus, in reality there are likely few locations which would ever be truly irrelevant with respect to decision points (except the locations which have no significant alternative). The primary market for traffic information is the commute trip, which typically has travel times less than 36 minutes, with a few decision points along the way. (The median commute time in the Bay Area is approximately 24 minutes, one of the longest in the nation (Nolte, 1996).)

However, one might argue that an information provider would still be wisest to position his resources nearest the decision points, because an incident closer to the decision point is more likely to affect a driver as he chooses his route. In other words, an incident further downstream is more likely to be removed before it would affect the driver upstream at the decision point. A similar result comes when a provider must choose one of two incidents to gather information on; the incident closer to the decision point would on average affect more drivers, because it would be within the space-time region of interest to more drivers.

Resulting from this trend is a difference of interest between traffic information providers and freeway management crews (who might also use information). As argued, traffic information providers would care most about the incidents occurring closest to the decision points. Conversely, freeway management crews would place greater concern on the incidents occurring further downstream, because vehicles downstream would have (essentially) no alternate route. With no route for diversion, the delay from a downstream incident would grow larger and affect many more vehicles.

This also raises a question about the future of the two industries. Much research and fieldwork is attempting to improve the response of freeway management crews. As this work progresses, and the resulting distribution of incident durations becomes shorter, traffic information providers should ideally cluster to a greater extent around the major decision points.

How quickly does information have value?

Another important factor to remember is that drivers are not always diverted immediately, if the information is to provide user-optimal route guidance. Studies and simple observation can show that the delay resulting from an incident will continue to grow until the incident has been removed, after which the delay will decrease until the end of its duration (Al-Deek, 1993). Because the delay is initially zero and is insignificant in the beginning, the primary route continues to be of higher utility to a driver for a certain period after the incident. Thus information about the incident is not always of value immediately after the incident, as no action would be taken from that information. Also of interest is the fact that an information provider might not be giving a report immediately after an incident is detected; the information comes of value only when it is given in a report. In a third scenario, the information may be of limited value because the drivers have no alternate routes available, and thus cannot change their actions as a result of the information. In any of these cases, immediate information is thus of no more value than delayed information.

This raises another difference between information providers and freeway management crews. Once an incident has occurred, immediate notification of the freeway management crew could allow an incident to be removed faster; thus, the quicker the information is received the

greater will be its value to society, and information will always possess some immediate value. It is conceivable, however, that immediate information may not be of value to any of the information providers. The issue this raises is that of whether the objectives of the freeway maintenance crews could be as effectively fulfilled if their source of information is the traffic information providers. We hope to address this further in our later studies, with particular emphasis on the role that competition plays in the detection of incidents by information providers.

Aggregation of Drivers

The diagrams in Figures 6 & 8 represented the trajectory of only one vehicle. The objective of a traffic information provider, however, would be to capture the maximum number of customers. Each customer along this trajectory has his own origin-destination pair and his own desired departure time.

In addition to having a number of vehicles located along this trajectory, there are a number of trajectories along which vehicles travel. The demand for traffic information could be represented in a similar manner along each route. Consequently, traffic information providers have a much larger selection of decision points and routes on which they could focus their resources. Each of these alternatives must be evaluated.

Fortunately, many of the vehicles on the roadway during major periods of concern are headed toward common destinations. Many routes involve a network's major segments if they are accessible. In addition, most drivers face similar arrival times. Thus each of the large number of drivers faces the same decision points. As a result, drivers will likely cluster around certain decision points at certain times, allowing traffic information providers to focus their resources more effectively.

4. Value of Information

The primary objective of present traffic information providers is to generate revenue from sponsors and radio stations, which is done by capturing as large an audience as possible. Thus these providers have little interest as to how much actual value each listener associates with their

information (as long as they listen). Because information providers presently do not market their goods directly and can thus not employ direct pricing, they do not directly attempt to capture those drivers who place the highest value on their information.

Related to the issue of direct pricing is the fact that the market for value-added resellers, i.e. those provider who might sell information directly for a price, has only recently begun to develop. Many of the operations proposed are still early in their developmental stages and thus it is difficult to make observations about their behavior. In addition, much of the information these VARs market is only information repackaged from the primary providers; thus, even if the information of higher value were desired, it might still not be collected.

Two categorizations can be made for the value which a driver would associate with the time saved from using information. The first category considers the direct value of time. Many stated-preference studies have found that drivers could (if asked) associate a certain dollar value with the amount of time they might save. Information providers may use these conclusions and focus their resources on areas where listeners may be more easy to capture. (If an individual has a higher value-of-time, he may be more eager to listen to information.) But this is not easily observable, because of the indirect relationships within the market. In addition, this also raises questions of equity if the information provider were publicly funded; the attention of the provider would likely be focused on wealthier neighborhoods.

The second category, largely absent in the literature, involves what could be considered an opportunity cost for the time which could be saved. This opportunity cost arises because the prospect of one consequence (e.g. arriving late to the airport) would hold much more disutility for a driver than another consequence (e.g. arriving late to the grocery store); thus some drivers would place a higher value on information. This opportunity cost is similar to the findings of studies which have shown that drivers will change routes more readily on home-to-work trips than on work-to-home trips, likely since the consequence of arriving late to work would be worse than that for arriving home late (Khattak 1991).

Unfortunately, we have already described how drivers heading from different origins to different destinations tend to travel along similar medians. However, it is possible that an

aggregate measure of all users of a segment would show the value of information, on average, is relatively larger in certain areas. (The drivers nearest the airport would, on average, show an increased value for information.)

5. Conclusion

Before confidence is to be placed in either of these models, we must state again some of our initial observations from the survey of traffic information providers. Of main interest is the providers' tendency to gather information for an entire metropolitan area, and then disseminate information over the regions of concern for a particular customer; the fact that each provider's clientele generally consists of many radio stations forces them to cover an entire region. As a result, the main application of these models might be toward the distribution of fixed information-gathering equipment, for example CCTV or automatic-vehicle identification, etc. We might also use them to determine the areas to receive the highest level of attention.

Another important factor is the differences in the media which are used for the dissemination of information. The radio stations' selection of certain regions results from their decision to allocate only 60-90 seconds for traffic information. Because an Internet location or a personalized information source has much more space available, such a provider would have interest for information about any region which could be added. The contrast between these media will be addressed further in a later report.

To now discuss the models proposed, we recognize that each has its own advantages. The strongest qualities of the first model include the representation of the number of vehicles along the roadway, the quantity which an information provider would attempt to capture. This representation enables one to visualize the benefits (in terms of number of listeners) which an information provider might receive by positioning in certain locations. It also shows the tendency information providers would have to cluster around certain locations. This model could also potentially be modified to include the interaction between competing providers, and different models could be used for different time periods or different locations.

The second model allows the analyst to easily conceptualize the behavior of one individual driver. The incorporation of incident duration and the effect of decision points (either

of which could be added by weights to the first model) allows one to imagine the decision process being undergone by a driver, and the methods by which an information provider might be most successful in influencing this.

A very interesting question raised involves the differences in the detection time and the positioning desired for incident response and the gathering of information. The primary differences result from the immediate detection would be beneficial in all cases for incident removal. From the perspective of information providers, particularly those providing route guidance, immediate detection may not be as productive in all cases. These differences exist because the freeway maintenance crew is often publicly funded (and thus benefit-maximizing) while the information providers are private industry (and profit maximizing).

These differences are of importance because the incident detection schemes used in most metropolitan areas involve a high degree of coordination between these two operations. Hopefully our future research will explore further the precise methods used by each of these information gatherers in their detection of incidents and search for ways in which these two might combine their operations.

Finally, the observations made in this paper regarding the models revolve around our initial impressions of information providers' behavior. The next phase of the research will involve a much deeper discussion of the information providers and their operations, allowing us to check many of the assumptions which were used to develop the models in this paper.

References

- Al-Deek, Haitham and Adib Kanafani. 1993. Modeling the Benefits of Advanced Traveler Information Systems in Corridors with Incidents. *Transportation Research*, vol. 1C, no.4.
- Giuliano, G. 1989. Incident Characteristics, Frequency, and Duration on a High-Volume Urban Freeway. *Transportation Research*, vol. 23A, no. 5.
- Hirshleifer, J. and J. Riley. 1992. Information and Informational Decisions. *The Analytics of Uncertainty and Information*. Cambridge University Press.
- Khattak, A. 1991. Driver Response to Unexpected Travel Conditions: Effect of Information and Other Factors. Ph.D. Dissertation, civil engineering, Northwestern University, Evanston, IL.
- Malchow, M., A. Kanafani, and P. Varaiya. 1996. The Economics of Traffic Information: A State-of-the-Art Report. California PATH Working Paper, UCB-ITS-PWP-96-16.
- Marschak, J. 1974. Remarks on the Economics of Information. *Economic Information, Decision, and Prediction., Selected Essays: Volume II*. Boston, MA: D. Reidel.
- Nolte, C. and E. Deakin. 1996. Typical Bay Commute - 24 Minutes, It's No Better than L.A., Study Says. *San Francisco Chronicle*, page 1A, March 8.
- Skabardonis, A., R. Bertini, K. Petty, P. Varaiya, H. Noeimi, and D. Rydzewski. 1997. The I-880 Field Experiment: Analysis of the Incident Data. To be published at Transportation Research Board.

Appendix

The primary objective of this research, as well as this particular paper, was to address the issue of whether clustering would exist at all between competing information providers. Thus, the precise optimal positioning of information providers in a competitive environment is not as important as the fact that at some level, it will happen. Nevertheless, the method used for estimating the locations will be described here for detail. It should also be noted that the positioning which was modeled was only to maximize the demand to be captured. The net benefit (or the profit) is of course a function of the operating costs and the revenue generated by a number of listeners; this is information which we do not yet have but hope to address in later stages of our research.

To represent the location of information providers relative to their market (the listeners) a few key assumptions had to be made (and could be argued against):

1. An individual driver will subscribe to that information provider which provides information regarding the longest segment of his trip relative to other providers.
2. An individual will not change providers (by changing stations) once he has crossed from the area of one provider into the area of another provider. The individual chooses one service and maintains his allegiance.

In the next phase, the different relationships which might result between the positioning of competing providers with respect to the length of trips were addressed. The first relationship would be if the two competing providers were to position themselves immediately next to each other, with no locations being divided. Thus, if the length of the segment covered were d , the first provider would position himself at $x = 1-d/2$ and provide coverage for the segment $[1-d, 1]$. Any driver whose trip entered his segment would listen to his information; thus, the first provider would capture all listeners whose trip originated in the segment $[1-d-L, 1]$, where L is the length of the individual's trip. The second provider would position immediately adjacent to the first, with a central location of $x = 1-3/2d-L$ ($d/2$ units upstream from the location at which the first provider's listeners begin). Thus, the segment of listeners which he will capture is $[1-2d-2L, 1-d-L]$.

This behavior will occur so long as the marginal benefit of moving to the left (gaining the listeners at $x = 1-2d-2L$) is less than that gained by moving right (gaining one-half the listeners at $x = 1-d-L$). When this behavior becomes no longer optimal, the two values just described will be equal. Because the demand is linear (with Q being the demand at $x = 1$) with respect to the location, set:

$$\begin{aligned} Q(1-2d-2L) &< Q(1/2)(1-d-L) \\ 2-4d-4L &< 1-d-L \\ 1 &< 3d + 3L \\ 1/3 &< (d+L) \end{aligned}$$

Thus, the second information provider will position himself immediately adjacent to the first provider's segment (at $x_2 = 1-3d/2-L$) if $(d+L) \leq 1/3$.

The second scenario occurs when the segments covered by the two providers overlap but no individual's trip is covered entirely by both providers. (In other words, the area of overlap does not exceed the trip length, and one provider will be preferred to the other for all drivers.) Note that this overlap does not occur if the trip originating furthest downstream but still entirely contained in the second provider's area, at $x = x_2 + 1/2d - L$, starts downstream of the first provider's area, which starts at $1-d$. Thus, $(x_2 + 1/2d - L) < (1-d)$ or $x_2 < (1 + L - 3d/2)$.

The position of the first provider will again be $x_1 = 1-d/2$. The positioning of the second provider will again be such that the demand captured on the upstream side is equal to the demand captured on the downstream side (thus, the marginal benefits of moving in either direction is approximately zero, the property of a maximizing location). The second information provider will capture all trips which originate upstream of the segment he covers but enter his segment somewhere along the trip, as well as those trips which travel in both providers' segments but have a greater portion of their travel in his segment. Thus, we must determine the location at which these two extremes are equal.

$$Q(x_2 - d/2 - L) = (1/2)Q(x_2 + d/2 - ((1/2)((x_2 + d/2) - (1 - d - L))))$$

where the latter term on the right represents the segment of overlap between individual who could listen to either provider. This segment is divided in half because all drivers originating on the upstream half will choose the second provider, all drivers on the downstream half the first provider.

Setting these equal,

$$\begin{aligned} x_2 - d/2 - L &= (1/2)(x_2 + d/2 - (1/2)(x_2 + 3d/2 + L - 1)) \\ 2x_2 - d - 2L &= x_2/2 - d/4 - L/2 + 1/2 \\ 3x_2/2 &= 3d/4 + 3L/2 + 1/2 \\ x_2 &= d/2 + L + 1/3 \end{aligned}$$

Thus, in the second scenario, in which information providers' segments overlap but individuals should have a clear favorite, the second provider will position at $x_2 = 1/3 + d/2 + L$ if $x_2 < 1 + L - 3d/2$, or if $(1/3 + d/2 + L) < (1 + L - 3d/2)$; rearranging this, if $d < 1/3$.

Thus, the second provider will position at $x_2 = 1/3 + d/2 + L$ if $(L + d > 1/3)$ and $(d < 1/3)$.

The third scenario arises when an individual's trip is entirely contained within both provider's segments. In this scenario, it was assumed that an individual would be indifferent between the two providers, and as a result, listeners whose entire trip is included in this area of overlap between the providers would be shared between providers. All individuals originating upstream of this segment would choose the second provider, and all individuals downstream would choose the first provider.

The area of overlap between the two providers' segments would be $(x_2 + d/2) - (1-d)$. All trips which originate within $[1 - d, x_2 + d/2 - L]$ would be indifferent between providers. Thus the margins for the second provider should be such that:

$$\begin{aligned} Q(x_2 - d/2 - L) &= Q(1/2)(x_2 + d/2 - L) \\ 2x_2 - d - 2L &= x_2 + d/2 - L \\ x_2 &= 3d/2 + L \end{aligned}$$

Thus, in the third scenario, in which $(d > 1/3)$, the second information provider will position himself at $x_2 = 3d/2 + L$.

The fourth scenario is quite simple in that an information provider will position himself in a manner such that the entire segment for which he is gathering information is included on the $[0,1]$ segment. This scenario only arises when that location given in the third scenario, $x_2 = 3d/2 + L$, exceeds $1 - d/2$ (or if $(2d + L > 1)$). In this scenario, the information provider would be best off positioning at $x_2 = 1 - d/2$, immediately on top of the first provider.

Thus, in the final scenario, the second information provider will position himself at $x_2 = 1 - d/2$ if $(2d + L > 1)$.

Summarizing,	$x_2 = 1 - 3d/2 - L$	if $(L + d) < 1/3$
	$x_2 = 1/3 + d/2 + L$	if $(L + d) > 1/3$ and $d < 1/3$
	$x_2 = 3d/2 + L$	if $(d > 1/3)$ and $(2d + L) < 1$
	$x_2 = 1 - d/2$	if $(2d + L) > 1$

Clustering would occur between competing information providers under any of the final three scenarios. This would raise questions regarding the efficiency of the system, since a second provider would not likely gather information that provided much of a marginal benefit over the information gathered by the first provider.

