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SOME ASPECTS OF THE MARKET FOR BROADCAST TRAFFIC INFORMATION

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1. INTRODUCTION

In recent years, planners have looked toward traffic information systems as an immediate solution to the congestion on U.S. highways. ITS systems are low-cost relative to many alternatives, and simple implementation allows for quick results. Alongside these investments has been research investigating the use of information systems by drivers and the results to be expected. Many studies have shown that the primary source of information for drivers has been broadcast systems such as the radio (e.g. Yim et al., 1997). Additional research has addressed other media which are used to transmit information to its users, yet little has been presented toward the development of economic models to represent the behavior of the providers of broadcast information. This paper will serve as an attempt to fill that gap.

Before the economic models can be constructed, we must first describe some conditions which make the industry for broadcast information in the United States unique from most other industries. With over 90% of the traffic information which is produced, three primary parties are involved; the information provider, the broadcast station, and a sponsor. The information provider is allocated an amount of airtime by the broadcast station, who hopes to attract more listeners. (Only in some cases is additional money transferred; this will be described further later.) The majority of this airtime is to be filled with traffic information. The information provider then reallocates a segment of the allotted time to a sponsor (for a fee); this reselling serves as the primary source of revenue for the information provider.

This unique mechanism results in a few characteristics making the market for traffic information distinct. First, the three-party mechanism makes the direct transfers of services for money difficult. This results because the revenue received by a provider for sponsorship often exceeds the value of that airtime (if allocated to other purposes) to the broadcast station. This does not occur when money is transferred, as the money holds the same value for both parties. In one way, this presents a benefit in itself for society, as the transaction itself elevates the value of the good. In addition, the allocation of time necessary for the good's consumption is more directly related in this case.

Other characteristics, those which create the incentive for public involvement, are the monopolistic tendencies and the public-good status present within the market. The former characteristic results from the increasing returns to scale exhibited in the production of traffic reports. The latter results from the unlimited consumption of information and the extension of benefits to individuals not using the information directly. In addition, the benefits which can be expected for one user of the service is very much a function of how many others use the system (Al-Deek, 1991).

With this report we will explore the economic behavior of information providers more thoroughly. In particular, models will be constructed to represent the supply and demand function of industry participants, and three different "equilibria" will be discussed. An exploration of these equilibria will address the roles in which public management might become involved, such as to increase the benefits which can be expected from broadcast information.

2. THE SUPPLY FUNCTION

In this section, the operations of the industry members will be explored. In particular, the costs which contribute to the production and distribution of traffic information will be described, and the economy-of-scale characteristics which result will be briefly addressed. These economy-of-scale characteristics will then lead to a discussion of the behavior which then results within the industry. A theoretical model will be proposed by which the supply curve could be approximated for different markets. Our observation of the industry will then be shown to support the proposed characteristics.

2.1 The Contributing Costs

The primary costs which contribute to the production and distribution of traffic information can be divided into three classifications. The first cost is the broadcasting equipment and office space which is necessary as a central point, at which information can be gathered and processed, and from which reports can be broadcast for commercial stations. The second primary cost is the equipment necessary to collect traffic information, such as aircraft, cellular phone operators, closed-circuit television, etc. Numerous arrangements have been made to distribute the costs (e.g. free cellular calls to subscribers of specific companies for specific stations). The third cost would be the personnel necessary for various operations, such as flying the aircraft or delivering reports. The flow of information through this network is shown simply in Figure 1.

Together, these costs result in an economy which exhibits increasing returns to scale, or decreasing average costs, with respect to the number of reports delivered. The costs of equipment, for both broadcasting and information-gathering, would be essentially fixed with respect to the number of reports to be given. Of course, one firm could choose to invest in higher-quality broadcast equipment, or could choose to fly four aircraft instead of three, but this would not effect the cost of an additional report. With respect to the number of reports, this would only raise the level of “fixed” costs.

The costs of personnel, however, would represent the marginal, or variable costs; this cost would remain constant with respect to the number of reports given. Each “voice” is generally used for 2-4 stations during a period, depending upon the frequency of reports for each station. So, although labor too must be hired in discrete blocks, the acquisition of contracts requiring additional reports would, on average, require additional labor.

Together the high fixed costs and the constant marginal costs result in a decreasing average cost, and hence the opportunity for the largest firm to control the market. The largest firm (in terms of the number of reports given) would, of course, exhibit the lowest average cost and could thus outprice its competition if they were to remain profitable in the long run. This characteristic creates one of the primary incentives for public involvement, to ensure the efficient operations of a market prone to monopolistic behavior. The shapes of these cost functions are shown in Figure 2; the results which follow will be discussed more thoroughly after our construction of the demand function in the following section.

To make this model more explicit, and to determine the parameters from which an econometric estimation could be made, one would have to specify the good being produced. This is of course more difficult, as traffic reports are not a standard, uniform product. In particular, the level of quality of the product must be specified. But imagine the product as being a report with an X% chance of detecting an incident within Y minutes. (For this discussion, assume X = 90, Y = 10.)

One could use the duality which exists between cost functions and production functions to find the production set for producing a certain output; in other words, the production set would consist of all combinations of inputs (incident detection methods) which would give a 90% chance of detecting an incident within ten minutes.

$$X = \alpha * f(I_a, I_h, I_c, I_p, L, K, Y)$$

where X is the probability of detecting an incident within Y minutes
Y is the window during which incident detection could be measured
I_a is the number of aircraft in surveillance
I_h is the number of helicopters in surveillance
I_c is the number of closed-circuit cameras in place
I_p is the number of cellular phone users patrolling the network
L is labor
K is capital (for leasing of space, broadcast equipment, etc.)
α is some constant representing the area or the population to be covered

(Of course other equipment could be deployed; our inputs here were limited for simplicity.) To the authors' knowledge, no study has even attempted to estimate such a production function. Inhibiting factors would include the variations between different geographical settings, the density of population and development, etc. A different production function could be generated for each environment. One method of simplification might be to make assumptions of course, for example on the layout of the network (rectangular) or the population.

From duality theory, this could be converted back to a cost function. Let c(X, Y) represent the cost function which would correspond to the production function described above for the gathering of information. The cost function, then, for the gathering and the dissemination of information would then be:

$$C = \beta * c(X, Y) + \gamma * T$$

where β is a constant similar to α in the production function

c(X, Y) is the cost of gathering the information for one report

X is the likelihood of detecting an incident within the window, Y

Y is the window of evaluation for the detection of incidents

γ is the marginal (labor) cost of giving one more report

T is the number of traffic reports to be given from the information collected

The cost function of course would give the minimum cost necessary for obtaining a specific level of information. From this the marginal cost of a traffic report would be :

$$\delta C/\delta T \quad = \quad \gamma,$$

the cost of the labor necessary for one more report, and the average cost would be :

$$C/T \quad = \quad (\beta * c(X, Y))/T + \gamma,$$

which clearly would be greater than the marginal cost. Thus if services are to remain profitable, either suppliers would have to charge a price exceeding marginal cost or the operations would have to be subsidized through taxes collected from other sources.

2.2 Observed Trends

The market for traffic information in the U.S. has migrated in recent years toward a monopolistic state, particularly in medium-sized cities. Competition exists in most of the largest twenty-five U.S. cities, whereas only one provider exists in the majority of the next fifty. The largest cities (e.g. New York, Los Angeles, Boston) are presently served by more than two providers. This trend is a result of the economies of scope and scale inherent in the market, as well as some characteristics of larger agencies. Economies of scale are exploited when larger agencies buy out local information providers. The buyer who already has operations in the area does not absorb many additional costs and inherits a profitable list of new customers. The additional costs are small since the provider experiences decreasing average costs.

Economies of scale result from larger agencies having the resources and capital to provide more information than their smaller competitors (i.e., more accurate reports). Large agencies (such as Metro Networks or Shadow Broadcast Services in the U.S.) have two additional characteristics creating a greater advantage over small, local providers: (i) they have a larger financial base, due to their wider operations, and (ii) sponsors can be collected with the promise of a national platform. The first characteristic allows them to expand their operations more easily to experience the economies-of-scale, as well as allowing them more security if competition were to produce marginal-cost pricing. The second characteristic makes the development of revenue sources simpler.

3. Demand Model for Traffic Information

One particularly unique characteristic of the traffic information economy is the shape of the demand function for traffic reports which characterizes broadcast stations. The derivation which follows comes primarily from the authors' interviews with industry members as well as the assumed profit-maximization objective of industry members.

3.1 Characteristics Describing Broadcast Decisions

For the commercial station, it is assumed that the cost of airing a traffic information spot is the same as running a regular program. In addition, all other programming decisions are assumed to remain fixed, e.g., number of songs, weather reports, etc. Thus, the objective of the station managers would be to maximize the revenue with respect to the number of traffic reports included, which in turn maximizes their profits. The revenue of a station can be given as :

$$R = f\left(g(T)\right) ? h(T)$$

where R = revenue of the station
T = number of traffic reports given
$g(T)$ = number of listeners, as a function of traffic spots
$f\left(g(T)\right)$ = advertising rate, as a function of the number of listeners
$h(T)$ = number of spots remaining to be sold to advertisers

The first function, $g(T)$, would be of a shape similar to that shown in Figure 3a. As shown, the initial reports have little impact on the number of listeners, because the traffic reports would be spaced too far apart to affect a listener's decisions. As the number of reports increases (i.e., the reports become more frequent), the size of the audience would also gradually increase, until it reaches a maximum level, after which listeners would begin to turn away because traffic reports become too frequent. The second function, $f\left(g(T)\right)$, is shown in Figure 3b, and would be a function which increases monotonically with $g(T)$, but at a decreasing rate; that is, $\frac{\partial\left(f\left(g(T)\right)\right)}{\partial(g(T))} > 0$ and $\frac{\partial^2 f\left(g(T)\right)}{\partial(g(T))^2} < 0$. This implies that the advertising rate would increase monotonically with the number of listeners, but at a decreasing rate. The third function, $h(T)$, shown in Figure 3c, would be a decreasing function, with its rate of decrease becoming larger as the number of reports increased. This relationship would result because broadcast stations would initially use traffic reports to replace other programming, but would gradually be forced to use them in place of commercial spots. Mathematically, $\frac{\partial h(T)}{\partial T} < 0$ and $\frac{\partial^2 h(T)}{\partial T^2} > 0$.

The demand function for the broadcast stations then could be summarized as follows :

$$D(T) = (\delta R/\delta T)/T,$$

that is, the willingness-to-pay (or demand) of broadcast stations, the average price paid for T traffic reports, would be equivalent to the change in revenue they could expect, on average, from each of T traffic reports. The additional revenue would be generated from the changes in rates charged to advertisers which result from the changes in the size of the listener base as T traffic reports become incorporated.

Another void in the literature necessary to evaluate this model empirically comes in the curve to represent g(T). It can be assumed that broadcasting literature includes discussion of the function f(x), but to the authors' knowledge no research has been performed to estimate g(T). More specifically, as referenced earlier (Yim et al. 1997), studies have estimated what percentage of people listen to traffic reports; however, no study has attempted to determine how influential the presence of or the amount of traffic reports are in the drivers' selection of a station.

3.2 Decisions of Information Providers

The objective of the information providers, to maximize profits, can be formalized as:

$$\boldsymbol{\pi = W(T) - C(T)}$$

where π = provider’s profits
T = number of reports given
W = provider's revenue from sponsors of traffic reports
C = provider’s total cost

From this equation (and intuition):

$$\frac{\partial \pi}{\partial T} = \frac{\partial (W)}{\partial T} - \frac{\partial (C)}{\partial T} = 0$$

if the provider is maximizing profits.

Thus $\frac{\partial (W)}{\partial T} = \frac{\partial (C)}{\partial T}$, or the market price is equal to the marginal cost.

For the commercial station, it is known that:

$$\frac{\partial R}{\partial T} = \frac{\partial f}{\partial g(T)} \cdot \frac{\partial g(T)}{\partial T} \cdot h(T) + f\left(g(T)\right) \cdot \frac{\partial h(T)}{\partial T} = 0$$

if the station is maximizing its profits (and thus its revenue) and there is no direct transfer of money. This case is represented by point T_1 on the proposed demand model for traffic information shown in Figure 4.

After the value T_1, at which $\frac{\partial r(T_1)}{\partial T} = 0$, the radio stations themselves will not willingly trade for traffic information, since they will not gain revenue. (The advertising rate no longer increases, and the number of advertisements can only decrease.) Although radio stations exhibit a willingness-to-pay, this amount is less than the opportunity cost of the time necessary for a report. At the same time, information providers are not yet maximizing their profits, i.e., $\frac{\partial \pi}{\partial T} > 0$. (The amount sponsors would be willing to pay exceeds the marginal cost of a report, but remains less than its opportunity cost.) As a result, the information providers could choose to pay the radio station an amount $\left(-\frac{\partial R}{\partial T}\right)$ to allow them to give another traffic report. In effect, the information provider would buy airtime (at a reduced rate) since they could resell it to a sponsor for a higher price.

As T increases, the radio stations would lose more money and R would further decrease. Thus we can hypothesize that $\frac{\partial^2 R}{\partial T^2} << 0$, and the amount of money which the information provider would need to compensate the radio station would continue to increase with T. Information providers would continue to pay radio stations as long as the revenue derived from one additional report exceeded its cost (i.e., the combination of their operations and the payment to the radio station). This continues until the provider's marginal profit falls to zero, at which

$$\frac{\partial \pi}{\partial T} = S(T) - \frac{\partial C}{\partial T} - \left(-\frac{\partial R}{\partial T}\right) = 0 \ ,$$

where S(T) is the sponsorship rate as a function of the number of reports. The sponsorship rate is assumed to be constant, though it may decrease (slightly) if the number of reports became excessively large. This equilibrium would correspond to T_2 in Figure 4.

In the absence of competition, i.e. under a monopoly, one can assume that the information provider would set the price and the quantity such as to maximize his internal profits. This point of equilibrium would be represented by T_0 in Figure 4, under which a fewer number of reports would be given and broadcast stations would be forced to pay a higher price.

3.3 Expected Results

Observations can be made from this arrangement regarding: (i) the differences in the number of reports ideally produced under competitive and monopolistic environments; (ii) the changes in the direction of monetary transfers under competitive and monopolistic environments; and (iii) the differences between the competitive equilibrium and where participants (are presently believed to) position themselves, as well as the assumptions which could be made about the quality of the information gathered under different environments.

With regard to the first and second observation, recall how the broadcast station's willingness-to-pay for information under competitive equilibrium would fall below the value of necessary airtime. As a result, information providers in a competitive market would ideally buy airtime at a fraction of the cost commercial advertisers paid. As the amount of compensation received by the radio stations increases (i.e., as their demand curve falls), the market approaches competitive equilibrium at T_2 (if the number of providers is large enough such that they act as price-takers). In the case of a monopolistic environment, in which one firm would be profit maximizing, the point-of-stability would be somewhere near T_0. In the oligopolistic environment, the providers would likely choose, through competitive interactions, an intermediate equilibrium (at which the price exceeds the marginal cost). (In the two-player environment, the formulas derived from a Cournot- or Nash-equilibrium model could be used to determine the exact price and quantity of outputs, as suggested by Rasmusen (1989)). Thus, a lessening of competition would raise the market price and lessen the number of reports to be sold. An extreme case would occur under a monopoly. The information provider would likely limit sales to an amount less than T_1 such that the broadcast station pays the information provider a monetary sum in addition to allocating the airtime. In either case, the number of traffic reports available to drivers would be lower, and the direct customer would pay higher costs. This is similar to most other monopolies, where the level of production is limited and the market price is raised based upon the elasticity within the market.

With regard to the second and third observations, it is clear that a gap exists between the maximum price which broadcast stations are willing-to-pay for a traffic report and the minimum price at which information providers can produce one. This situation arises particularly at the level of traffic reports consumed at $T_{1.}$ This is believed to be the current situation because information providers are not believed to be bartering with radio stations to increase the number of traffic reports. The information provider's immediate objective is to contract a station and allow the station to decide the program format. It should be noted that, at this point, the information providers can make a sizable profit from the contracting of a broadcast station. The profit potential is high in the industry, allowing providers to offer some broadcasters "generous compensation packages" (Borden, 1992). Providers are willing to pay up to the amount of this profit to ensure that the station does not contract with the competition instead. As a result, under competitive scenarios, the information providers will pay the broadcast stations to allow them to provide their traffic information. Under monopolistic environments, the amount paid to broadcast stations would be held back, increasing the provider's profit. The important point this reiterates is that it would be in the economic interests of the broadcast stations, in particular, to ensure that competition is present within the market for traffic information.

Another inference can be made about the effects of competition on the quality of the traffic information. Clearly, as the quality of traffic information increases, the costs necessary to gather it must increase as well. With a higher average cost, an information provider would have a smaller profit margin (assuming the sponsorship rates remain unchanged), and thus would not be able to compensate a contracted station with as much as they could previously. Therefore, the broadcast station would be forced to decide between more money or a higher quality of information. This issue raises the question of how aware station listeners are of the accuracy of traffic information provided by various stations; in other words, what is the incentive for a broadcast station to raise the accuracy of its reports? Will additional listeners raise commercial prices enough to compensate for a lower transfer? Likely not. From observation, listeners are generally unaware of the differences. It may be that stations of a certain format (e.g. news) would hold the accuracy of such reports more highly. However, a minimum standard should be set for the quality of information such that the station's listeners feel confident using it. Otherwise, the incentive for the accuracy of reports may not exist. A representation of the possible cost curves and corresponding demand curves can be found in Figure 5, with s' and d' representing a higher level of accuracy. Which set of (all possible) sets of curves would maximize the area of rectangle WXYZ, the information providers' profits in an oligopolistic environment?

Another perspective on accuracy can be gained from the use of game theory in a two-player competitive environment. Numerous articles, including Hotelling (1929), have argued that players in a two-person environment will act very similar to their competitor. From an unscientific sampling of the traffic reports produced by competing providers in the Bay Area, one can argue that competing providers tended to go toward the same level of accuracy. A similar argument could be made by comparing the methods for incident detection used in various cities across the country. Upon simple observation, a much greater correlation could be seen between the methods used by competing providers within one region than between the different chapters of one company in different regions. An important question to address is whether this level of accuracy (the saddle point in a game-theoretic environment) upon which providers will converge could be raised in any manner.

4. FUTURE DIRECTIONS

The primary objective of this modeling was to address the issue of whether or not public involvement would be pertinent in the collection and dissemination of traffic information. The primary role for public involvement would appear to be a preservation of competition, or market activity resembling that which would occur under competition. Unfortunately, due to the proprietary nature of the industry, not enough data was available to determine precisely at what level competition becomes beneficial. So herein we can only hope to have offered some insights as to how this question might be addressed. In addition, earlier in this report are proposed models for the cost and demand functions for broadcast traffic information, to which data from specific environments could be fit for future calibration.

As suggested, as the number of reports becomes larger, the fixed costs will begin to play a less-important role in determining the average cost of the service. As the average cost approaches the marginal cost, smaller firms would be able to become competitive within the market. And as mentioned, competition in the United States presently exists only in the twenty or so largest cities. Thus one might suspect that as the cities become larger, the possibilities for competition expand. But there are other factors as well which might determine the need for additional traffic reports, for example, the number of outlets which are available or the level of congestion frequently experienced within an area. The first factor might vary with the number of broadcast stations in operation; in addition, some cities might not yet have added traffic reports to the local news, but once they are added their availability can grow rapidly. The second factor would of course raise the interest within a station's audience, which is of course the largest reason for a station to incorporate such reports.

To determine whether an additional provider would be beneficial would involve an estimation of the costs and benefits to be incurred. The additional (unnecessary) costs would of course come from the repetitious operations (e.g. six aircraft instead of three, often circling above the same incident). The economy-of-scale present naturally discourages competition. The additional benefits would be primarily the presence of more frequent reports, as well as a higher level of accuracy to be achieved within reports. (It is conceivable that providers might raise their presence in order to achieve contracts in competition.) Each of these effects would serve to increase the utility of the information users, in terms of travel time saved, or reduced stress during congestion, or other similar factors.

The second area which is being affected by the emergence of broadcast information is the competition with other forms of other information. Numerous studies have explored the potential for other types of in-vehicle information, for example (Hall et al., 1996; Perez et al., 1993). Particular focus has been on the market potential for such devices. Yet too often these studies do not take into account the information which is already available to them through broadcast media. And as broadcast reports have become much more frequent in recent years, the additional benefit afforded by in-vehicle information (in terms of immediate access, or higher information content of reports) become smaller. This trend is of particular importance because the source of information for in-vehicle information sources is often that same source which provides the information for broadcast reports. As these additional benefits become smaller, of course the market potential for spin-off devices becomes smaller, and thus the developments within the industry can come to a standstill.

5. CONCLUSION

In this paper we have attempted to introduce the complex interactions which describe the economic behavior within the market for traffic information. Particular focus has been given to the characteristics which would describe the level of equilibrium which would prevail in different types (or sizes of) markets. The potential for public involvement in the regulation, or at least oversight, of this industry arises from the opportunity for monopolistic control, coupled with the characteristics of traffic information which can allow it to be considered a public good. Particular interest for public involvement was shown to arise from the nonuser benefit which can be derived from the consumption of traffic information and the diminishing of the product (and its level of consumption) which would result if competition were not maintained within each market.

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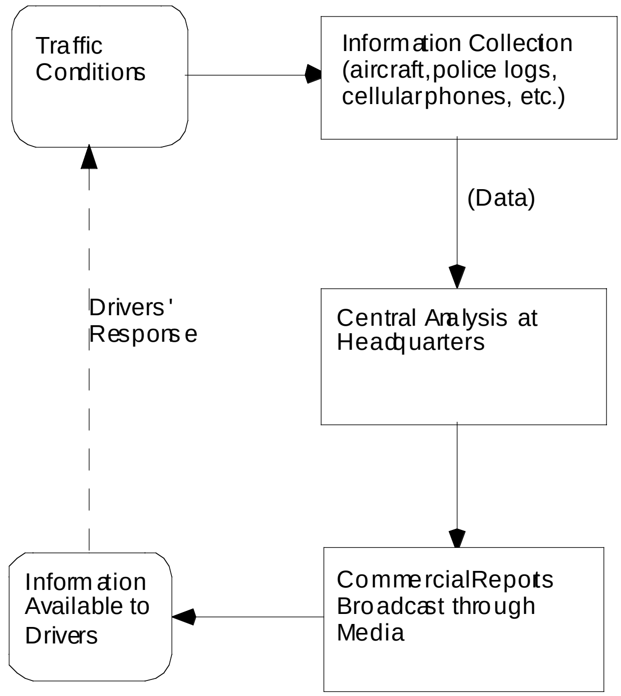

Figure 1. The Network by which information is gathered and distributed to drivers.

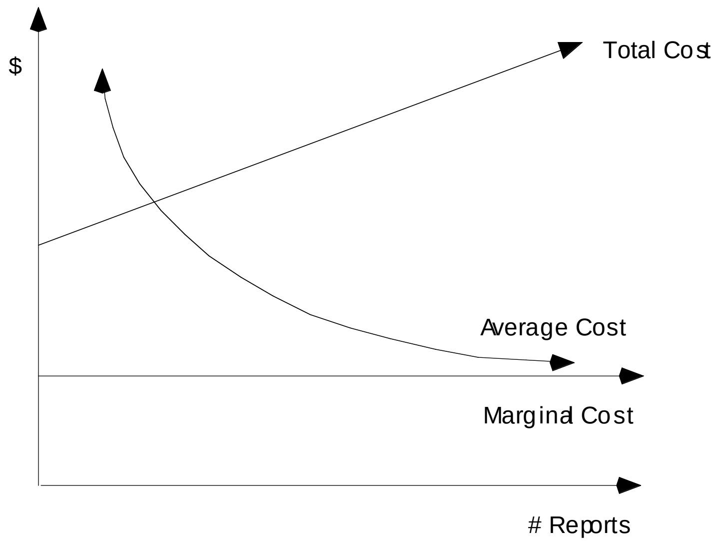

Figure 2. The nature of the costs incurred by U.S. traffic information providers.

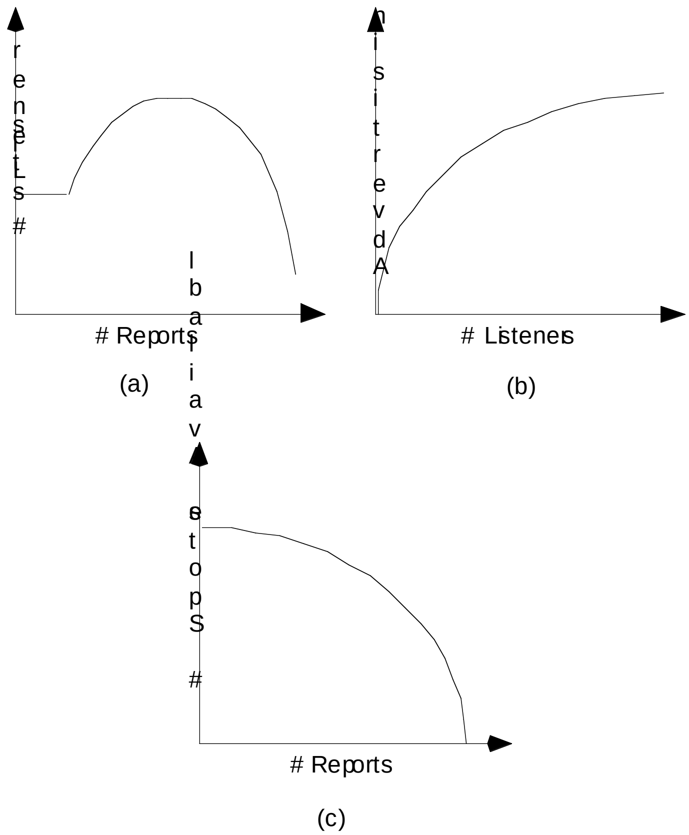

Figure 3 The fundamental relationships used to construct a demand model for traffic information.

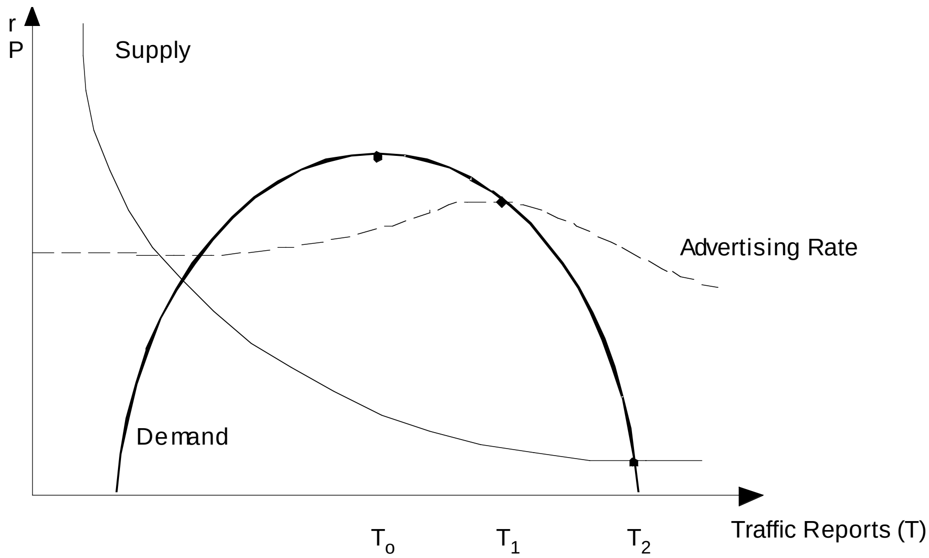

Figure 4. The equilibrium resulting from the supply and demand models describing the traffic information industry.

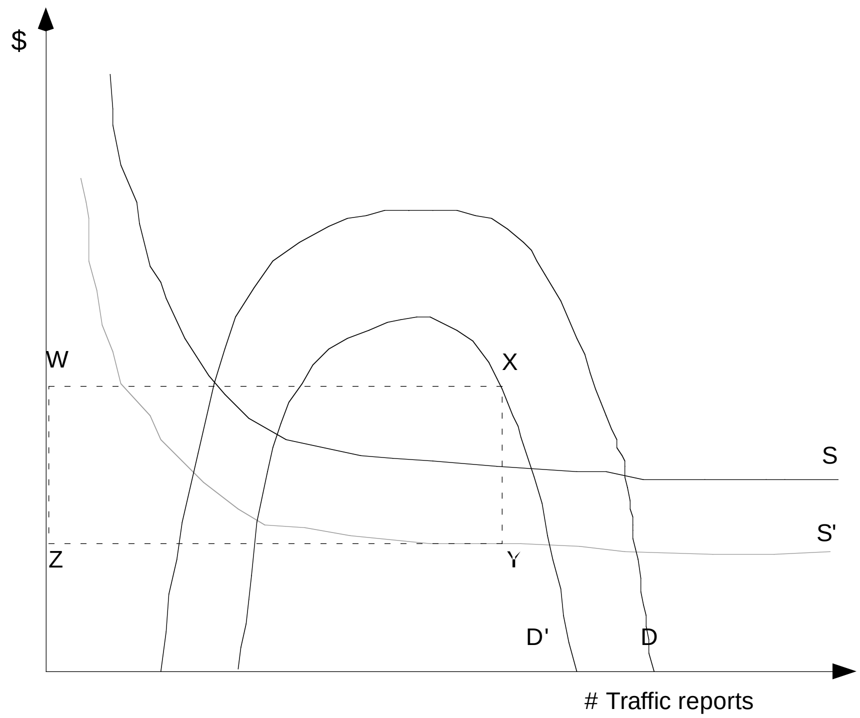

Figure 5. Supply-Demand curves for traffic information at two different levels of accuracy (S,D >>S',D'). Which (among these and others) will maximize suppliers' profits (the area of WXYZ)?