

TRAVEL TIME ESTIMATION USING TOLL COLLECTION DATA

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Abstract. Transportation System Management (TSM) permits optimizing the current available road network. Travel time and its reliability are key factors in road management systems, as they are good indicators of the level of service in any road link, and perhaps the most important parameter for measuring congestion. This paper presents a new approach for direct travel time measurement using existing toll infrastructure. An efficient and simple algorithm has been developed and implemented in the toll highways in Catalonia, around Barcelona, Spain.

1. Introduction

Travel time and travel time reliability are key factors in road management systems, as they are the best indicators of the level of service in a road link, and perhaps the most important parameter for measuring congestion [Palen (1997)]. Travel time estimation is necessary to assess the operational management and planning of a road network. Moreover, travel time information is the best and most appreciated traffic information for road users.

Most of the European countries (Spain, France, Denmark, Italy, Finland, United Kingdom, Sweden, the Netherlands, Norway and Germany) consider travel time as an emerging issue in Europe and realize of the growing demand for real time travel time information. Most of the Trans-European Road Network (TERN) in these countries is now covered by an euro-regional project in travel time.

Because of the growing interest in measuring travel time, there have been several studies attempting to determine link travel times in a road segment. So, Dailey (1993) and Petty et al. (1997) focus on the travel time estimation from loop detector data. These algorithms have been proven to be quite effective in road segments with high detection point density and free flow traffic conditions, but they don't perform well in less monitored

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roads or under heavy congested situations. For these last situations, Westerman and Immers (1992) propose a cumulative flow balance algorithm at successive detector sites for estimating travel time. The counter detector drift is the problem in this case. Other studies analyze the direct measure of travel time, using AVI systems [Levine and McCasland (1994), Christiansen and Hauer (1996), Seki (1995)] or license plate matching [Cui and Huang (1997)], among others.

This paper presents a new approach in travel time measurement using toll infrastructure. A simple algorithm for estimating travel times in toll highways is developed. The algorithm uses the travel time data included in the toll tickets for different itineraries in order to estimate the section travel time for consecutive entry and exit points. The results of a pilot test in the AP-7 highway in Spain are also outlined in the paper.

2. Contribution of the proposed algorithm

The data on travel times can be obtained by measuring the time taken for vehicles to travel between two points on the network. In toll highways, the data needed for the fee collection system, can be also used for travel time measurement.

The toll tickets allow for measuring travel time for all origin – destination relations in the highway. However, travel time data is obtained once the vehicle has left the highway. This involves a great delay in the information in long trips. Moreover, travel time for long trips can be increased by factors that are unrelated to traffic conditions, for example if the driver stops for a break. In order to reduce the influence of such events and the information delay on the calculated average travel time, it is needed to estimate the single section travel time, between consecutive entry and exit points (see Fig. 1). This will also provide valid information for all drivers in the highway (not only for vehicles with the same origin – destination itineraries), and could also enable incident detection applications.

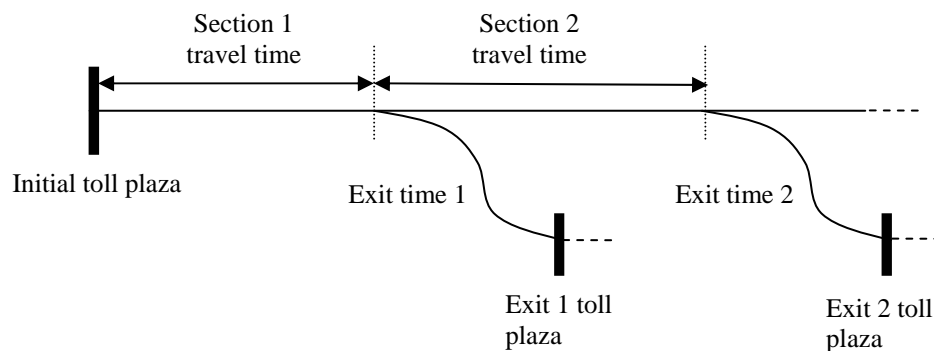


Fig. 1. Highway travel time definition

One possible solution to estimate the section travel time could be to include only measurements between consecutive entry and exit points. This solution, used in the Italian “AutoTraf” system [Hopkin et al. (2001)], may reduce in excess the amount of data in certain sections of the network, where the volume of traffic entering and leaving the

highway at consecutive junctions is low, but there is a large volume of passing traffic. Moreover, this solution does not account for the “exit time” (i.e. the time required to leave the highway). The exit time includes the time required to travel along the exit link plus the time required to pay the fee in the toll plaza. Then, if the time to travel along a particular itinerary, composed of various single sections, is calculated by adding the single section travel times, the resulting itinerary travel time will be excessive, because it includes as many exit times as single sections compose the itinerary.

The algorithm presented in this paper solves the problem of long journeys by estimating the single section travel time and allows for dividing this time into the strict single section travel time and the exit time. The estimated exit time is a very useful measure for highway operators, as it is an indicator of the level of service in the toll plazas. Moreover, the algorithm uses data from most of the itineraries in the highway increasing the accuracy and reliability of results.

3. Estimating section travel times from toll ticket data

For each particular vehicle “ k ” been driven along a highway with a closed tolling system (see diagram in Fig. 2), the travel time spent in its itinerary between “ i ” (origin) and “ j ” (destination) expressed as “ $t_{i,j,k}$ ” can be obtained by matching the entry and exit information recorded in its toll ticket.

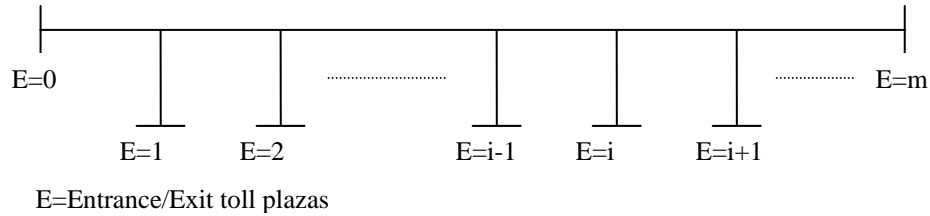


Fig. 2. Highway diagram with a closed tolling system

The average travel time for the itinerary in a particular time period “ e ” (e. g. 1 hour) can be obtained by averaging the travel times of all vehicles that have entered the highway within the time period and have traveled along the same itinerary “ i,j ”.

$$t_{i,j}^{(e_i)} = \frac{\sum_{k=1}^{n_e} t_{i,j,k}^{(e_i)}}{n_{e_i}} \quad \forall i = 0, \dots, m-1 \quad \forall j = 1, \dots, m \quad \forall e = 0, \dots, 23 \quad (1)$$

Where: (e_i) is an hourly time period in the vehicle entrances in the toll plaza “ i ” of the highway.
 $t_{i,j,k}^{(e_i)}$ is the travel time for the itinerary “ i,j ” for a particular vehicle “ k ” that has entered the highway within the time period “ e_i ”.

$t_{i,j}^{(e_i)}$ is the average travel time for the itinerary “ i,j ” in a particular hourly time period “ e_i ”.

n_{e_i} is the number of vehicles that have entered the highway within the time period “ e_i ”.

From these calculations, the average travel time for all the itineraries in a particular time period, “ $t_{i,j}^{(e_i)}$ ”, is obtained. The next step is to calculate the single section travel time (i.e. travel time between consecutive entry and exit points) and the exit time (i.e. the time required to travel along the exit link plus the time required to pay the fee in the toll plaza).

In general, the average travel time “ $t_{i,j}$ ” can be divided in two parts: the section travel time “ $t_{s(i,j)}$ ” and the exit time “ $t_{ex(j)}$ ” (see Fig. 1).

$$t_{i,j} = t_{s(i,j)} + t_{ex(j)} \quad (2)$$

If we consider the highway stretch between entrance 0 and exit 1:

$$t_{0,1} = t_{s(0,1)} + t_{ex(1)} \quad (3)$$

Then it can be seen that subtracting different travel times of selected itineraries, the section travel times and the exit times can be obtained (see Fig. 3). Then for the (0,1) itinerary:

$$t_{s(0,1)} = t_{0,2} - t_{1,2} = t_{0,3} - t_{1,3} = \dots \quad (4)$$

$$t_{ex(1)} = t_{01} - t_{s(0,1)} \quad (5)$$

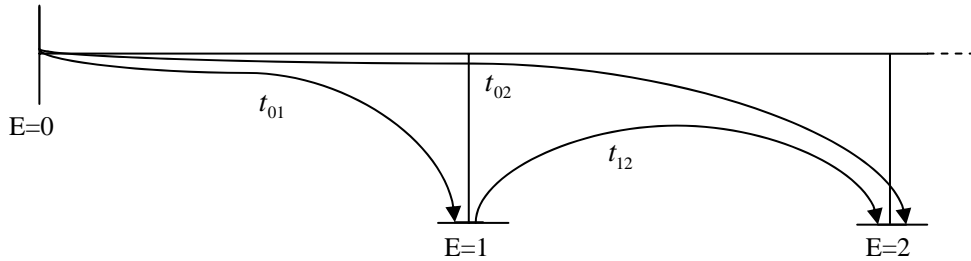


Fig. 3. Section (0,1) travel time estimation

Note that for sections with entrance different from the initial toll plaza, equation (3) should be rewritten as:

$$t_{i,j} = t_{en(i)} + t_{s(i,j)} + t_{ex(j)} \quad \forall i = 1, \dots, m-1 \quad \forall j = 2, \dots, m \quad (6)$$

Where: $t_{en(i)}$ is the “entrance time” (i.e. the time required to travel along the entrance link)

In the present paper it is assumed that the entrance time “ $t_{en(i)}$ ” is smaller enough in relation to the section the section travel time “ $t_{s(i,j)}$ ” and to the exit time “ $t_{ex(j)}$ ” to be rejected. So, in a general expression for all entry and exit points, the average single section travel times and the average exit times can be calculated for each stretch as:

$$\bar{t}_{s(i,i+1)} = \frac{\sum_{j=i+2}^m (t_{i,j} - t_{i+1,j})}{m - (i + 1)} \quad \forall i = 0, \dots, m - 2 \quad (7)$$

Where “ m ” is the last toll plaza in the highway, and “ $\bar{t}_{s(i,i+1)}$ ” is the average travel time for the single section $(i, i+1)$.

To obtain the exit time we only need to subtract this average single section travel time to the total itinerary travel time in adjacent entrance/exit points. Then:

$$\bar{t}_{ex(i+1)} = t_{i,i+1} - \bar{t}_{s(i,i+1)} \quad (8)$$

Where “ $\bar{t}_{ex(i+1)}$ ” is the average exit time for the $(i+1)$ toll plaza.

4. Application to the AP-7 highway in Spain

The AP-7 highway runs along the Mediterranean cost corridor in Spain, from the French border to the Gibraltar strait. The pilot test was restricted to the north east stretch of the highway from “*La Roca del Vallès*” toll plaza to the French border at “*La Jonquera*”, of approximately 120 km long.

The pilot test was performed with the 10th of July 2005 data, which was a particular conflictive day in the highway. The results of the application of the algorithm allow for obtaining the single section travel times for each of the 13 sections of the stretch and for each of the 24 hours of the day. Moreover the exit times for each toll plaza are also calculated in an hourly time period basis. The analysis of the obtained results determines that the proposed algorithm is a suitable new approach to estimate the single section travel times in toll highways.

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