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Estimating Travel Time Distribution Under Different Traffic Conditions

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Abstract

Increasing mobility and congestion results in an increase in travel time variability and in a decrease in reliability. Reliability becomes an important performance measure for transportation facilities. A variety of performance measures have been proposed to quantify it. Many of these indicators are based on percentiles of travel time. The knowledge of the distribution of travel time is needed to properly estimate these values. Congestion distorts the distribution and particular statistical distributions are needed. Different distributions have been proposed in the literature. In a previous paper, we presented a comparison of six statistical distributions used to model travel time. These six distributions are the Lognormal, Gamma, Burr (extended by Singh-Maddala), Weibull, a mixture of two Normal distributions and a mixture of two Gamma distributions.

In this paper a probabilistic modeling of travel time which takes into account the levels-of-service is given. Levels of service are identified, then travel time distributions are modeled by level of service. This results in a very good fit between the empirical and modeled distributions Moreover, the adjustment was improved, thanks to the calibration of “Bureau of Public Roads” functions, linking the travel time to the traffic flow by level of service.

The superiority of the Singh-Maddala distribution appears in many cases. This has been validated, thanks to travel time data from the same site at another period. However the parameters of the distributions vary from one year to another, due to changes in infrastructure. The transferability of the approach, not performed, will be based on travel time data on another site.

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Keywords: congestion; traffic flow; travel time; motorway; modeling; statistics; reliability; distribution; Level of Service; Bureau of Public Roads.

1. Introduction

Traffic congestion impacts speed, thus travel time. When traffic increases and approaches the full capacity of the network, the flow becomes unstable and much more vulnerable to incidents, road works or bad weather. This

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increases the variability of travel time, to which users are very sensitive. Therefore, travel time reliability has become an important performance criterion for transportation facilities, complementing the traditional measures such as delay and average travel time. In recent research, a variety of performance measures have been proposed to quantify reliability and monetize it. This includes planning time, buffer time, standard deviation, coefficient of variation, skewness,... - an overview is given in Lomax et al. (2003). These indicators are based on percentiles of travel time. The knowledge of the travel time distribution is then needed.

Different distributions are presented in the literature as the best way to model the travel time distribution. Richardson and Taylor (1978), Rakha et al., (2006), Pu (2010) and Arezoumandi (2011) concluded for a Lognormal distribution. Polus (1979) concluded for a Gamma distribution; however Al-Deek and Eman (2006) proposed a Weibull one. Taylor and Susilawati (2012) and Susilawati et al. (2012) adopted the Burr XII distribution; the advantage of this latter method is that its tails often fits the empirical ones. Aron et al. (2012) presented a comparison of six statistical distributions used to model travel time. The parameters of these distributions have been identified on the basis of real time data collected on a weaving section of the A4-A86 French urban motorway.

Based on the same data, this paper uses the Burr XII distribution, completed by a scale parameter introduced by Singh and Maddala (1976) to model travel time over five levels of service. The next section is dedicated to data collection. A method for levels-of-service extraction using the fundamental diagram is given in section 3. Calculation of the travel time and modeling of its distribution over five levels-of-service are presented in section 4. In section 5, the travel time distribution calibration is improved, using relations linking travel time to flow.

2. Data collection

The data used in this paper was collected on a weaving section of the A4-A86 French urban motorway. A two-lane urban motorway ring (A86) round Paris and a three-lane West-East urban motorway (A4) meet in the east of Paris and share a four-lane 2.3 km-long section. Traffic is particularly dense at some hours, and causes the greatest traffic bottleneck in Europe. Data used in this paper were collected in the year 2002 and 2006, on a 3-km long stretch (2.3 on the weaving section, 0.7 km downstream), in the Eastbound direction. 133,000 and 131,000 vehicles circulate by day on the weaving section in 2002 and 2006. Four inductive loops (three on the weaving section, one downstream) provide every six minutes flow, occupancy and average speed by lane.

Table 1 provides the average speed, after weighting by the six-minute traffic flow, in 2002 and 2006.

Table 1 Average six-minute flow and average speed (in km./h) by lane and section

Year	2002				2006			
Station\Lane	Lane 1	Lane 2	Lane 3	Lane 4	Lane 1	Lane 2	Lane 3	Lane 4
Station 1	55	54	62	68	66	68	74	75
Station 2	53	64	83	92	67	79	87	96
Station3	44	56	69	73	66	77	87	92
Downstream	78	77	97	108	118	101	108	117

Note than in 2006, a Hard Shoulder Running (HSR) experiment consisted in opening the hard shoulder to vehicles when traffic density was high - Bhouri and Aron (2014). The average speed on this lane is not given here.

Although the data are generally very good, some are missing, inaccurate or irrelevant. A mean speed for one lane lower than 2 km/h or higher than 150 km/h, is considered as an outlier. Other anomalies in traffic data are identified – occupancy greater than 100% or 6-minute flow (by lane) greater than 400 vehicles. In these cases the data for the corresponding period and lane are cancelled and considered as missing. When this occurs in 2002, the missing data for a given period and lane is substituted, when possible, by data from a corresponding period from the year 2001 or 2000, the same day of the week, the same exact time and approximately the same date.

Although there are 24*365=8,760 hours a year, or 87,600 6-minute periods, only 53,646 periods are considered here because data are “good” for a period only when all the four inductive loop are “good” in 2002 and 2006.