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The association of rainfall and other weather variables with road traffic volume in Melbourne, Australia

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Abstract

An investigation into the effect of weather variables on traffic flow at a site in Melbourne, Australia, for the period 1989–1996 was performed. Rainfall was the strongest correlated weather parameter and it had the greatest impact in winter and spring, when traffic volume is reduced on wet days. There are statistically significant decreases of 1.35 and 2.11% in traffic volume on wet days in winter and spring. The reduction increases to 2–3% over the 2–10 mm range, the largest being 3.43% for the 2–5 mm class in spring.

For the first time, our study considers separately daytime and nighttime periods. We found a reduction of 1.86% in winter and 2.16% in spring during daytime rainfall. The reduction at nighttime is significant over all seasons, ranging from 0.87% in winter to 2.91% in spring.

We have explored an application where the traffic volume was used to normalise the road accident count and found the rain effect to increase by 2.4, 1.9 and 5.2% relative to the daily, daytime and nighttime dry mean accident count. Generally, the normalised count is greater than the raw count, with a larger increase for the higher rainfall classes.

Keywords: Road traffic; Rainfall; Weather; Road accidents

1. Introduction

There is an appreciation that inclement weather is associated with more hazardous driving conditions. Various studies show that precipitation in the form of rainfall and snowfall generally results in more accidents (Codling, 1974; Satterthwaite, 1976; Sherretz and Farhar, 1978; Brodsky and Hakkert, 1988; Fridstrøm et al., 1995; Levine et al., 1995; Edwards, 1999; Eisenberg, 2004). Furthermore, there is some evidence that wet or snowy weather, particularly if coupled with severe storms, can deter motorists from venturing onto the road, i.e. there is a reduction in traffic volume (Knapp and Smithson, 2000). This avoidance of the prevailing weather may be due to a self-assessment by the road user or based on road weather information systems that convey road weather alerts via the media or telephone services (Khattak and DePalma, 1997; Hansen et al., 2001).

In order to assess the risk of an accident in wet conditions, one would ideally like to know the exposure of a given vehicle to other traffic during these conditions compared with dry periods. The most useful measure of this is traffic volume, which tends to be recorded as 'snapshots' on major roads in urban areas or more continuously only at a small number of locations. Hence, in many studies where volume is not available, techniques such as the matched-pair method (Codling, 1974; Changnon, 1996; Andrey et al., 2003) are used to control for differences in traffic volume during wet and dry periods. Gasoline sales are sometimes used as a proxy for traffic volume (Fridstrøm et al., 1995).

Therefore, we have the situation where the risk of an accident in wet or snowy conditions is dependent on the traffic volume, which *itself* is dependent on those same conditions. However, there are few references on the effect of rainfall and other weather variables on volume (Codling, 1974; Changnon, 1996; Hassan and Barker, 1999). In this study, we will establish the associations between rainfall and traffic volume since it is of interest in its own right as well as for accident research. The relationships between traffic volume and other weather variables will also be explored. We will also present a short application where the traffic volume is used to normalise the accident count, which is then analysed for rainfall effects.

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The study pertains to the city of Melbourne, Australia and its metropolitan area, with a population of 3.5 million (June 2002) and covering an area of 8800 km^2. The city is located at 37.8°S, 145.0°E on Port Phillip Bay and enjoys a temperate climate with mild winters (the average July maximum temperature is 13.4 °C) and moderately hot summers (the average January maximum is 25.8 °C). We use traffic volume data for the period 1989–1996. A preliminary investigation revealed that standard linear regression was an appropriate method of analysis. Levine et al. (1995) also found this to be true for their analysis of daily road accidents in Honolulu.

In Section 2, we describe the data available for this study, followed by an outline of the method of analysis in Section 3. The main results and an application are presented in Section 4, and these are discussed in Section 5. Finally, our main conclusions are given in Section 6.

2. Data

This study is based on data of traffic volume, weather variables, holiday information and accident counts. Ideally, we would like information on the traffic volume over the Melbourne metropolitan area (MMA) for each day of our study period 1989–1996. However, the only data available are intermittent counts of the volume on a small number of major roads. VicRoads, a state government authority responsible for managing Victoria's major road network, recorded the volume used in this study at two sites: one on the Southeastern Freeway (now renamed as the Monash Freeway) (VSE), and the other on the Westgate Freeway (VWG). The former is a major southeastern arterial road, the latter is the major link to the western side of the city. The data were provided as 1-h volume counts for each direction of travel. These sites had the best overall coverage over time but the data are not sampled uniformly, often only as 'snapshots'. Thus, we have an uneven spread of data over the period 1989–1996. Owing to the high correlation between the two volume datasets (a correlation coefficient of 0.96 for the daily series), it was decided to exploit this and augment the VSE dataset using the VWG data. The best technique was to fit a regression model incorporating a linear time trend, day of the week (DOW) effects and holidays to each of the two datasets to get two residual series RVSE and RVWG. The series RVSE was regressed on RVWG:

$$\mathrm{RVSE} = a_0 + a_1\,\mathrm{RVWG} \qquad (1)$$

to get a series of fitted values $\widehat{\mathrm{RVSE}}$. This series was then considered to be a pseudo-residual series from the model for VSE. Using $\widehat{\mathrm{RVSE}}$ at times in VWG that were *not* present in VSE, the regression model for VSE then gave pseudo-observations in VSE at these times. There were 360 points in VWG that were not present in VSE, increasing the number of volume points in VSE from 542 to 802. This final series is called the *augmented* volume series (VSEA) and is shown in

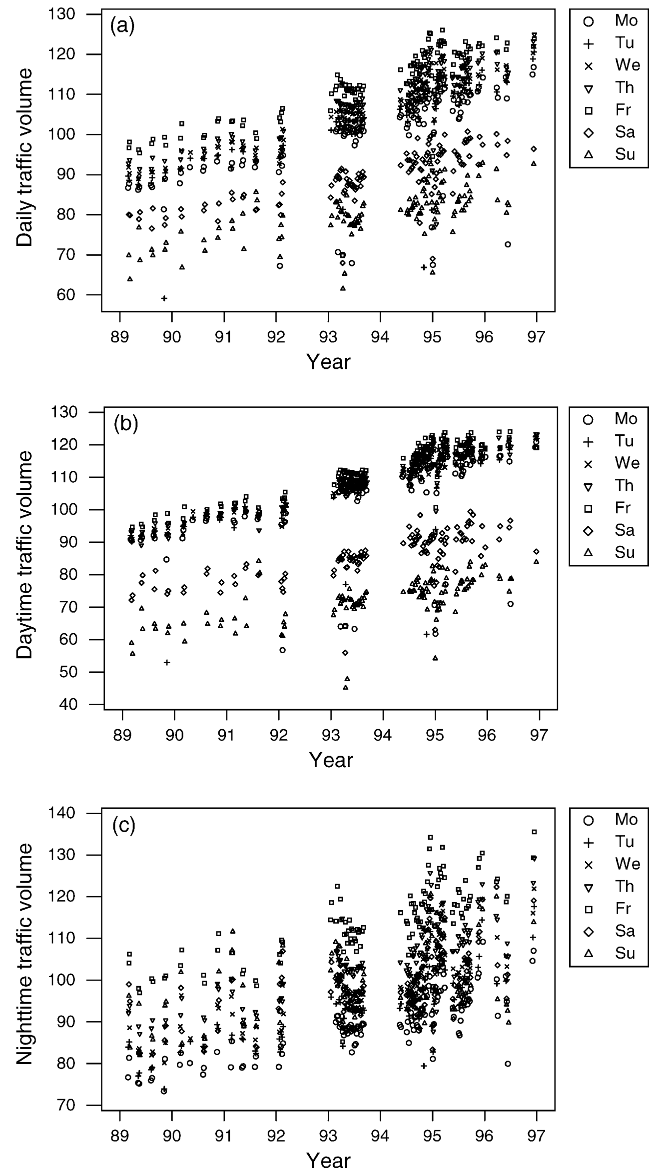

Fig. 1. Traffic volume at the Southeastern Freeway recording site. Each series is normalised to a mean of 100. Data over 1993 is infilled using the Westgate Freeway traffic volume. The series are: (a) daily traffic volume, (b) daytime traffic volume, and (c) nighttime traffic volume.

Fig. 1(a). In particular, augmentation improved the coverage over 1993. For the traffic volume period, there are 802 days in all with 171 days in summer, 208 days in autumn, 264 days in winter and 159 days in spring.

Since we do not know the total number of vehicles on the road in the MMA on a given day, we will normalise VSEA to have a mean daily volume of 100. In our volume regression models, this means that many effects (coefficients) are expressed as percentage changes relative to the mean of the VSEA series.

At a late stage in the study, some additional volume data at the two sites for the period 1997–2003 were made available. However, there are major changes to the freeway system that occurred over this period, especially in April 2000 with