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Understanding the effects of complex seasonality on suburban daily transit ridership

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ABSTRACT

Fluctuations in transit ridership pattern over the year have always concerned transport planners, operators and researchers. Predominantly, metrological elements have been specified to explain variability in ridership volume. However, the outcome of this research points to new direction to explain ridership fluctuation in Brisbane. It explored the relationship between daily bus ridership, seasonality and weather variables for a one-year period, 2012. Rather than segregating the entire year's ridership into the four calendar seasons (summer, autumn, spring, and winter), this analysis distributed the yearly ridership into nine complex seasonality blocks. These represent calendar season, school/university (academic) period and their corresponding holidays, as well as other observant holidays such as Christmas. The dominance of complex seasonality over typical calendar season was established through analysis and using Multiple Linear Regression (MLR). This research identified a very strong association between complex seasonality and bus ridership. Furthermore, an expectation that Brisbane's subtropical summer is unfavourable to transit usage was not supported by the findings of this study. A nil association of precipitation and temperature was observed in this region. Finally, this research developed a ridership estimation model, capable of predicting daily ridership within very limited error range. Following the application of this developed model, the estimated annual time series data of each suburb was analysed using Fourier Transformation to appreciate whether any cyclical effects remained, compared with the original data.

1. Introduction

Transit provides basic mobility services to people in their day-to-day activities. It helps to reduce road congestion, travel time, air pollution, and energy consumption compared to other travel modes. Nevertheless, a large proportion of commuters are reluctant to use transit as their preferred mode choice. Understanding of reasons behind disinclination to transit ridership is of utmost importance to transit agencies. Many factors that directly or implicitly influence human travel behaviour have received their fair share of attention in the realm of transit research, including socio-economic characteristics of trip makers, household socio-economic characteristics, attitude towards using transit, as well as built environment, geographic and metrological elements (Cervero and Kockelman, 1997; Hendricks, 2005; Zarei, 2007).

Studies that have dealt with weather have focused on weather and vehicle safety, speed and traffic conditions (Edwards, 1998, 1999; Andreescu and Frost, 1998; Holdener, 1998; Hassan and Barker, 1999; Kyte et al., 2001;Eisenberg, 2004; Keay and Simmonds, 2005; Chung et al., 2006). Extant research on the effects of weather on transit provides conflicting results; some studies support a notion that weather acts as deterrent to public transport usage, while others suggest the opposite (khattak, 1991; Changnon, 1996; Khattak and de Palma, 1997; Guo et al., 2007; Stover and McCormack, 2012). Similar to weather, the impact of calendar season is well documented in areas of human physical activity (Pivarnik et al., 2003; Tucker and Gilliland, 2007; Reilly and Peiser, 2006; Bélanger et al., 2009; Shephard and Aoyagi, 2009) and non-motorized transportation (Nankervis, 1999; Yang et al., 2011; Tin Tin et al., 2012). Calendar season is normally defined as having four temporal states of weather conditions (summer, autumn/fall, winter and spring), while tropical season is normally defined as having two states of weather conditions (wet season and dry season). While the effect of calendar season on transit ridership has attracted the interest of some researchers (Guo et al., 2007; Stover and McCormack, 2012), given its potential

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importance it is surprising that it has not received broader attention in the literature. This paper will explore some plausible reasons why this is so.

Distinct from calendar season, this paper defines complex seasonality as a systematic partitioning of the year into discrete blocks of time. Each block possesses relative internal consistency with respect to the dependent variable, whereas variation in the dependent variable between seasonality blocks is a result of complex but systematic patterns observed in independent variables. These variations may reflect influences such as holidays and festivals, annual socio-economic patterns, annual educational and institutional cycles, as well as other actions including meteorological patterns.

Seasonality tends to be eclipsed by the implication of calendar season. Segmentation of complex seasonality does have some conjunction with temporal variation due to calendar season. Since human activities are somewhat linked with calendar season it might appear that ridership fluctuation is directly linked to it. However, segmenting the year into four distinct calendar seasons may mask some of the ridership variability caused by human activities. Consequently, this research was designed to investigate this by analysing transit ridership fluctuation over the year by segmenting it into internally, relatively consistent seasonality blocks, and identifying the influencing factors.

A transit system devoid of riders does not improve social welfare. Hence, this paper focuses on transit ridership, because conceivably it is the single most important dimension of transit system performance, especially for a city like Brisbane, Australia. Understanding complex seasonality effects on transit ridership has considerable value to transit authorities in their scheduling system if they are hoping to apply their resources more efficiently and productively.

1.1. Case study background

Brisbane is the capital city of the State of Queensland, Australia. Being subtropical, the climate is characterised as warm temperate, with a fully humid precipitation and hot temperature in summer (Kottek et al., 2006). Four calendar seasons are distinct. Summer officially occurs between 1 December and 28 or 29 February (typically high heat, humid and wet); winter between 1 June and 31 August (dry, low humid and cold); autumn between 1 March and 31 May; and spring between 1 September and 30 November.

Brisbane City local government area has a population of 1.1 million people as the centre of a larger metropolitan area of over 2 million people. Approximately 43,707 of Brisbanites use bus for their main daily travel while 26,840 use heavy rail. Bus ridership is higher than rail and substantially higher than ferry. Brisbane's bus system is reliant on its busway (BRT) network of four lines, spanning more than 25 km (16 mi), which serve more than half of the city's routes and offer strong connections to the heavy rail network. It comprises a mixture of grade-separated bus-only sections with on-street transit way sections, complementing the heavy rail network to provide faster and more efficient bus services to its residents (Brisbane Metropolitan Transport Management Centre, 2013). The maximum load segment (MLS) on Brisbane's South East Busway carries over 11,000 p/h during the a.m. peak (National Research Council. TCRP Report 145), which equates to approximately five to six busy motorway lanes each carrying approximately 2000 veh/h with average car occupancy of 1.0 or slightly above, or a train operating at maximum schedule load every 5.5 min.

The weather pattern of Brisbane is highly variable by season due to its subtropical climate. It is prone to severe weather events such as severe thunderstorms during spring and summer, both heat waves and heavy rainfall during summer (Brisbane City Council, 2013), as well as occasional cold snaps during the drier winter. Considering that daily bus passenger volume may be influenced by seasonality and weather, the links between daily ridership, seasonal differences along with the variation of day of week, and weather deserve further attention. Given the dominance of the bus transit mode, Brisbane is ideal for such analysis to establish whether adverse weather conditions affect transit ridership. Compared to rail, research elsewhere has found that bus is more susceptible to adverse weather as it shares the road network system, which bolsters the perception of weather's effect on ridership. Guo et al. (2007) confirmed this assumption in their case study of Chicago.

1.2. Research objectives

To the authors' knowledge, no studies have explored how seasonality and day-of-week variation affect daily bus ridership in a developed, subtropical city such as Brisbane, Australia, or how a weather variable such as daily temperature variation affects daily bus ridership. This analysis examines the effect of seasonality and daily weather conditions on daily ridership for the year 2012. To achieve this goal this paper will explore several questions:

- How do meteorological variables and seasonality affect bus ridership variation in Brisbane?
- What is the underlying reasoning behind daily and seasonal patronage variation?
- How will transport agencies benefit from this knowledge?

The next section (Section 2) of this paper provides a detailed literature review of the effects of weather and variation in calendar season on ridership. Section 3 provides a detailed description of research study area. The fourth section categorizes the sources of data sets used in this study. The following section (Section 5) illustrates methods adopted to analyse seasonality and day-of-week variable. The sixth section develops models, and presents and interprets estimation results. The final section concludes the analysis and proposes further research, and provides recommendations for transit agencies, transport planners, and policy makers.

2. Literature review

This section will focus on the influences of weather and calendar season on transit ridership from three distinct aspects. Firstly, it will discuss how weather variables such as temperature, rain influence transit ridership. Then, it will explore earlier research that has focused on the combined effect of weather variables on active transport. Finally, it will consider the impact of calendar season variation on ridership.

2.1. Effects of individual weather variables on ridership

With modern innovation and technology, people have learned to control their surrounding weather to their utmost comfort. Yet, when they leave their comfort zone weather influences their lifestyle in various ways. One particular topic that has caught researchers' eye in recent years is the effect of weather on transit.

The effects of weather variables on transit are mostly contextual. As an example, in the cold settings of Europe and North America, increase in temperature has been found to have a significantly positive effect on transit ridership (Guo et al., 2007; Shih and Nichols, 2011). In contrast, in regions with hot climates increase in temperature has been found to negatively affect transit ridership (Lin, 2009). Not all weather variables influence ridership to the same degree, and intensity varies with the climate of that