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Bus accident analysis of routes with/without bus priority

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ABSTRACT

This paper summarises findings on road safety performance and bus-involved accidents in Melbourne along roads where bus priority measures had been applied. Results from an empirical analysis of the accident types revealed significant reduction in the proportion of accidents involving buses hitting stationary objects and vehicles, which suggests the effect of bus priority in addressing manoeuvrability issues for buses. A mixed-effects negative binomial (MENB) regression and back-propagation neural network (BPNN) modelling of bus accidents considering wider influences on accident rates at a route section level also revealed significant safety benefits when bus priority is provided. Sensitivity analyses done on the BPNN model showed general agreement in the predicted accident frequency between both models. The slightly better performance recorded by the MENB model results suggests merits in adopting a mixed effects modelling approach for accident count prediction in practice given its capability to account for unobserved location and time-specific factors. A major implication of this research is that bus priority in Melbourne's context acts to improve road safety and should be a major consideration for road management agencies when implementing bus priority and road schemes.

1. Introduction

Various types of bus priority initiatives exist internationally, each differing essentially by the amount of road space or time (or combination of both) that has been allocated for transit vehicles. Regardless of its form, there has been overwhelming evidence that bus priority brings about improved travel time, reliability and attractiveness of public transport. However, little in-depth research has been undertaken to measure the road safety implications of these schemes. A literature review has also revealed that evidence from previous studies on the safety implications of bus priority has been mixed (Goh et al., 2013a). In addition, previous research has been mainly confined to applications in North America (Jovanis et al., 1991; Cheung et al., 2008; Quintero et al., 2013). As such, very little is known on the validity of such models in other countries, where the traffic and transit environment could differ considerably.

This paper explores the road safety impacts of bus priority through an empirical analysis of bus accident data in Metropolitan Melbourne, Australia. The focus of this research is on understanding the effects of bus priority that had been implemented in the 'SmartBus' BRT system in Melbourne since 2006. SmartBus is an entirely on-road BRT system with similar features to the LA Metro Rapid and has had impressive ridership and cost effectiveness performance compared to busway based BRT systems (Currie and Delbosc, 2010, 2011). It also aims to identify key factors that influence bus accident frequencies at the route-section level. For analytical rigour, two modelling approaches are employed—(1) mixed-effects negative binomial modelling and (2) neural network modelling. This allows for a comparison of methodologies, which is a secondary aim of the study.

This paper is structured as follows. The next section reviews previous research and findings concerning bus safety before the research aim is presented. Details on the data as well as development of the statistical regression and neural network models are then provided. Results from both models and implications of findings follow. Finally, the paper concludes with a summary and recommendations for further research.

2. Background

2.1. Bus priority

Bus priority is typically provided with the aim of improving travel time and reliability of bus operations, minimising commuters' waiting time at stops and interchanges and altering the traffic balance in favour of public transport. Achieving all these objectives at the same time often involves compromises between improving the bus operation and needs of private vehicles and other

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Table 1
Summary of transit priority measures.

Bus priority strategy	Form of priority	Traffic management strategies
Right of way (space allocation)	Transit-way, queue jump Prohibited parking Stop consolidation	Full-time, Part-time, intermittent, with-flow, contra-flow, etc.
Signal priority (time allocation)	Transit-only phase Green extension Red truncation Phase insertion/rotation	Active/passive Conditional/unconditional Differential

road users (Slinn et al., 2005). The types of bus priority initiatives used vary from city to city (Hounsell et al., 2004; Gardner et al., 2009). However, their differences lie essentially in the amount of road space or time allocated for transit vehicles. Bus priority, in terms of space allocation, generally involves giving the right of way to the bus along its route of travel. Various forms of priority treatments fall under this category. The most common are bus lanes, where road space is allocated for buses use only. Priority in terms of time reallocation typically involves the application of transit signal priority, which is currently growing in use internationally (Smith et al., 2005). Typically, this involves the use of bus-only phase, green extension or red truncation, where the traffic phasing is adjusted at intersections to favour buses (Table 1).

2.2. Literature review

Previous studies on bus safety have focused on understanding crash characteristics and identifying accident causation factors at the incident-level (or micro-level). af Wåhlberg (2002) developed a taxonomy of buses as a means to study the causes of accidents in terms of driver behaviour and environmental factors. Based on pre-defined categories, he found the number of bus-to-bus and side-swipe accidents to be high, which led to the belief that drivers aim to stop just shy of the bus ahead and that bus stops do not offer enough space for buses to move into. af Wåhlberg (2004a) followed up with an in-depth analysis of bus accidents based on exploring associations between chosen explanatory variables. An interesting observation that emerged from this study was that in only a third of accidents did the drivers report the state of the road had contributed to the crash. Half of all single accidents also happened at bus stops. In a subsequent study, the effect of acceleration behaviour on bus accidents was examined (af Wåhlberg, 2004b). Although the number of working hours and to a lesser extent age, are found to be significantly associated with crashes, there was not enough evidence to support the hypothesis that driver acceleration behaviour is a predictor of bus accidents.

A similar analytical approach was undertaken by Brenac and Clabaux (2005). Through an in-depth examination of police reports, the authors discovered that buses were either directly or indirectly involved in 3.6% of all injury accidents in France. Significantly, the proportion of cases where buses were indirectly involved was higher than those where buses were directly involved. Almost half of cases of indirect involvement of buses related to sight obstruction, with the other half involving pedestrians hurrying across the street to catch the bus. In an attempt to identify factors related to crash frequency of buses and injury severity types, Chimba et al. (2010) used an accident prediction approach by developing negative binomial and multinomial logit models. The results showed that the presence of on-street shoulder parking, lane in which bus was travelling in, posted speed limit, lane width, number of lanes and traffic volume were significant in increasing the accident and injury severity risks.

A number of studies had focused on bus safety in the U.S. One of the earliest studies in this field involved an examination of accident reports in Chicago to identify patterns of bus accidents and shed light on understanding the effect of vehicle, driver's characteristics, environmental and operational factors in accident occurrence (Jovanis et al., 1991). A key finding was that 89% of all accidents were collision events involving hitting another object or person. Another U.S. based study that analysed 8897 commercial bus crashes found crashes in winter months and those involving older buses to be over-represented in accidents (Zegeer et al., 1993). Rear-end accidents where one vehicle stopped and sideswipe accidents were also found to be most common. This was similar to findings by Yang et al. (2009), who found rear-end collisions to be most common. In the study by Strathman et al. (2010), extensive ITS and operations data were used to analyse factors contributing to bus accidents in the Portland Oregon metropolitan region in the U.S. It was found that the expected non-collision frequencies for low floor buses and those older than 15 years were lower. There were also positive effects of running early on collision frequency.

Only a handful of studies have explored transit safety at a macro-level, i.e. route-section or zonal-level. Apart from Jovanis et al. (1991), only two other published studies had been found in the literature. The first was by Cheung et al. (2008), who developed zonal-level and route-level models that relate collision frequency to road geometry and transit related characteristics in Toronto, Canada. Model results indicated that higher traffic exposure (in terms of vehicle or bus kilometres travelled), lower posted speed and longer arterial road length were associated with increased risk of transit-involved collisions. More collisions were also recorded when transit frequency, bus stop density and percentage of near-side stops were greater. These results were expected given that conflicts between right-turning (or left-turning in Australia's context) vehicles and buses when stops are likely to be higher when stops are located on the near side. More conflicts are also expected when more buses are on the road or when stops are located closer to one another. The second study by Quintero et al. (2013) centred on zonal-level collisions, in which prediction models relating collisions to transit physical, operational elements and network indicators based on graph theory were developed. The models showed that increased collisions were positively correlated to the number of stops, number of routes, bus stop density, overlapping degree and connectivity. It was interesting to note that high occupancy vehicle (HOV) lanes were also found to be positively correlated to collisions.

Although the above marco-level studies provided valuable insights into key risk factors in route and zonal-level collisions, they relate to both auto and transit collisions and hence risk factors for collisions involving only transit vehicles remain unclear. Both studies were also confined to applications in North America, and as such very little is known on the validity of such models in other countries, where the traffic and transit environment differ substantially.

In summary, the bulk of previous transit safety research had focused on understanding crash characteristics and identifying accident causation factors. Only a handful has examined transit safety at a route or section-level. At present, our understanding on