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Modelling the net traffic congestion impact of bus operations in Melbourne

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ABSTRACT

Bus services can be seen as a way to reduce traffic congestion where they can encourage a mode shift from car. However, they can also generate negative effects on traffic flow due to stop-start operations at bus stops. This paper aims to assess the net impact of bus operations on traffic congestion in Melbourne. The methodology used to achieve this aim comprised of three main stages. First, a primary survey was conducted to determine the mode shift from bus to car when buses are unavailable. This figure was used to estimate the positive impact of buses on relieving congestion. Second, the negative impact of buses was investigated by considering the effect of bus stop operations on vehicle traffic flow using microsimulation. Finally, the net effect was estimated by contrasting congestion measures determined from a traditional four step model between two scenarios: 'with bus' and 'without bus'. The results indicated that Melbourne's bus network contributes to reduce the number of severely congested road links by approximately 10% and total delay on the road network by around 3%. The highest congestion relief impact was found in inner Melbourne with a 7% decrease in vehicle time travelled and total delay, and 16% decrease in the number of heavily congested road links. In inner areas, the level of congestion is relatively high so the mode shift from car to bus, even if not as high as middle and outer areas, have a significant effect on relieving traffic congestion. Areas for future research are suggested such as investigating the long-term effect of buses on traffic congestion.

1. Introduction

In order to tackle rapidly increasing traffic congestion, particularly in urban areas, public transport systems have been developed in many cities around the world (Litman, 2016, Nguyen-Phuoc et al., 2017, Mackett and Edwards, 1998). Public transport can support reductions in car use and if improved, its attractiveness can also provide a long term solution towards encouraging mode shift. With a number of advantages such as cost effectiveness, reliability and accessibility, buses have been able to attract car users (Waterson et al., 2003). In 2015–2016, the bus system in Melbourne carried 139 million passenger trips, with this figure expected to increase in the future (Public Transport Victoria, 2016a). A 'Better Bus Network' program, costing more than $100 million, will be delivered in 2018 to improve the existing bus system in Melbourne by providing more buses where they are needed, increasing access

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to trains, education, employment, health services and retail precincts (Public Transport Victoria, 2016b). However, the operation of buses also contributes to traffic congestion (Chand et al., 2014, Kwami et al., 2009, Tang et al., 2009). The capacity of roads with bus routes can be influenced by bus stop operations, particularly at curbside bus stops (Koshy and Arasan, 2005). During bus dwell time, the presence of a stopped bus creates a temporary bottleneck at the location of bus stops which reduces the road capacity. In addition, the relatively low acceleration/deceleration rate of buses at bus stops as well as at intersections can also cause delays for other vehicles on the road network.

Even though congestion relief is considered to be one of the main rationales for providing public transport in cities, research focusing on traffic congestion impacts associated with public transport in general and bus in particular is limited (Larwin, 1999, Gray, 1992, Nielsen et al., 2005, Vuchic, 2005). Understanding the congestion impacts associated with buses can help authorities to identify the effectiveness of bus operations in relieving congested areas or congested routes. From this, related policies or improvement projects can be proposed to seek a desired level of congestion relief.

While a number of studies have explored either the congestion relief impact or congestion generation impact of bus operations, no research has investigated the net impact of bus operations on an entire road network. This paper aims to fill that gap by exploring the net congestion impact associated with the operation of buses, using a case study of Melbourne. It considers both the positive effect of buses on reducing traffic congestion and the negative impact of buses on creating congestion to determine the 'net' impact. This paper also represents a methodological advancement from previous research that has explored the congestion relief impacts of public transport (Nguyen-Phuoc et al., 2017, Aftabuzzaman et al., 2010b). Firstly, a primary survey of bus users is conducted to explore the mode shift used for estimating the positive effect. Secondly, a more comprehensive range of factors affecting the negative congestion impact are investigated using calibrated traffic microsimulation models.

The paper is structured as follows: the next section outlines previous studies in relation to the traffic congestion impact of buses. The research context is then described, including a description of Melbourne's bus network. This is followed by a description of the research methodology. The results are then presented, followed by a discussion, concluding remarks and areas for further study.

2. Background

The congestion impact of bus operations on a road segment or a corridor has been explored by a number of researchers. In particular, the negative impacts of buses on generating traffic congestion has received much attention. These congestion effects mainly include the effect of bus stop operations and the effect of bus priority such as exclusive bus lanes or signal priority for buses. Zhao et al. (2007), Yuan et al. (2007) and Tang et al. (2009) used theoretical models to simulate the impact of bus operations at bus stops on traffic flow. Other researchers have investigated bus stop impacts on vehicle traffic by collecting field data and using statistical models to find the relationship between the impact and bus related parameters such as frequency and dwell time (Kwami et al., 2009, Ben-Edigbe and Mashros, 2011). The wide range of characteristics related to bus stops is normally very difficult to collect in the field so traffic simulation has commonly been used to analyse traffic flow at and around bus stops (Fitzpatrick and Nowlin, 1997, Koshy and Arasan, 2005). Parameters typically assessed include dwell time, bus frequency, bus stop location, bus stop type, number of road lanes and components of heterogeneous traffic flow. Results of traffic simulation research has found that curbside bus stops tend to have a much higher impact on vehicle traffic flow than bus bays.

In terms of measuring the impact of bus priority on traffic congestion, particularly the provision of exclusive bus lanes, several studies have been undertaken (Shalaby, 1999, Currie et al., 2007, Arasan and Vedagiri, 2010). Shalaby (1999), with the help of the TRANSYT-7F simulator, examined changes in the performance measures of through buses and adjacent traffic following the introduction of reserved bus lanes in an urban arterial in downtown Toronto, Canada. He found that the bus lanes resulted in an increase in bus ridership while adjacent traffic volumes showed a reduction. Currie et al. (2007) developed a comprehensive methodology to evaluate tradeoffs in the use of the limited road space in Melbourne, Australia for new bus and tram priority projects. Under this methodology, traffic microsimulation was used to assess the impact of road-space reallocation, while changes in travel patterns were assessed through travel behaviour modelling. Arasan and Vedagiri (2010) applied microsimulation techniques to explore the impact of reserved bus lanes on the flow of highly heterogeneous traffic on urban roads. They found that the addition of exclusive bus lanes contributes to a 3–8% increase in travel time of other vehicles on the road network.

Studies investigating the network-wide congestion effects of buses have been limited to date. One study using models to simulate and assess the congestion relief impact of buses on the entire road network was conducted by Aftabuzzaman et al. (2010b). This research assumed that a proportion of bus users would divert to cars if the bus system is removed. From secondary research, they found that, on average, 32% of all public transport users would shift to car. This fixed value was adopted for bus trips and applied to a transport network model in Melbourne to estimate the congestion relief impact of bus operations. The contrast between congestion measures obtained from two scenarios, 'with bus' and 'without bus', was considered to represent the amount of avoided congestion associated with buses. They found that Melbourne's bus operations contribute to reduce the number of congested road links by approximately 13% and total vehicle travel delay by nearly 37%.

2.1. Gaps in knowledge

While there has been several attempts to explore the congestion impacts of buses on a road link or a corridor, little is known about the network-wide impact of buses on traffic. Indeed, the operation of buses not only affects adjacent links but also results in traffic volume changes in surrounding areas due to traffic diversion and reassignment. To date, only one study has examined the network-wide effect of buses on reducing traffic congestion (Aftabuzzaman et al., 2010b). In this study, the mode shift from bus to car was