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Selecting tram links for priority treatments - The Lorenz Curve approach

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ABSTRACT

Road and public transport authorities often have a difficult task in deciding which road links to select for investment in preferential traffic and public transport measures to improve public transport service performance. This paper presents a new approach which adopts the economic concept of the Lorenz Curve to compare link performance in terms of transit operations as well as weighted passenger volume of travel. The paper explores if, and how, these metrics can be re-interpreted to help with targeting improvements for on-road public transport and priority mitigations. The approach collates operational performance data, in this case link speed and also link public transport travel volume to plot the cumulative distribution of link speed/ridership performance as a curve. Two sets of test applications are presented; on a route level basis and secondly a network level analysis. The network level results present the most powerful results with the Lorenz Curve analysis able to quickly identify links that justify greater attention for preferential treatments since they have the worst 20th percentile of operational performance but the highest 40th percentile of relative link ridership. Mapping shows the problem links to be busy routes leading into the central city. Implications for wider application of these methods are discussed.

1. Introduction

Public transport priority schemes are being increasingly adopted in cities internationally (Currie and Sarvi, 2013). They seek to improve transport efficiency of cities by providing preferential road space or additional intersection time to the benefit of public transport vehicles (buses or trams) because these vehicles carry greater volumes of passengers than the private car (University of Southampton, 2002). However a number of studies have now identified significant limitations in the methodological approaches to planning where the priority should be allocated (Currie et al., 2007). Tools are either highly prescriptive suggesting simple “warrants” for priority based on a limited range of single measures like bus movements (e.g. Kittelson and Associates et al., 2003, Kittelson and Associates Inc et al., 2013) or are overly complex requiring measurement of a large number of ridership, operations and traffic impact metrics using time consuming economic evaluation methods and numerous measures (DTLGR, 1997b, NCHRP, 2009). World practice in managing congested urban roads needs a simpler approach which includes important operational performance metrics but balances this against ridership volume measures.

This paper introduces a new approach to identify the preferred location of public transport priority treatments on transit networks and routes using operational performance and ridership demand measures.[1] It adopts the Lorenz Curve, a measure usually used in income economics, to explore the spatial distribution of the performance of bus or tram links and applies these methods to a case study of tram routes in Melbourne, Australia.

The paper is structured as follows: firstly a literature review of public transport priority treatments and warrants is presented. This is followed by a discussion of the Lorenz Curve. The proposed methodology is then described. Results are then presented followed by a discussion and conclusions.

2. Literature review

Public transport priority is a road design preferential treatment of road space allocation or travel time to improve the operational performance of public transport vehicles (Currie et al., 2007).

There are two main perspectives adopted when designing where to apply priority treatments; the ‘Road Management Perspective’, considering the road capacity and congestion of the shared road space and

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[1] This paper has been presented in a peer reviewed conference but not previously published in a research journal. The full citation of the conference paper will appear here in the final version of the paper. It is not published here to avoid the Double Blind reviewing problem

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the 'Public Transport Perspective' considering public transport operations issues and demand. Most published research focusses on road management perspectives.

Road Management Perspectives - Jepson and Ferreira (2000) reviewed guidelines for bus priority treatments and identified a range of warrants in the United Kingdom. UK warrants are conditional on the level of road congestion and the volume of buses. At high road congestion levels, lanes were considered justified only when there are very frequent buses. One warrant identifies a minimum criteria for priority at around 30–40 buses per hour (TRB, 1994). Vuchic (1981) states, that a bus lane is justified when the amount of people using public transport equals the number of people using cars in the remaining lanes. This concept can be 'warrantable' in high traffic conditions as long as vehicle capacities and occupancy are high and services very frequent.

Overall these types of warrants are simple to use but have unclear links to actual impacts on passengers in relation to the operational performance of public transport. They are simple to apply but rather simplistic in their construction. In most cases it is unclear why and how warrants of this kind have been determined.

The majority of studies with a public transport perspective (b.) focus on the design of individual measures and their impacts. Very little research explores approaches which help to decide where to allocate public transport priority.

One of the few tools the authors have identified where priority is allocated from the Public Transport Perspective, is a ranking model developed by consultants Aecom (2006) in Australia. This model is based on route segments and takes into account three factors:

a. Demand;
b. Strategic importance; and
c. Operational factors. e.g.: travel time, level of existing impendence and the intensity of service.

These inputs are then weighted by a degree of importance, but also matched by the service characteristic/context conditions (i.e. A.M. peak v. off-peak speed and P.M. peak v off-peak speed). Final results of this model were proven to match intuitive expectations.

A more complex assessment, including economic appraisal, can be found in the work of Currie et al. (2007). A cost benefit analysis of converting a traffic lane into a bus rapid transit lane was presented in a report by NCHRP (NCHRP, 2011). An evaluative approach was also reported in the UK (DTLGR, 1997a), however it is unclear how often these more complex approaches are used in practice. None of these approaches are feasible for a network-wide evaluation of where priority should be located and all are rather too complicated for more frequent day to day planning assessment. A simple set of measurements, which can be applied by planning authorities in a clear, open and comprehensive manner is needed.

However, overall, very few studies or methods consider where to allocate public transport priority from a public transport perspective.

2.1. The Lorenz Curve and the Gini Coefficient

The Lorenz Curve is a well-established economic tool typically used to describe inequality in the distribution of wealth and income in society. It was devised by an American economist Max Lorenz in 1905. The standard definition of the Lorenz Curve proposed by Gastwirth (1971) is derived as a function of the cumulative proportion of ordered individuals $L(y)$ against the corresponding cumulative proportion of "interest variable" (such as income) $F(x)$:

$$L(y) = \frac{\int_0^y x \, d \, F(x)}{\mu}$$

Where μ is the average of the interest variable (Silber, 1999, Damgaard, 2016).

Graphic representation of Lorenz Curve is a chart (Fig. 1) displaying the cumulative proportion of a population on the horizontal axis and a cumulative distribution function of the "interest variable" on the vertical axis, both quantities are presented as percentages (Ahmad-Kiadaliri et al., 2011). If the cumulative distribution values are perfectly aligned with the cumulative distribution of population, the Lorenz Curve results in a 45 degree straight line that is known as the 'line of equality'. The area between the Lorenz Curve and the line of equality is a measure of the discrepancy between the income and population distributions (Frees et al., 2014).

The graph in Fig. 1 shows an example of Lorenz Curve in comparison to the line of equality. The red and green lines cutting in at the bottom and top of the Lorenz Curve demonstrate selected aspects of the distribution. Line A crosses the Lorenz Curve where 50% of Population earns only 10% of the shared Income. Line B crosses the Lorenz Curve at the point where the last 10% of the Population earns some 38% of Income. By exploring these aspects of the distribution it is possible to better understand how variable the distribution of income is.

The area between the straight line of equality and the Lorenz Curve is also known as Gini Index or Gini Coefficient, developed by Italian statistician Corrado Gini in 1912 (Sen, 1998, Frees et al., 2014, Damgaard, 2016).

$$G = \frac{\sum_{i=1}^{n} (2\,i - n - 1) x_i'}{n^2 \, \mu}$$

Values of the Gini Coefficient are between 0 and 1, the higher the Gini Coefficient; the more unequal is the distribution of the studied. This is a potentially powerful value since it indicates the variability of inequality (or distribution) as a single number for a large dataset.

The idea of using the Lorenz Curve and the Gini Coefficient in other fields outside of economics is not new. A number of applications can be found in the spatial sciences. For example Knowles (1981) used the Lorenz Curve to analyze the spread of political representation in Norway. Minnich and Chou (1997) used the Lorenz Curve and the Gini Coefficient to evaluate the distribution of large wild fires. Ahmad-Kiadaliri et al. (2011) utilized the measure to identify the distribution

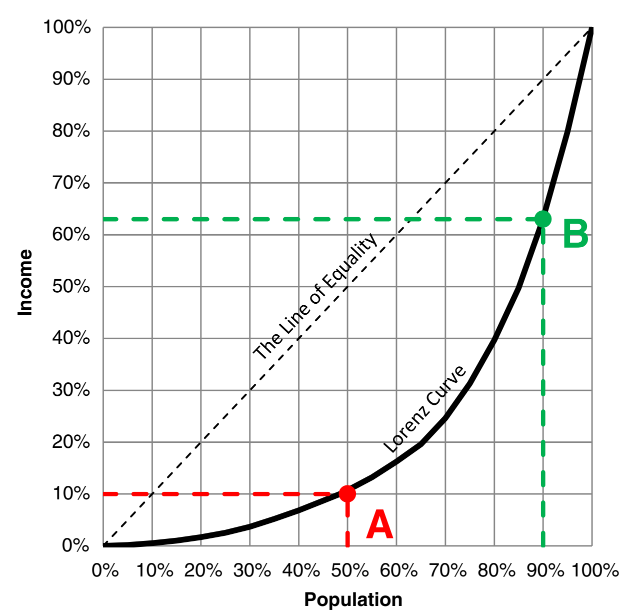

Fig. 1. The Lorenz Curve in income economics.