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Evaluating the impacts and benefits of public transport design and operational measures

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ABSTRACT

Design and operational measures are designed and implemented to improve public transport performance and level-of-service. In the case of urban bus systems, priority, operational and control measures are aimed to elevate bus services to buses with high level of service (BHLS). Even though there is an explosive growth in design and operational measures implementation and growing research interest in investigating their impact on performance indicators, there is lack of a systematic evaluation of their benefits. We present an evaluation framework and a detail sequence of steps for quantifying the impacts of public transport design and operational measures. The effects of service performance on travel times and costs are assessed by accounting for relations between reliability and waiting times, crowding and perceived travel times, and vehicle scheduling and operational costs. The evaluation integrates the implications of reliability on generalized passenger travel costs and operational costs. We deploy the proposed evaluation framework to a field experiment in Stockholm where a series of measures were implemented on the busiest bus line. The results suggest that the total passenger and operator benefits amount to 36.8 million Swedish crowns on an annual basis. The overall assessment of the impacts of design and operational measures enables the comparison of different implementations, assess their effectiveness, prioritize alternative measures and provide a sound basis for motivating investments.

1. Introduction

Policy makers and transport planners design and implement a large range of design and operational measures aimed to make public transport a more attractive travel alternative. These measures are designed to reduce travel times and improve service reliability. Reliability is crucial for both passengers and operators since a reliable public transport service leads to operational efficiency gains, improves users' satisfaction and their loyalty and potentially attracts new users (Perk et al. 2008). A synthesis of evidence from Europe, North America and Australasia by Currie and Wallis (2008) concluded that the largest increase in ridership was related to design and operational measures that targeted improving reliability.

A substantial introduction of bus priority measures will result with buses of high level of service (BHLS) which have shown an explosive growth in the last decade (Hidalgo and Gutierrez 2013). BHLS often serve a function between regular urban bus and light rail train in European cities in terms of their position in network hierarchy, right-of-way, capacity and the cost associated with their construction and operations. The Transit Capacity and Quality of Service Manual (TCRP 2003) provides guidelines for estimating the expected performance impacts of public transport design factors. While these guidelines are useful for substantiating design choices and benchmarking system performance, they do not allow estimating the overall benefits associated with design and operational measures.

Even though there is evidently a great interest in implementing public transport design and operational measures, there is lack of a systematic analysis framework of performing an ex-ante evaluation of their impacts. Results of design and operational measures are often reported in terms of ridership and speed changes aimed to promote the transfer of best practices. In a review of primarily European BHLS schemes, Finn et al. (2011) stressed the importance of developing a structured impact analysis and post-implementation evaluation of the impacts of benefits of related measures. An overall assessment of their impacts will enable the comparison of different implementations, assess their effectiveness, prioritize alternative measures and provide a sound basis for motivating investments in such measures.

The primary objective of this study is to develop a systematic

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evaluation framework for quantifying the impacts of a combination of public transport design and operational measures which encompasses both operators and passengers' benefits. Travel time savings, reliability benefits and operational costs are evaluated in detailed in this paper. The approach taken in this study goes beyond measuring the improvements in vehicle and service performance by quantifying and monetarizing the operational and travel time savings associated with the implemented measures.

This paper empirically analyses the impacts of a package of design and operational measures by estimating the implications of reliability on the costs associated with the fleet operations and passenger travel time savings. The analysis is based on automated data collection which facilitates detailed performance monitoring and post-implementation evaluation. Design and operational measures can potentially influence several operators and passengers' cost factors and hence result with non-trivial global effects. For example, holding at stops prolongs dwell times for vehicle and on-board delay for passengers whilst potentially increasing service reliability and hence reduce passenger waiting time. The implications of such measures on vehicle scheduling and consequently operational costs often remain unknown because of the contradictory effects of mean vehicle trip time and its variability. A comprehensive analysis is thus needed to consider operators and passengers' perspective in order to evaluate the deployment of design and operational measures.

The remaining of this paper is organized as follows: we first review previous studies that evaluated the impacts of measures to improve public transport performance, focusing on their analysis method and performance indicators (Section 2). Then, the proposed framework for evaluating design and operational measures is described in detail – from data through performance metrics to costs (Section 3). A case study of a field experiment concerning a trunk bus line in Stockholm, Sweden, is presented (Section 4), followed by the results of applying the analysis framework to evaluate the benefits of this pilot study (Section 5). We then conclude with an overall assessment of the proposed approach, its limitations and suggest venues for future research (Section 6).

2. Literature review

The growing availability of automated data collection techniques and in particular automatic vehicle location (AVL) data enable researchers to analyze public transport operations and the determinants of service performance. Most commonly, the explanatory variable of vehicle trip times were analyzed in order to measure the importance of route attributes such as length, number of stops, passenger activity at stops and bus stop spacing (e.g. Berkow et al. 2009, Li and Bertini 2009,). The effect of driver heterogeneity on running times at the route-level was studied by Strathman et al. (2002) and Mishalani et al. (2008). Mazloumi et al. (2010) analyzed vehicle trip time variability and its relation to schedule adherence. While these studies shed light on the main determinants of public transport vehicle travel time, they do not allow assessing the impacts of design and operational measures.

The impacts of design and operational measures are either analyzed by conducting a before-after comparison of public transport performance indicators or by simulating public transport operations and investigating the expected effects. Simulation studies were often used to study the effects of real-time control strategies such as public transport signal priority (Chandrasekar et al. 2002), stop skipping (Sun and Hickman, 2005), holding (Cats et al. 2011) and short-turning (Tirachini et al., 2011). Performance indicators such as headway variability, passenger waiting times and on-board delays were compared for alternative set-ups and control strategy design based on simplified line representation. While simulation models allow testing and estimating the effects of a large number of scenarios, there is lack of empirical evidence on the impacts of control strategies, in particular when they are combined with other BHLS features.

Table 1 summarizes the analysis approach, design and operational measures considered, performance indicators and main findings for empirical studies of bus design and operational measures in the last fifteen years. It is evident that the impact of a large range of measures-including the introduction of bus lanes, public transport signal prioritization, smart card fare collection, limited-stop operations, articulated buses – were examined in previous studies. With the exception of Diab and El-Geneidy (2013), previous studies considered the impact of a single measure. Empirical studies were most commonly facilitated by AVL data, often supported by automatic passenger counts (APC) or automatic fare collection (AFC) to gain information on dwell times or passenger demand.

Most of the studies considered only vehicle-related performance metrics with vehicle trip time metrics been most commonly used, whereas effects on passenger travel time received less attention in the literature (Table 1). Moreover, even when both vehicle and passenger travel times were investigated, changes in selected performance metrics were investigated rather than monetarizing the benefits associated with the implemented measures, preventing the overall assessment of BHLS-related investments. While Tirachini (2013) monetarized the benefits of better fare collection on passengers time, operation cost and air pollution, he evaluated a single measure and travel times were estimated rather than deduced from automated data. Adopting a multi-criteria approach, Cascajo and Monzon (2014) performed an exhaustive assessment of BHLS-related measures, where the change in key performance indicators was aggregated based on normative judgment.

In line with previous studies that undertook an empirical post-implementation approach, this study develops an analytical framework that details a work process for evaluating the impacts of service improvement strategies. As described in the following section, the effects of service performance on travel times and costs are assessed by accounting for relations between reliability and waiting times, crowding and perceived travel times, and vehicle scheduling and operational costs.

3. Evaluation framework

The proposed evaluation framework constitutes a systematic process to quantify and assess the impacts of design and operational measures on service users and providers in monetary terms. This process comprises a sequence of steps as shown in Fig. 1. First, the change in vehicle performance is investigated through analyzing service speed and reliability metrics using AVL data. Design and operational measures are classified based on their consequences for vehicle time components: link-related (e.g. bus lanes, signal priority, elevated crossing), stop-related (e.g. docking guidance, boarding procedure) and operations and control (e.g. stopping pattern, holding strategy). These classes of measures are expected to impact running time between stops, dwell time at stops or both time components, respectively. Second, the operator and passengers' benefits are derived from the change in vehicle performance. Improvement in vehicle performance by delivering faster and more reliable service can potentially lead to a reduction in operational cost and passenger travel time. Quantifying the overall passengers' time gain or loss requires information on passenger demand patterns. This information can be retrieved from either APC or smart card data. Information on access and egress walking times can be retrieved from a travel survey or