Intelligent Transportation Solutions for Planning, Optimizing and Measuring Public Transport Performance

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Abstract

In recent years, the use of performance measures for transit planning and operations has gained a great deal of attention, particularly as transit agencies are required to provide service with increasing demand and diminishing resources. The widespread application of intelligent transportation systems (ITS) technologies in transit systems has opened the window for automating the generation of comprehensive performance measures. In Portland Oregon, the local transit provider (TriMet) has been on the leading edge of the transit industry since they implemented their bus dispatch system (BDS) in 1997. The BDS is comprised of automatic vehicle location (AVL) on all buses, a radio communications system, automatic passenger counters (APCs) on most vehicles and a central dispatch center. Most significantly, TriMet had the foresight to develop a system to archive all of its stop-level data that is then available for conversion to performance indicators. In the last decade TriMet has extensively used this system to generate performance indicators through monthly, quarterly, and annual reporting. TriMet currently generates a number of performance indicators, yet the road is still open to explore more opportunities beyond general transit performance measures. In particular, based on an analysis of one year of archived BDS data, this paper demonstrates the power of using visualization tools to understand the abundance of BDS data. In addition, several statistical models are generated to show the power of statistical analysis in conveying valuable and new transit performance measures (TPMs) beyond what is currently generated at TriMet or in the transit industry in general.

With increasing attention being paid to performance and financial issues related to the operation of public transportation systems, it is necessary to develop tools for improving the efficiency and effectiveness of service offerings. Transit service generally favors bus stop accessibility, sometimes based on past history and tradition rather than rigorous ongoing analysis at the stop level. It is generally held that bus stops are too close to one other on many routes, slowing bus operations and increasing operation expenditures. On the other hand, by reducing the number of stops, transit operators risk making their service inaccessible in perception and/or reality, which may lead to loss of patrons when bus stops are moved or distantly spaced to avert the problems associated with closely spaced stops. Bus stop spacing has been studied in the U.S., in which the optimal solution was an average stop spacing of 1,300 ft, in sharp contrast to the actual average spacing of 650 ft. Some other model was considering relationships among velocity, uniform acceleration/deceleration, and displacement, and among the average bus operating speed, headway, required fleet size, and potential system capacity. Also, in Portland an analysis of a corridor on which stop consolidation had been applied was conducted in order to measure the costs and benefits of such a program.

With the availability of high resolution archived stop-level bus performance data, it is shown that a bus stop spacing model, which is able to incoperate into transit operation agencies' tool box, can be generated and tested with the aim of minimizing the operating cost while maintaining a high degree of transit accessibility. In this paper, in order to find a reasonable number of stops along a bus route to minimize operation cost with the lowest impact on accessibility, two cost components are considered in the stop spacing model including passenger access cost and in-vehicle passenger stopping cost, and are combined and optimized to minimize total cost. A case study is conducted using one bus route in Portland, Oregon, using one year's stop-level archived BDS data provided by TriMet. Based on the case study, the theoretical optimized bus stop spacing is 1,200 feet compared to the current value of 950 feet. The paper discusses trade-offs and presents an estimate of transit operating cost savings and sensitivity on user cost based on the optimized spacing. According to a benefit/cost assessment, there is a potential for a $60,000 reduction in annual operating cost. Similarly, the entire bus system's operating cost can be evaluated. The theoretical stop spacing value is provided for planners and decision-makers as a powerful performance metric. Given the availability of high resolution archived data, the paper illustrates that this modeling tool can be applied in a routine way across multiple routes as part of an ongoing service planning and performance measurement process. It is envisioned that systematic use of these new visualization methods and TPMs can assist TriMet and any other transit agency in improving the quality and reliability of its service, leading to improvements to customers and operators alike.

Assignment under consideration of seat availability: An application to London's underground network

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Abstract

Congested transit assignment has recently attracted significant research attention. Especially, but not only, in large metropolitan areas problems arise for passengers during the peak hour. Firstly, passengers might not even get onto the service because of insufficient capacity and secondly, passengers might encounter significant inconvenience on the train or bus due to not getting a seat but having to stand in a very limited space. It is well known that passengers appreciate reliability as well as being able to sit on the service significantly. It is therefore reasonable to assume that capacity problems as well as on-board congestion both have an influence on passengers' route and departure time choice.

Within the group of frequency based transit assignment models the capacity constrained assignment problem has been addressed by various authors either by using various forms of an effective frequency model (e.g. Cepeda et al, 2006) or by using "fail-to-board probabilities" (Kurauchi et al, 2003; Schmöcker et al, 2008). Within the group of schedule-based assignment models the departure time as well as route choice model under consideration of congestion have been addressed simultaneously. In particular Tian et al (2007) describe a schedule-based transit model that considers congestion effects including seat availability. Their model is however only applicable for a many-to-one network. Recently Sumalee et al (2008) have developed a stochastic transit assignment model that explicitly considers the effect seating availability on route choice as well as departure time choice. They consider priorities of on-board passengers over newly boarding passengers and further assume that passengers who have stood for a longer time and/or are travelling further have a higher motivation in chasing any free seats. The model is tested on a small example network, illustrating the effects of explicitly modelling standing and seating passengers on the service performance as well as the overall costs for passengers.

Questions remain however, whether the Sumalee et al (2008) model is feasible to be used for large scale networks in which specific modelling of each service run including a simulation to allocate each passenger to either a vacant seat or to be standing might be too computationally expensive. This paper proposes a simpler model to be used within frequency based assignment. The model proposed here introduces a "fail-to-sit" probability (similar to previous publications considering "fail-to-board") in order to be able to consider the influence of seat availability on passengers route choice in large scale transportation networks. The main idea of the approach is illustrated in Figure 1.

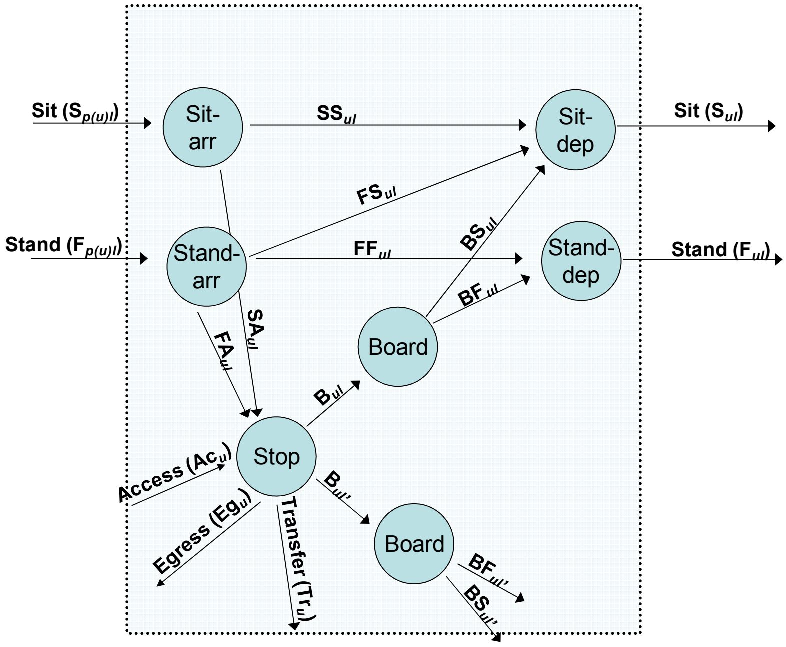

Figure 1 Network representation of a single platform

The stop node represents the bus stop or platform at which passengers wait for the service to arrive. From each stop node passengers might be able to board several services. It is assumed that the common lines problem applies so that the hyperpath minimising passengers expected travel cost might contain non-zero boarding probabilities for several boarding nodes. For simplicity Figure 1 only illustrates the nodes and links associated with a single line. Besides the stop node in total 5 nodes and 8 arcs are associated with each line. The names of the nodes are self-explanatory. The S within the arc names stands for *success* or *seating* whereas the F is used to describe *failing* (to sit). The eight arcs types are hence, SS: "keep sitting" (success + success), FF: "keep standing", FS: "previously standing getting a seat", BS: "board and sit", BF: "Board and stand" and SA: "Sit and alight", FA: "Stand and alight" and B: "Boarding". Besides these line specific arcs at each stop node there might be a number of further walking arcs for passengers transferring to other platforms as well as access and egress arcs for passengers starting or ending their journey at this station.

For simplicity the model presented here assumes that all passengers wishing to board a service are able to do so meaning that the capacity of standing arcs is not limited. Therefore, once a service that is within the set of attractive lines has arrived the passenger only faces uncertainty whether it is possible to find a seat. It is assumed that all passengers prefer to sit. This is expressed as the path split between successful transferring to the *Sit-dep* node or (unsuccessfully) transferring to the *Stand-dep* node. The passengers who are already on board are assumed to have priority over the newly boarding passengers in two ways: Firstly, passengers arriving at the station at the "Sit-arr" are guaranteed a seat, so that they either alight or remain seated. Secondly, passengers from the "Stand-arr" who do not alight are further assumed to have priority over the passengers newly boarding, i.e. these passengers have a prior c hance to occupy any seat that might become vacant through alighting passengers. These priority rules can be expressed as follows:

$$seat_l \geq x_{Sit_{ul}} \quad , \quad \forall u \in U_l,\ l \in L \qquad (1)$$

$$\begin{aligned} x_{S_{ul}} &= x_{SS_{ul}} + x_{FS_{ul}} + x_{BS_{ul}} \\ &= x_{SS_{ul}} + \left(1 - q_{FS_{ul}}\right)\left(x_{F_{p(u)l}} - x_{FA}\right) + \left(1 - q_{BS_{ul}}\right)\left(x_B\right) \end{aligned} \quad , \quad \forall u \in U_l,\ l \in L \qquad (2)$$

$$x_{F_{ul}} = x_{FF_{ul}} + x_{BF_{ul}} = q_{FS_{ul}} x_{F_{i(u)l}} + q_{BS_{ul}} x_B \quad , \ \forall u \in U_l, \ l \in L \qquad (3)$$

$$q_{FS_{ul}} := 1 - \max\left(0, \min\left(\frac{\left(seat_l - x_{SS_{ul}}\right)}{\left(x_{F_{i(u)l}} - x_{FA_{ul}}\right)}, 1\right)\right) \quad , \ \forall u \in U_l, l \in L \qquad (4)$$

$$q_{BS_{ul}} := 1 - \max\left(0, \min\left(\frac{\left(seat_l - x_{SS_{ul}} - x_{FS_{ul}}\right)}{x_{B_{ul}}}, 1\right)\right) \quad , \ \forall u \in U_l, l \in L \qquad (5)$$

where $x_{i,ul}$ denotes the flow on arc i of line l at station u. Eq (1) ensures that the overall seat availability of the service is not exceeded. Eq. (2) and (3) describe the flows of the passengers leaving the station sitting and standing respectively. To ensure the seat capacity constraints are kept the probabilities describing the chance of not getting a seat for those who were standing $\mathbf{q}_{FS}$ at arrival and those newly attempting to board $\mathbf{q}_{BS}$ respectively need to be adjusted. These adjustments are done with Eq. (4) and (5), which imply that at equilibrium either at least $\mathbf{q}_{BS}$ is non-zero or there are still spaces available at the departure of the service.

The perceived travel time of passengers standing is assumed to be higher than the travel time of passengers sitting. This means that the probability of getting a seat is one factor in the passengers route choice. The hyperpath search algorithm used in this paper is similar to the one used in Kurauchi et al (2003). The full paper will describe a solution to the deterministic assignment problem which can be formulated as a fixed point problem and results will be illustrated with London data. Extensions of the model to consider “fail-to-sit” as well as “fail-to-board” probabilities are further straightforward and will be discussed as well as other extensions and applications of the presented model.

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Governance in Railway Systems

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Abstract

Governance in Railway Systems combines two brand-new analytical frameworks to compare European rail networks. The paper, which takes into account the entire set of institutions involved in running a rail network, goes beyond existing research, which is mostly limited to cost structures and economic models. Furthermore, the paper examines various structures of “bound governance”, where public bodies, regulators, operators or manufacturers work and interact according to largely undisputed rules. Preliminary findings suggest that railway networks are more successfully run when bound governance prevails, as little energy is lost in rule-disputing and hierarchical or behind-the-scenes, power-based governance. Consequently, this paper introduces a new model of governance structures, leaving behind the entrenched positions in the debate over the separation of infrastructure and train operations. It argues that the main concerns of railway reform involve not the separation of infrastructure operators and train operators but the separation of strategic authorities and the operating companies. Five case examples – from the United Kingdom, Germany, France, Sweden and Switzerland – have been selected to reflect a large but still comparable variety of governance options. In its preliminary conclusion, the paper finds that the UK’s massive legislative and administrative efforts are an example of successful bound governance, as are Switzerland’s well-established separation of government strategy and rail operations. The paper is highly critical toward the current (on hold) German rail privatisation plan, which includes no clear separation of responsibilities between the government and the Deutsche Bahn.