What factors determine the variability of the level of service experienced by transit users?

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Understanding how public transport travellers make their decisions (in terms of mode, departure time and route choices) is essential in transport planning. Demand models have been usually structured around traditional variables such as fare and travel time. However, service reliability has increasingly been identified as a key element of travel behaviour (Engelson & Fosgerau, 2016; Fosgerau, 2016). For example, in The Netherlands some measures of service reliability have been incorporated in public transport planning models, based on the premise that reliability reveals the difference between travellers' expectations and experiences (Kouwenhoven et al., 2014). At least three elements are needed to incorporate reliability in a demand model: a monetary value for reliability (VOR), a model that can predict the reliability level of a service based on the context in which it will operate, and a model predicting the marginal impact of reliability indicators on users' decisions (Kouwenhoven, 2015). For the second element, this is, to predict the reliability level of a service based on its context, it is necessary to understand which are the circumstances and variables that affect the level of variability of a public transport service and how.

In Santiago, Chile, lack of travel time reliability (mostly through waiting time) is one of the main complaints about public transport. To address this issue, several reliability performance indicators were included in the private bus company contracts, but they have addressed limited noticeable changes. This work will explore the roots of unreliability for the case of Transantiago, the public transport system of Santiago, to understand the main causes of its poor performance in this issue.

In users' dissatisfaction, waiting time is known to be weighted more heavily than the time spent inside the vehicle. Headways variability affects not just waiting time variability, but also its expected value. Indeed, given a sequence of bus intervals visiting a bus stop, the average waiting time can be expressed as

$$E(W) = \frac{1}{2} E(h) \left(1 + CV(h)^2\right)$$

where $E(W)$ is the expected passenger waiting time, $E(h)$ the mean bus headway, and $CV(h)$ the coefficient of variation of headways. If buses visit the stop at regular intervals, this last term would be zero and the waiting time would take its minimum value, i.e. half of the average headway. Thus, the difference between E(W) and this minimum waiting time is denoted as the excess waiting time and it is due to an unreliable service.

Headway variability may be affected by many elements of the context in which a bus service operates. In this work, we propose a linear regression to explain headway variability in terms of a set of attributes of the service.

The dependent variable selected is the coefficient of variation of headways since it is directly related with excess waiting time. For each bus service operating in Santiago and every stop each of them visits we compute the *CV* of the headways over 30 minute periods. We chose the CV as the main reliability indicator, but we also calibrate models for other dependent variables as the headway variance, standard deviation, and the percentile difference with the mean.

The independent variables considered for our model are grouped in three categories: street, route and bus characteristics. This information is obtained from Automated Vehicle Location data, Automatic Fare Collection data, and other available sources. Regarding street characteristics along the route, we considered the impact of exclusive lanes and segregated lanes, as well as the number of traffic lights between two consecutive bus stops. Route characteristics are those related to the service design, considering traveller's trip length, frequency, distance and number of stops from the head of the service to the stop, bus company, type of service (express or all-stop), time period, passenger demand, off-board payment stop and route congestion. We also considered the size of the bus, which determines the number of doors and capacity. To avoid autocorrelation between two consecutive stops, the headway variability index measured at an upstream stop is also included as an independent variable. This allows us the model to explain only the headway variability induced within both stops, and not the variability occurring elsewhere upstream in the route.

To evaluate the forecasting capability of the resulting model, a validation process will be conducted. For this purpose, a subset of the available data will not be used in the calibration process. This validation data will be used to compare the observed and predicted reliability indicators, computing the mean error, mean squared error and the mean absolute error. This process will allow us to assess if this type of models could be used in the evaluation of a public investment project.

Preliminary results show that, as expected, upstream disturbances have a significant effect on the service regularity at downstream bus stops. Traffic congestion and occasional stops, explained by the mean velocity and its standard deviation respectively, showed to be significant too. Finally, the variables related to special infrastructure, such as segregated corridors and off-board payment zones, exhibited a low significance level due to the presence of endogeneity. By correcting this issue, those variables revealed a significant and positive impact in the performance of the system.

The contribution of this work is the calibration of a predictive model, able to estimate changes in reliability of a public transport service, induced by a given project. For example, it will be possible to predict the impact in reliability of segregating a bus lane or equipping a set of bus stops with off-board payment systems. This way, projects with limited impact in average travel time, but which reduce headway variability, may justify their implementation. Currently, there is no methodology available for cost-benefit analysis to evaluate the benefits of a transport project that affects headway variability significantly. Thus, the proposed model will not only be novel, but also quite useful.

Keywords: Regularity, Headway, Public Transport, Reliability, Transantiago, Coefficient of Variation

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