Decomposing journey times on urban metro systems via semiparametric mixed methods

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Abstract

Journey times on metro systems consist of the following components representing the different stages of a typical passenger journey: access time from the entry to the origin station platform, platform wait time, on train time, interchange time (if required), and egress time from the destination station platform to the exit. Subject to the demand levels, service conditions, and individual passenger behaviour, there can be high levels of variance in travel times within each component of the journey.

The aim of this paper is to determine the underlying drivers of journey time variance via regression analysis, using the key physical and operational characteristics of metro systems as covariates. The results will then be used to recommend measures that can be taken to improve journey time performance. The findings can also be applied to improve travel time valuation estimates, used as inputs in the economic appraisal of transport projects.

Existing work in the field has largely focused on developing descriptive measures of journey time performance. Indicators to measure the spread of journey times, including the Reliability Index and the Reliability Buffer Time have been well documented (Chan, 2007, Uniman, 2009, Schil, 2012). A limited number of analytical studies, however, do exist: Polus (1979) and Taylor (1982) investigated linear relationships between measures of journey time variance and the time of day, length of route, and congestion for road, metro and bus travel. El-Geneidy and Vijayakumar (2011), El-Geneidy et al (2011) and Ma (2015) also used linear models to analyse the relationship between journey times on buses and variables including time of day, weather, route length, number of stops, and passenger loadings.

The imposition of linear relationships may omit key information about the relationship between variables. To enable the investigation of more flexible, non-linear relationships, we will use semiparametric regression methods which have not been previously applied in this field of research. We make use of a detailed data set comprising of a combination of train movement, station infrastructure, and smart card transaction data from the London Underground. To our knowledge, this combination of data has not been previously used, and it will enable a more thorough level of analysis of metro journey times than previously possible.

The regression model framework comprises of the following:

- Response variables

  - Journey time, disaggregated at a passenger level for each possible origin-destination (OD) pair on the network. A total of 72,900 unique OD pairs will be analysed.
  - Journey time variance, disaggregated at a passenger level for each possible origin-destination (OD) pair on the network over 15 minute time intervals.
- Covariates:
  - Passenger demand/congestion
  - Line specific characteristics
  - Station specific characteristics
  - Individual specific effects
  - Headway/frequency of service
  - Travel distance/number of stops
  - Speed of service
  - Dwell times
  - Interchange properties
  - Time of day

Elasticities of each covariate with respect to journey time and journey time variance will be derived. One of the key findings of the analysis is the elasticity of passenger demand with respect to journey time and journey time variance. These values will provide an understanding of how congestion effects journey time performance for the different OD pairs. Another important finding is the elasticities of individual stations; through comparison, stations that perform the best and worst with respect to journey time performance will be identified. Based on the results, recommendations on specific physical measures and operational strategies will to be made to improve journey times and journey time variance on the London Underground.

The above analysis focuses on journey times under regular operating conditions. Extensions to the regression model presented in this paper in the future will involve the analysis of journey times under incident conditions.

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