PUBLIC TRANSIT SERVICE RELIABILITY ASSESSMENT USING GPS DATA

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INTRODUCTION

Many major metropolitan areas around the world, including the Greater Toronto Hamilton Area (GTHA), are currently trying to improve their public transit services for their citizens. Reliable public transit service is a key aspect of promoting the use of public transit services. The most popular indicator currently used to measure public transit service reliability is on-time performance (OTP) which simply measures how well a transit service keeps to the scheduled travel time. Many public transit service companies, including GO Bus, Metrolinx, use OTP as the main measure of their service reliability. However, OTP can easily be improved not by improving the operational level quality of the transit service, but by changing the scheduled travel times. For instance, a bus company can simply defer a scheduled transit arrival time to improve the OTP. This study suggests a new measure of transit service reliability based on a traffic flow theory known as the two-fluid model. We discuss the approach and summarize an outcome from a small-scale case study.

PUBLIC TRANSIT SERVICE RELIABILITY BASED ON TWO-FLUID MODEL

Herman and Prigogine (1979) developed a two-fluid model to evaluate traffic flow performance on urban street networks. The model quantitatively evaluates the performance of the urban street network using two parameters, $\boldsymbol{T_m}$ and $\boldsymbol{n}$. The two-fluid model assumes a curvilinear relationship between a vehicle's stop time and travel time per unit distance (Herman and Ardekani, 1984). The first parameter, $\boldsymbol{T_m}$, measures free-flow travel time per unit distance. It can be used to estimate free-flow travel speed. The second parameter, $\boldsymbol{n}$, is associated with a road network's resilience to increased traffic demand. A higher $\boldsymbol{n}$ on a route indicates that travel time on that route increases more quickly as the stop time increases than on a route with a smaller $\boldsymbol{n}$. This means that the travel performance of a route with a higher $\boldsymbol{n}$ deteriorates more quickly than on a route with a smaller $\boldsymbol{n}$ by the increased traffic demand (Dixit, Crowe, Radwan & Ramdatt, 2009).

Our study proposes $\boldsymbol{n}$ as a new indicator of transit service reliability. Our target road network is certain specified GO Bus routes. As far as we know, no previous study has applied a two-fluid model to evaluate public transit services.

DATA AND METHODOLOGY

Metrolinx supplied one day of GPS data (July 10, 2015) covering all GO Bus services in the GTHA. The data include the position (x and y coordinates) of all GO buses simultaneously every seconds, a total of more than 8M GPS records covering 3,545 trips and 73,890 stops. We selected only the AM peak data (roughly 7am to 9am) which resulted in 88 trips and 3,398 stops for 54 GO Bus routes.

Using this information, we estimated the stop time and travel time of each GO Bus travel per unit distance (1 mile) and calculated the two-fluid parameters ($\boldsymbol{T_m}$ and $\boldsymbol{n}$). Note that 1 mile was the most popular unit distance in previous studies that applied two-fluid model (Ardekani, 1984; Amini, Shahi & Ardekani, 1998;

Lee and Kwon, 2003; Jones and Farhat, 2004; Hong, Lee, Chung & Kho, 2005; Lee, Yu, Yoon & Sohn, 2005; Vo, Mattingly, Ardekani & Dilshad, 2007; Xiang, Jian, Jiancheng & Changqiao, 2007; Dixit et al., 2009; Jeong, Kim & Kim, 2009; Kim, Byun, Hong & Lee, 2009; Wu, 2009; Dixit, Crowe & Radwan, 2011).

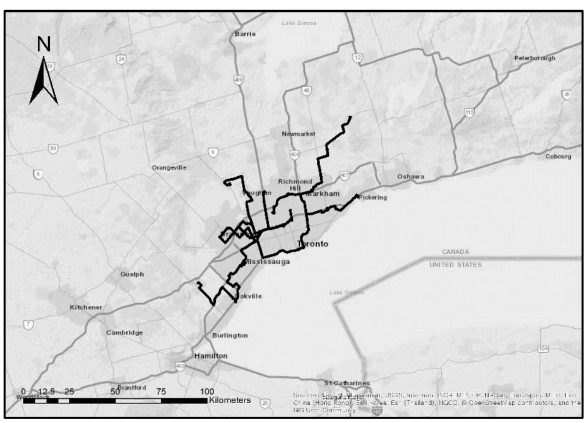
Note also that we used 4 km/hr or less as our cut-off travel speed for estimating the stop and travel times. In other words, a GO bus is considered to be moving if running speed faster than 4 km/hr (Amini et al., 1998; Hong et al., 2005; Vo et al., 2009; Xiang et al., 2009; Wu, 2009; Manuel, Kattan, Tahmasseby & Barros, 2018).

RESULTS OF ANALYSIS

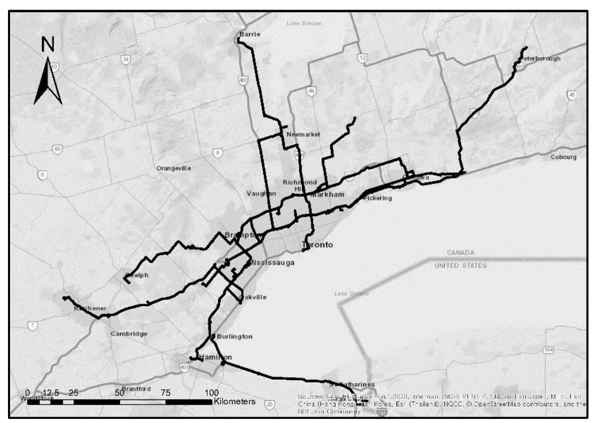
The average ***n*** estimate was 5.8 and the average $\boldsymbol{T_m}$ estimate was 62.7 (sec/mile). Our ***n*** value is somewhat larger than those of previous studies which usually ranged from 0.6 to 3.7. The $\boldsymbol{T_m}$ value of previous studies which usually ranged from 74.4 to 199.2 (sec/mile).

Our result can be explained by our $\boldsymbol{T_m}$ value. The $\boldsymbol{T_m}$ refers to the free-flow travel which is 91.9 km/h in our case. Go Bus routes in the GTHA includes express services across a city (rather than transit services within a city). These routes include high speed highways or even freeways where there few or no signalized intersections. As a result, we can expect to see high values of $\boldsymbol{T_m}$ and ***n*** compared to previous studies conducted mainly on arterials with frequent signalized intersections. **FIGURE 1** shows GO Bus routes classified by our estimated values of ***n***.

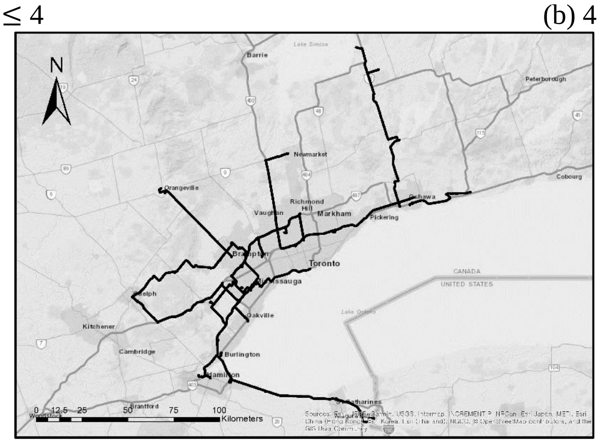
FIGURE 1. GO Bus Routes Classified by "n"



(a) n ≤ 4



(b) 4 < n ≤ 6



(c) 6 < n

The GO Bus routes with small ***n*** values (see examples in **FIGURE 1 a**) are the most reliable routes. These routes show the highest resilience to increased traffic during the AM peak hours. Routes with high ***n*** values (see examples in **FIGURE 1 c**) have the lowest resilience to increased traffic. The routes in **FIGURE 1 b** are the moderate routes in terms of the transit service reliability based on our proposed parameter.

We found a (weak) geographical pattern showing lower ***n*** values for GO Bus routes operating largely within or close to the boundary of Toronto. This may be due to different levels of infrastructure provided for different routes. Some GO Bus routes traveling in areas at a considerable distance from Toronto use two lane highways (one lane per direction) where the road may show less resilience to increased traffic demand.

CONCLUSION AND RECOMMENDATIONS

This study investigated the possibility of using the two-fluid model parameter ***n*** as a new measure of public transit service reliability. We note, however, that we are not proposing that ***n*** should be a complete replacement for an existing reliability indicator such as OTP. OTP has some obvious advantages. It is easy to calculate and interpret for public transit suppliers and users. Nonetheless, we think that the two-fluid parameter ***n*** can provide additional insights into public transit service reliability as it can show the impact of increased traffic on a bus route which OTP cannot do.

Future work will need to investigate the relationship between OTP and two-fluid model parameters. Future work will also need to investigate the impact of various route characteristics on two-fluid model parameters. Route characteristics could include, for example, the number of signalized intersections per route, the length of roadway providing interrupted and uninterrupted traffic flow, and the total number of passengers boarding and alighting from the transit vehicle.

We hope that the proposed new measure of public transit reliability can provide additional insights for bus service providers and that service providers will find the measures useful contributions to improving transit service reliability by making it easier to plan better routes and better scheduled stop times.

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