Identifying congestion bottlenecks with automated vehicle location systems: an application in Transantiago

Christopher Bucknell
Centro de Desarrollo Urbano Sustentable (CEDEUS), Pontificia Universidad Católica de Chile
Email: cpbuckne@uc.cl

Juan Carlos Muñoz
Departamento de Ingeniería de Transporte y Logística, Pontificia Universidad Católica de Chile
Centro de Desarrollo Urbano Sustentable (CEDEUS), Pontificia Universidad Católica de Chile
Email: jcm@ing.puc.cl

Matías Navarro
Centro de Desarrollo Urbano Sustentable (CEDEUS), Pontificia Universidad Católica de Chile
Email: mns@ing.puc.cl

Sebastián Tamblay
Centro de Desarrollo Urbano Sustentable (CEDEUS), Pontificia Universidad Católica de Chile
Email: stm@ing.puc.cl

Alejandro Schmidt
Centro de Desarrollo Urbano Sustentable (CEDEUS), Pontificia Universidad Católica de Chile
Email: asg@ing.puc.cl

Jaime Moya
Centro de Desarrollo Urbano Sustentable (CEDEUS), Pontificia Universidad Católica de Chile
Email: jfmoya@uc.cl

Antonio Gschwender
Gerencia de Desarrollo, Directorio de Transporte Público Metropolitano
Email: antonioe.gschwender@dtpm.gob.cl
Introduction

One of the most important variables to improve in any bus system is commercial speed. The reason is two-fold. On the one hand, speed improvement is related with users’ travel time (in-vehicle travel time savings plus possible waiting time savings). On the other hand, it has a direct impact on the efficiency of the system. The same transport capacity can be given with a lesser fleet (with cost reductions), or more capacity can be given with the same fleet (hence the higher frequency, and therefore lower waiting time).

In order to improve the speed, one has to first monitor it. Most of the monitoring is focused on identifying the streets with the lowest speeds when done using massive AVL data. This is often done at an aggregated level, usually preventing to characterize the problem (exactly where and when it is happening) and to identify improvement thresholds (if the problem is solved, what speeds can be achieved?). Thresholds are important to be able to select projects with the highest return-over-investment, i.e., those that will be more beneficial for the system.

Automated data collection systems have created new opportunities to monitor and manage public transportation systems. This is the case of Transantiago (the integrated public transportation system of Santiago, Chile) where the software ADATRAP was developed to provide different insights about it. The two main outputs of the software are: reconstruction of trips based on smartcards used in buses and metro (Munizaga & Palma, 2012; Munizaga et al., 2014) and bus speed profiles (Cortés et al., 2011). The latter provides, for every bus service, commercial speeds every 500 meters (~0.3 miles) and half-hour periods.

We leveraged this new data to provide a disaggregated monitoring of the system, in order to (i) easily identify where and when problems happen and (ii) their respective improvement thresholds, through the identification of congestion bottlenecks. As stated in Thredbo (Munizaga & Sánchez-Martínez, 2015), the biggest challenge is to obtain enough value from this new data in order to increase tangible realized gains.

This paper develops a simple methodology to identify congestion bottlenecks with the information provided by ADATRAP in the case of Transantiago. Then, the methodology is applied to real data provided by the software, identifying as a result the worst bottlenecks of the system. Some of the bottlenecks that are identified with the proposed methodology are presented.
Methodology

This section first describes the data generated by ADATRAP and then the proposed algorithm to determine the worst bottlenecks in the system.

Data

Transantiago has a fleet of over 6,000 buses equipped with GPS devices providing position at regular 30-second intervals. This is the first dataset used for the speed estimation procedure. Also, bus routes (r; with a total of R) are used in order to project GPS pulses to rectified paths. Then, speeds are determined using definitions proposed by Edie (1965) for predetermined space cells (i; with a total of I) and timesteps (h; with a total of H) for each route. This creates an $I \cdot H$ element matrix for every route with speeds $s_{r,h,i}$ in each element. Each space cell $i$ has a length of 500 meters and each timestep $h$ has a length of 30 minutes.

Algorithm

The algorithm is a simple procedure that was implemented in PostgreSQL, and its structure is as follows:

For routes $r = 1$ to $R$; For timesteps $h = 1$ to $H$; For space cells $i = 2$ to $I - 2$

$$\text{if}(s_{r,h,i+1} - s_{r,h,i} \geq 5 \frac{km}{h} \text{ and } s_{r,h,i} \leq 20 \frac{km}{h}) \text{ then } \Delta_{r,h,i} = \min\left(20, \frac{s_{r,h,i+1}}{s_{r,h,i}}\right)$$

For each route $r$, timestep $h$ and space cell $i$ (except the first and the last two; since speed estimation at the boundaries is difficult to achieve with precision because of bus layovers) a parameter $\Delta_{r,h,i}$ is computed if (i) a bottleneck is present with a speed difference of at least 5 km/h between two consecutive cells and (ii) the cell in analysis has a speed lesser than or equal to 20 km/h. $\Delta_{r,h,i}$ calculates, for each route $r$, the relative speed difference between cells $(i, h)$ and cell $(i + 1, h)$, assuming a maximum speed of $(i + 1, h)$ of 20 km/h (otherwise, the relative difference increases notably). Therefore, $\Delta_{r,h,i}$ indicates the severity of the bottleneck.

Results

This section will show some results of the methodology using a week of selected data. Examples of the common type of problems that we found after site visits are: incorrect traffic signal timings, reduced capacity due to a high turn percentage of a lane or intersections with no priority.
Conclusions and perspectives

A methodology to identify congestion bottlenecks was presented based on the information provided by ADATRAP. This methodology was successfully used to identify the worst bottlenecks of the bus system of Transantiago.

Disaggregate information provided by automated data collection systems can be used to monitor the commercial speed of surface transportation, to easily identify when and where problems happen, identifying the worst bottlenecks of the system. Then, corresponding site visits can be scheduled in order to create a diagnosis.

In the future, the length of the queue can be incorporated into the methodology. We assume that the queue has a length of 500 meters and this is not necessarily true (the queue may be smaller or greater than this length). This affects how we measure the severity of the bottleneck. Also, a smaller disaggregation level will allow problems to be better identified and ranked. Finally, bus loads can be used to better prioritize bottlenecks identifying those with the highest hypothetical travel time savings.

References


