Transit Planning and Climate Change: Reducing Rider's Vulnerability to Heat

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Abstract

Public transit systems have been identified as a critical component to reducing energy use and greenhouse gas emissions associated with the transportation sector to mitigate future climate change impacts. A unique aspect of public transit is its use almost always necessitates environmental exposure and the design of these systems directly influences rider exposure via rider ingress, egress, and waiting. There is a tension between policies and programs which promote transit use to combat climate change and the potential impact an uncertain climate future may have on transit riders. In the American Southwest, extreme heat events, a known public health threat, are projected to increase between 150 and 840% over the next decade, and may be a health hazard for transit riders. There are opportunities to incorporate rider health risks in the overall planning process and develop alternative transit schedules during extreme heat events to minimize these risks. Using Los Angeles Metro as a case studies, we show that existing transit vehicles can be reallocated across the system to significantly reduce exposure for riders who are more vulnerable to heat while maintaining a minimum level of service across the system. As cities continue to invest in public transit it is critical for them to understand transit use as an exposure pathway for riders and to develop strategies to mitigate potential health risks

INTRODUCTION

Public transportation planning is a complex process that seeks to maximize the quality of service to users within agency budgets. Because these are two competing goals, tradeoffs need to be made and optimization techniques are frequently used to evaluate these tradeoffs (Guihaire and Hao 2008). In most cases, the goal of transportation agencies are not profit driven but their operations remain constrained by available budgets (Desaulniers and Hickman 2007). The public transit planning process can be divided into five steps: i) network design (route structure and stop placement), ii) route frequencies, iii) timetabling, iv) vehicle scheduling, and v) crew scheduling and rostering (Guihaire and Hao 2008). Each is a significant undertaking and is typically solved in sequence as separate optimization problems (Desaulniers and Hickman 2007). For a complete description of these steps and a description of the inputs, constraints and objectives of each, see Guihaire and Hao (2008). This analysis focuses on Step II and developing new route frequencies for the Los Angeles Metro (LA Metro) local bus system to reduce exposure during periods of extreme heat.

The time spent waiting for transit, which is inversely related to route frequencies, may increase the risks of negative health outcomes for transit riders during periods of extreme heat. As a public service, transit agencies should be sensitive to the increased health risks passengers may experience during extreme weather events. This case study analyzes existing schedules for LA Metro's local bus system and uses optimization to alter scheduled frequencies to reduce exposure for vulnerable transit riders.

Los Angeles Metro Heat Frequency Case Study

LA Metro ranks among the top five public transit systems in the United States for total transit vehicles operated, revenue kilometers, revenue hours, unlinked passenger trips, and passenger kilometers (APTA 2015). Between bus and rail service, the system supports approximately 1.4 million unlinked daily trips (weekday) originating from 16,047 transit stops and covers a service area of 3,711 square kilometers as of 2015 (LA Metro 2015). LA Metro, like other transit agencies, develops service frequencies from time-dependent estimates of demand and bus passenger capacities. LA Metro's frequencies vary throughout the day and during peak periods bus frequencies are as high as 10 times per hour for high demand routes. These high frequency routes typically follow major arterials. During off-peak times frequencies are typically reduced and some routes are even taken out of service. Due to demand based service, transit riders using the system during off peak periods likely experience longer waiting times than those who use transit during peak periods. Coincidently, off peak hours during 1pm to 3pm can be some of the hottest hours of the day (Figure 1).

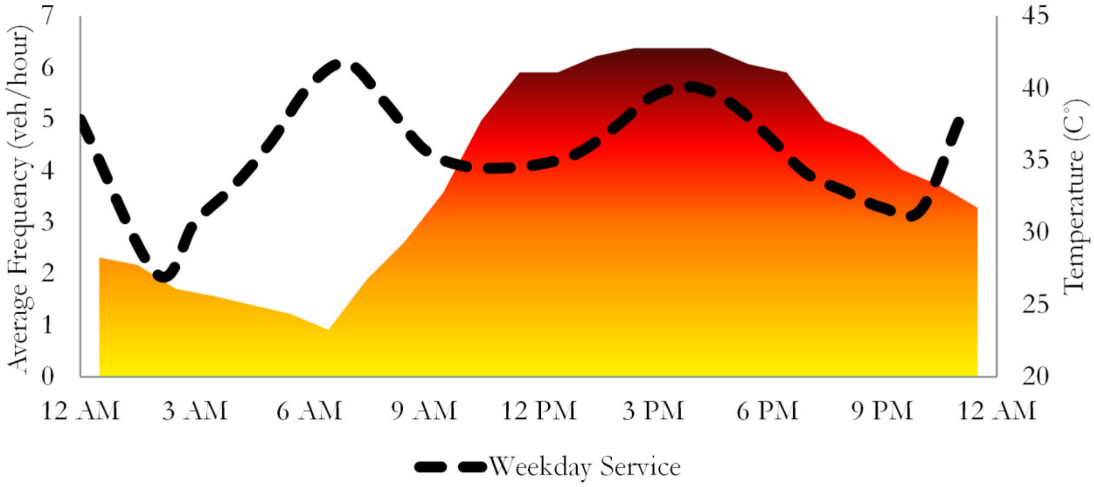

Figure 1 Average Transit Frequency and Daily Temperatures.

The dotted lines depicts average frequency across all active local routes by time of day and the shaded background shows ambient air temperature during an extreme heat event (September 27, 2010)(NCDC 2016). Demand-based scheduling reduces waiting times during peak periods. Waiting times are longer between the hours of 9am and 3pm when outdoor temperatures exceeded 43 C°

A simple solution to reducing waiting times during extreme heat events would be to increase frequencies along all routes. However, given budget constraints, this type of solution is infeasible. A methodology is developed to reduce health risks for vulnerable transit riders by altering transit frequencies without increasing the costs for the transit agency.

METHODS

This case study develops new frequencies for all weekday LA Metro local bus routes operating between 2pm and 3pm. This time slot was identified as an off peak time where service frequencies are low on a number of a routes and temperatures are expected to be near daily maximums. General transit specification data for LA Metro was used to determine existing transit frequencies and the total number of vehicles beginning operation during this time period (LA Metro 2015).

Determining Transit Rider Demand Potential

Detailed time-dependent demand is the most difficult data requirement to obtain for developing transit frequencies. Transit agencies rely on on-board surveys and statistical forecasting to generate time-dependent origin-destination matrices. Due to the expense and effort required to generate system wide demand estimates, transit agencies are often reluctant to share these data (Guihaire and Hao 2008). For this assessment, rider demand was estimated using the American Community Survey which details transit use among workers. For Los Angeles census tracts, potential transit demand is estimated based on the relative use of public transit among resident workers and the general population of the census tract (USCB 2015).

Rider Heat Vulnerability

Relative heat vulnerability scores are developed for each census tract. The scores are based on the principle component that was found to be the overall best predictor of both all-internal causes and heat related deaths during periods of extreme heat (Figure 2) (Eisenman et al. IN REVIEW).

Transit Route Weights

Individual transit routes are weighted based on total ridership demand potential and ridership vulnerability. GIS tools developed by Morang (2016) are used to develop shapefiles for LA Metro transit routes and stop locations (Figure 2). Routes are assigned weights that are equal to the sum of the transit demand potential multiplied by heat vulnerability for all census tracts served by the transit route (Eisenman et al. IN REVIEW).

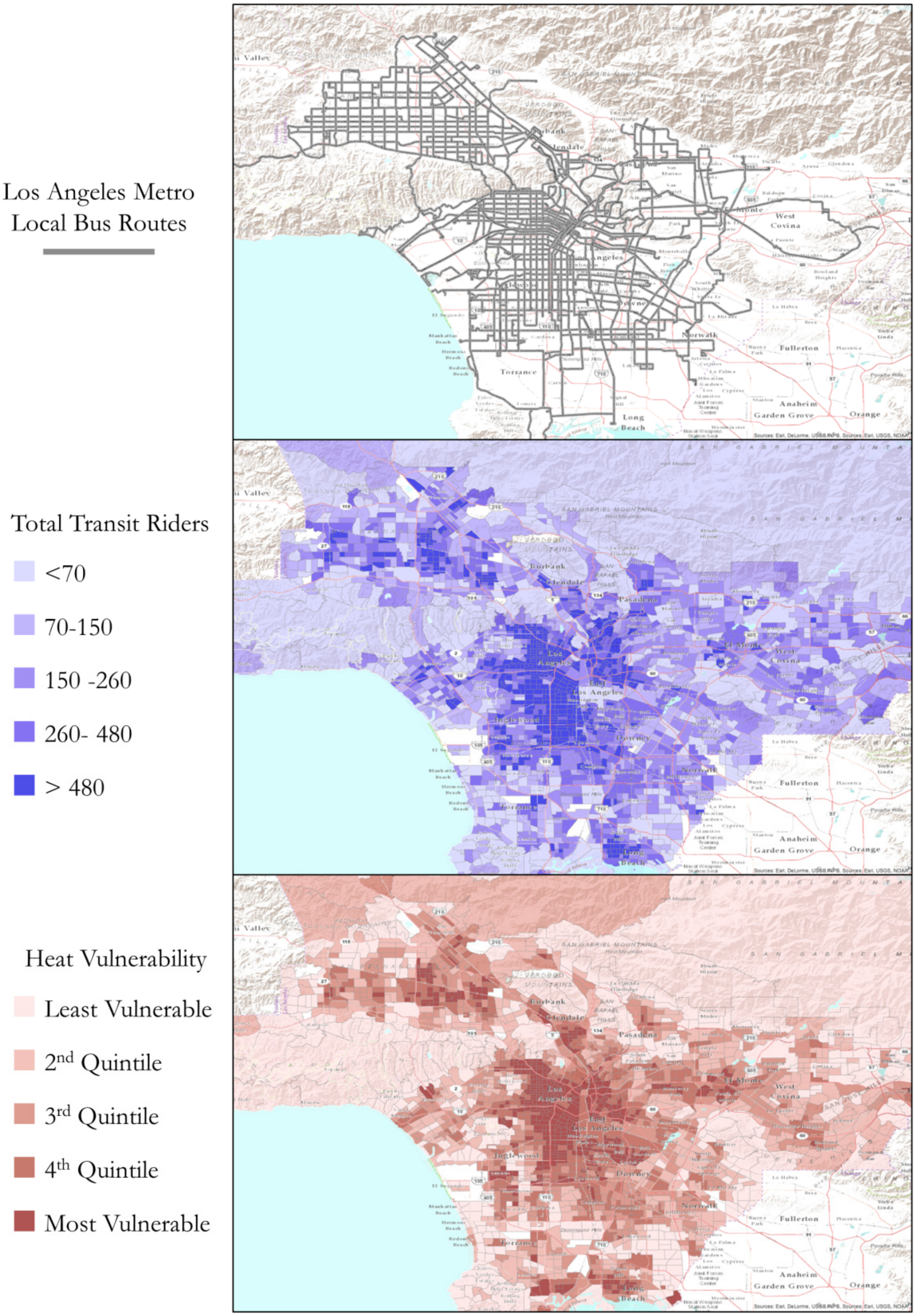

Figure 2: LA Metro Local Bus Routes, Potential Ridership Demand, and Heat Vulnerability

Optimization Framework

An integer programing based optimization model is used to determine new transit frequencies and is defined below:

$$Min \sum_{i} \sum_{j \in C_i} \overline{W_i}(f_i)\, D_j V_j$$

$$S.T. 1) \sum_{i} f_i < B \qquad 2)\ \frac{f_{i_0} Lf_i}{f_i} \leq M\ \forall i \qquad 3)\ 1 \leq\ f_i \leq N,\ \in Z\ \forall i$$

$Where: i = Transit\ route \overline{W_\iota}$

$(f_i) = Average\ waiting\ time\ for\ route\ i\ as\ fucntion\ of\ frequency\ of\ i$

$C_i = The\ set\ of\ census\ tracts\ served\ by\ transit\ route\ i$

$D_j = Transit\ demand\ in\ census\ tract\ j\ (\#\ of\ Transit\ Riders)$

$V_j = Heat\ vulnerability\ of\ census\ tract\ j$

$f_i = Frequency\ of\ route\ i\ \left(\frac{vehicles}{hour}\right)$

$B = The\ total\ number\ of\ buses\ currently\ opperating$

$f_{i_0} = Current\ frequency\ of\ route\ i\ \left(\frac{vehicles}{hour}\right)$

$Lf_i = Average\ load\ factor\ for\ route\ i\ \left(\frac{total\ passengers}{seats}\right)$

$M = Maximum\ allowable\ load\ factor \left(\frac{total\ passengers}{seats}\right)$

$N = Maximum\ allowable\ frequency\ (\frac{vehicles}{hour})$

Constraint 1) limits the total number of buses that can be assigned to all routes to those that are currently scheduled for service. Constraint 2) ensures that there is sufficient capacity to meet existing demand based on current load factors. The maximum average load factor for weekday service in Los Angeles is 1.42 (LA Metro 2016). Constraint 3) ensures that at least one vehicle runs along all routes that currently have service, limits the total vehicles servicing each route to 10, and only allows integer values to be assigned.

RESULTS

The routes serving the greatest vulnerable demand are those that serve the center of LA Metro's service area. The West Los Angeles, Mid-Wilshire, Mid-City West, Mid-City, West Adams, and Crenshaw neighborhoods are some of the most heat vulnerable neighborhoods in Los Angeles. These neighborhoods are in close proximity to downtown and are served by a large number of routes which currently operate at mid to high frequencies. Additionally, some of the routes that serve central part of Los Angeles are long routes that crisscross the LA Metro system which contributes to their high overall demand weight (Figure 3).

The 736 local buses beginning operation between 2 and 3pm are reallocated across 95 active bus routes (LA Metro 2015) using the optimization model. Current frequencies range from 8 to 1 times vehicles per hour. The optimization of route frequencies to reduce waiting times for vulnerable groups was able to improve the objective function by 13%. Routes in the center of LA Metro's service area generally received an increase in frequency due to the potential for high demand from vulnerable groups of riders. Vehicles that are reallocated to the these central routes are largely drawn from routes operating in the periphery of the LA Metro System and in the San Fernando Valley where both potential rider demand and heat vulnerability are lower (Figure 3).

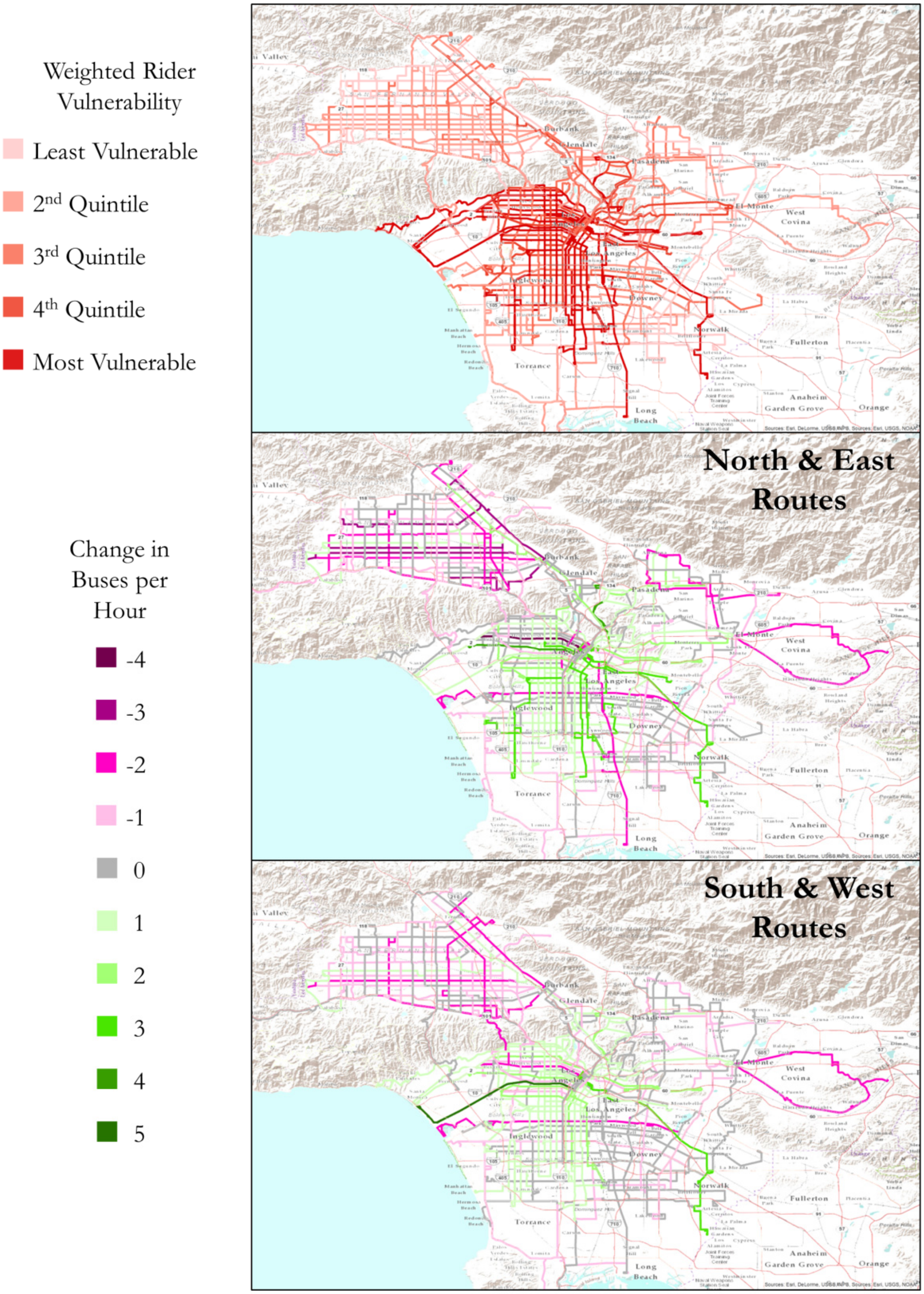

Figure 3 Weighted Transit Route Demand Vulnerability and Frequency Changes from Existing Schedules

The results show that it is possible for LA Metro to adjust transit schedules to reduce waiting time for vulnerable populations without incurring additional costs. During periods of extreme heat, services should be concentrated on the routes serving the center of the LA Metro System. The application of real demand data and rider demographics would significantly improve the ability of the model to identify routes should that be targeted for frequency increases and where these vehicles could come from. A consequence of this method is that it will increase waiting for those along routes where frequencies decrease. Additional constraints could be added to the model to limit frequency decreases and establish a ceiling for additional wait time on all routes. Because heat waves can be predicted with sufficient lead-time, it may also be possible to notify riders of alternative schedules in advance to minimize the impact of reduced frequencies on waiting time. This case study reflects a single step in the public transit planning process. The next steps for developing a functional emergency heat bus service include developing timetables, vehicle scheduling, and crew assignment.

Recently, LA Metro suggested changes to their bus system that mirror some of the changes developed in this case study. Motivated by a service review conducted by the American Public Transportation Association (APTA), LA Metro has proposed to make changes to their system based on a route performance (RPI) (LA Metro 2015). RPI is based on total passenger boarding, passenger miles, and overall operation cost. The APTA review included a recommendation to “critically review services & reallocate resources from poorer performers to higher productivity”(LA Metro 2015). Overall, the LA Metro proposal calls for no additional hours of bus service but reallocates existing services from lower demand routes to high demand routes. While the overall objective between LA Metro’s proposal and the one presented here different, the results are similar. The network recommended by LA Metro’s Blue Ribbon Committee strongly resembles the frequency shifts identified in this analysis (LA Metro 2015). LA Metro has not yet implemented these changes but if they do, the new network may also help reduce heat vulnerability because of the routes they are targeting for increased frequency.

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