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Transit system design and vulnerability of riders to heat

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ABSTRACT

In the United States public transit utilization has increased significantly in the last decade and is considered a critical component in reducing energy use and greenhouse gas emissions in urban areas. Despite public transit's climate change mitigation potential, the use of transit necessitates environmental exposure which may be a health hazard during periods of extreme heat. Transit system design, which includes stop location and schedules, is shown to contribute to environmental exposure resulting from access and waiting. Using Los Angeles Metro (Los Angeles County, CA) and Valley Metro (Maricopa County, AZ) as case studies of systems operating in extreme heat conditions, the research demonstrates how system design contributes to heat exposure times that vary significantly between neighborhoods. Household level access (walking) time estimates are developed using a shortest path algorithm to nearby transit stops. Waiting time estimates for individual transit stops are derived from published transit schedules and on-board survey responses. The results show that transit users from areas with low residential density, limited high capacity roadways and irregular street networks, and not located along direct paths between major activity centers are likely to experience prolonged access and/or waiting times. Public transit may help mitigate climate change impacts but transit proponents, agencies and planners should be cognizant of the impact an uncertain climate future may have on a growing base of transit riders. These insights can allow us to proactively govern and adapt transit systems to protect people from a growing health concern.

1. Introduction

In response to climate change concerns, the Federal Transit Administration (FTA) has identified public transit systems, and their increased utilization, as a critical component in reducing energy use and greenhouse gas emissions associated with the transportation sector (Hodges, 2010). Additionally, public transportation offers ancillary benefits including congestion reduction, reduced mobility costs, improved public health (by stimulating additional walking/cycling trips), and increased mobility equity (Litman, 2011). As a result, policies and programs, such as the *Safe, Accountable, Flexible, Efficient Transportation Equity Act* and *Moving Ahead for Progress in the 21st Century Act*, have encouraged the growth of public transportation infrastructure and transit ridership. In the United States between 2000 and 2012 public transit services (operated vehicle kilometers) increased by 32%, ridership (unlinked passenger trips) increased by 13%, and funding allocated to public transportation increased by 81% (APTA, 2014b). While these metrics indicate that policies and programs designed to promote and improve public transit in the U.S. have had some measure of success, there is a tension between policies and programs which promote transit use as a climate change mitigation strategy and the potential impact of an uncertain climate future on transit infrastructure and its riders. Recent research has begun to study the potential impacts associated with climate change on transit infrastructure but there is still very little known regarding how climate change may impact transit riders or how transit operators should respond to reduce environmental risks to their riders (Coumou and Rahmstorf, 2012; Ma et al., 2013; Meyer, 2008; Molarius et al., 2014; Rosenzweig et al., 2011).

Temperature, precipitation and wind have been shown to affect transit ridership (Arana et al., 2014; Guo et al., 2007; Kalkstein et al., 2009; Kuby et al., 2004; Singhal et al., 2014; Tao et al., 2016). These studies are largely concerned with predicting and understanding the loss of transit riders due to adverse weather and developing strategies to mitigate these losses. These studies do not, however, consider the

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impact adverse weather may have on the remaining transit users who may not have modal alternatives for necessary trips. Specifically, exposure during to weather extremes may increase certain health risks for transit riders. General circulation models predict the increasing duration, severity, and frequency of extreme weather events potentially compounding existing health risks. While the risks associated with some extreme weather events, such as hurricanes, may be obvious to riders and operators alike, previous research has found that individuals are generally less aware of the dangers of extreme heat exposure and even among those who acknowledge that heat exposure is a potential health threat, the level of perceived risk is often low (Abrahamson et al., 2009; Bittner and Stößel, 2012; Kalkstein and Sheridan, 2007). Despite individual perceptions, extreme heat is known to be a serious threat to public health and exposure to extreme heat, while often preventable, is a leading cause of weather-related mortality worldwide (Berko et al., 2014; Robine et al., 2008; USEPA, 2006). Moreover, exposure to extreme heat can result in heat-related illnesses such as heat cramps, heat stroke and heat exhaustion and exacerbate preexisting chronic conditions such as respiratory and cardiovascular diseases contributing to emergency room visits, hospitalizations, and premature death (Berko et al., 2014; Luber and McGeehin, 2008). Transit agencies and future transit policies should consider the potential risks of negative health-related outcomes due to extreme temperature exposure when designing and planning transit systems.

The design of a public transportation system contributes to outdoor exposure in two ways. First, transit stop location relative to a rider's origin or destination influences the mode used and time spent to access transit. In the United States, public transit systems are typically designed for pedestrians and as a result the dominant mode used to access transit in urban areas is walking, accounting for 85% of all U.S. transit trips with an average duration of 7.1 min (USDOT, 2009). Once at the transit stop, any rider would then experience waiting for the next transit vehicle, the duration of which is directly influenced by service frequency and reliability. On average, U.S. transit riders experience a wait time of 9.9 min (USDOT, 2009). While the average transit rider would experience 17 min of outdoor exposure there are likely areas served by a transit system where urban form characteristics and demand-based transit scheduling contribute to extended access and wait times.

To this end, this study develops a methodology to assess how current transit design contributes to environmental exposure for transit riders and where transit design may contribute to prolonged periods of outdoor exposure. Using Los Angeles Metro (Los Angeles, California) and Valley Metro (Phoenix, AZ) as case studies, we estimate environmental exposure resulting from transit use by examining transit ingress/egress walking times and waiting times. The method spatially identifies areas of the transit systems where current design may result in prolonged heat exposure. Though this research focuses on extreme heat exposure for pedestrian-transit users, the methods could also be utilized to assess exposure to extreme cold and exposure from alternative access modes including cycling.

The Los Angeles Metro and Valley Metro systems serve two of the largest metropolitan areas in the American Southwest and rank as the 3rd and 37th largest transit agencies in the country respectively based on total unlinked passenger trips (APTA, 2014a). Each agency is the largest transit provider in their respective region and the transit service areas for each agency, depicted in Fig. 1, extend across numerous municipalities with services that include local, commuter, and rapid bus service as well as rail options. These services are almost exclusively surface level (the exception being two subway lines operating in Los Angeles) and a majority of the stops ($>99\%$) are exposed to the environment. While Valley Metro operates as the primary provider of public transit in the Phoenix Metropolitan Area, Los Angeles Metro's service area includes regions where there are also additional local transit services (e.g. Santa Monica's Big Blue Bus). Though these other transit agencies may offer complimentary service, and sometimes redundant mobility options, the case study focuses specifically on transit users of these transit agencies.

These two agencies and regions are particularly suited for this case study as both are actively expanding service, have experienced significant ridership increases over the last decade, and found in areas where climate models predict increasing average summer temperatures as well as the increasing frequency, severity, and duration of extreme heat events (APTA, 2014a; Bartos and Chester, 2014; Bartos and Chester, 2015). The results provide a perspective on how transit system design within urban environments contributes to environmental exposure and can be used to develop transit strategies to respond to aspects of climate change which may impact transit riders.

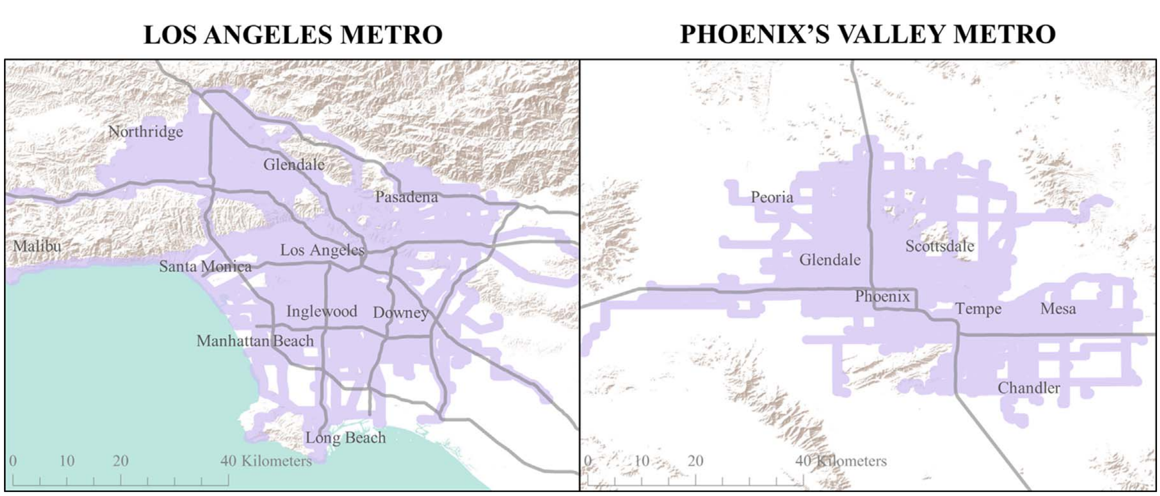

Fig. 1. Los Angeles and Valley Metro Service Areas. The colored portion of the map shows the areas of the Los Angeles and Phoenix Metropolitan regions within 800 m of a transit stop which are served by Los Angeles Metro and Valley Metro respectively.

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