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A Spatial and Longitudinal Analysis of Unmet Transportation Needs During Hurricanes Katrina and Rita

Abstract: Hurricanes Katrina and Rita struck the US Gulf Coast in 2005, leading to the largest mass evacuation in US history and straining the region's transportation infrastructure and services. This case study addresses the topic of disaster response to transportation unmet needs through an unprecedented spatial and longitudinal analysis of transportation-related disaster 2-1-1 call data collected in real-time, allowing for the investigation of unmet transportation needs by location and disaster phases. The authors analyze 25,205 transportation-related calls logged in Texas' 25 regional 2-1-1 Area Information Centers from August 1 to December 31, 2005, including a baseline period before Hurricane Katrina, evacuation and landfall, and 3-months recovery post-Hurricane Rita. The spatial results show that transportation unmet needs were concentrated in Texas' major metropolitan areas, especially in Houston-Galveston, and along highway evacuation routes. However, after controlling for population size, areas close to the landfall site and evacuation destinations had greater unmet transportation needs. Longitudinally, transportation unmet needs surged during evacuation and immediate disaster response then returned to baseline levels during recovery. Based on the results of the case study analyzing Texas 2-1-1 call data of unmet transportation needs, strategies and policies for improving mass evacuation and transportation support services are proposed and discussed.

Keywords: emergency management; evacuation; hurricane; Texas 2-1-1; unmet transportation needs.
1 Introduction

Hurricanes Katrina and Rita had a tremendous impact on transportation infrastructure and services in the US. While other parts of the world have suffered greater losses from natural disasters, such as the earthquakes and tsunamis in the Indian Ocean and Japan, Katrina and Rita rank among the deadliest and costliest natural disasters in US history (NOAA 2014). They ravaged the Gulf Coast of the US within a 3-week period, with landfall first on August 29 then September 24, 2005. Hurricane Katrina produced the largest relocation of US residents since the Dust Bowl of the 1930s; 1.2 million persons evacuated from New Orleans before the hurricane made landfall (Nigg et al. 2006). Hurricane Rita, aiming at the Texas and Louisiana coast, prompted an even larger evacuation of approximately 3 million, the largest in US history (Berger 2007). Over two million Texans evacuated inland from the Houston-Galveston area to flee from approaching Hurricane Rita. Despite the use of contra-flow operations, there were massive traffic jams and delays (Chiu et al. 2008). Texas was significantly impacted by the disasters, as the highest concentration of those displaced by Hurricane Katrina evacuated to Texas more than any other state besides Louisiana (Madera 2006). With Hurricane Rita striking the Texas/Louisiana border only three weeks later, Katrina evacuees also became Rita evacuees. The two hurricanes not only damaged and strained the region’s transportation infrastructure, but also tested the effectiveness of the State’s emergency management office to respond to calls for transportation needs.

Although there is a growing literature on the impacts of natural disasters on transportation infrastructure (Wolshon et al. 2005; TRB 2008; Freckleton et al. 2012; Szyliowicz 2013), there is scant research on emergency response to transportation needs, particularly unmet needs of disaster victims who face barriers to affordable transportation and services. This study fills this important gap through an unprecedented analysis of transportation-related 2-1-1 disaster call data collected in real-time during the period of the hurricanes, allowing for the investigation of unmet transportation needs by location and disaster phases. We conducted a spatial and longitudinal analysis of 2-1-1 transportation-related calls in all 254 Texas counties to identify “hot spots” of unmet transportation needs. This provided a unique opportunity to investigate unmet transportation needs in real-time, unbiased by recall, previous experiences or perspectives. This research is also the first-time descriptive analysis of unmet transportation needs over all phases of disaster and across such a broad geographic scope, including not only disaster sites but also evacuation destinations.
2 Background

Some of the deadliest disasters recorded have been the result of hurricanes that have struck southeastern and southern Asia, Central America, and Oceania. In the US, hurricanes are consistently the costliest form of natural disaster (NOAA 2014); Hurricane Katrina remains the costliest US disaster to date, exceeding $100 billion USD (Blake et al. 2011). Due to increased population growth and development in metropolitan regions along the Atlantic coast and the Gulf of Mexico in recent decades, the risks for property damage, injuries and fatalities have increased substantially.

The destructive nature of hurricanes has been known for centuries; however, the deadly Galveston Hurricane of 1900 was the first real “wake up call” for federal, state, and local officials to conduct research on hurricanes. Hurricane predictions were largely unreliable during the first half of the 20th century due to the lack of sophisticated forecasting technology. The evacuation of coastal areas for hurricanes became more feasible during the 1960s and 1970s with improved meteorological technology aiding in storm tracking and forecasting capabilities (Wolshon et al. 2005). Interest in hurricane evacuations increased in the late 1990s with large-scale evacuations and resulting traffic problems during Hurricanes Georges and Floyd in 1998 and 1999, respectively. The active 2004 Atlantic hurricane season brought the issue of hurricane evacuation to the forefront and highlighted the importance and vulnerability of transportation infrastructure during times of disaster. Most of the transportation literature prior to Katrina and Rita has focused on planning studies for local communities, state and federal department of transportation reports, along with law enforcement and emergency management operational manuals (Wolshon et al. 2005).

Hurricanes Katrina and Rita highlighted the problems of excessive reliance on the automobile for evacuations, and the lack of sustainable transportation options such as public transit. Therefore, residents without access to a personal vehicle and individuals with special needs such as persons with disabilities and the elderly, were at a serious disadvantage. Evacuation of New Orleans during Hurricane Katrina highlighted the inadequacy of public transit services for those without access to a private vehicle; the number of buses available were not enough to accommodate the 225,000 carless residents in the city (Wolshon 2002; Wolshon et al. 2005). Consequently, thousands of transit-dependent residents were left stranded in the city, and many of them were among the 1833 confirmed causalities from the disaster. Although residents with access to automobiles fared better, many were also left stranded when their vehicles broke down or ran out of fuel. Most vehicles faced daunting traffic congestion and access barriers for emergency vehicles to reach disabled vehicles, which were widely reported in the media (Patrick 2005).
During the past decade since Katrina and Rita, there have been a growing number of studies examining the resiliency of transportation infrastructure and other natural disasters, as well as emergency logistics of evacuations and response. Freckleton et al. (2012), building on previous research by Heaslip et al. (2009), developed resiliency metrics at the individual and community level to show whether the transportation network provides options and utility to individual users, and whether transportation systems satisfy the needs of the community. Several recent studies focus on the logistics of evacuation and response of Katrina and Rita (Eisenman et al. 2007; Holguín-Veras et al. 2007; Wolshon and Mc Ardle 2009; Wu et al. 2012), as well as Hurricane Sandy in 2012 (O’Neil 2014), which had a devastating impact on the transportation network in the Northeast US. These studies have shown that hurricanes and other disasters pose severe logistical challenges to emergency and aid organizations, which are exacerbated by damage to the transportation infrastructure of the impacted areas. In addition, the lack of knowledge of emergency supply chains during the Katrina response further hampered relief efforts (Holguín-Veras et al. 2007). While recent literature has focused largely on hurricane evacuation logistics and response, there are relatively few published research studies focusing on transportation impacts, and none found on assessing unmet transportation needs.

3 The Role of 2-1-1 in Disasters

In 2000, the Federal Communications Commission (FCC) approved 2-1-1 as a three-digit telephone number for information and referral services (FCC 2014). The 2-1-1 call centers were established throughout the US to serve their communities during local, regional, and national disasters including both natural and man-made environmental disasters. These call centers provide not only triage and appropriate referral for health and human services needs, but also reassurance and sustained support for callers through crisis and recovery (Bame et al. 2012). In 2004, Texas completed its 2-1-1 Texas Information & Referral Network (TIRN), comprised of 25 autonomous regional call centers with the telephone networking capability to provide statewide “24/7” coverage (Texas HHSC 2012). As of February 2013, 90.6% of the US population in all 50 states plus the District of Columbia and Puerto Rico was covered by 2-1-1 services; 39 states plus DC and Puerto Rico had 100% coverage (www.211us.org). Unlike 9-1-1 for emergency services, 2-1-1 helps callers with non-urgent requests for information and referral for available local and regional disaster and routine support services. The transportation-related requests have included information about evacuation
routes, transportation needs for individuals with disabilities, and locations of fuel stations and shelters. A 2-1-1 caller’s request is considered an unmet need; if the caller was able to access services to meet the need(s), one would contact the agency directly rather than the 2-1-1 number (Bame et al. 2012).

As Katrina evacuees arrived in Texas, the State’s Office of Emergency Management designated the Texas 2-1-1 Network as the State’s communication hub for non-emergency needs and support services during Hurricanes Katrina and Rita, linking callers to available disaster and community services (Bame et al. 2009a). Electronic road signs advertising 2-1-1 were posted for Katrina evacuees fleeing into Texas. Rita evacuees and host communities used 2-1-1 to search for services needed anywhere in Texas (Bame et al. 2009b). The 2-1-1 staff and volunteers provided information and referrals to available, appropriate, and/or affordable services, while at the same time logging the caller’s location and unmet needs. This 2-1-1 role in emergency management and recovery has continued in Texas for non-urgent disaster response for disaster victims and their hosts, and to support communication among social support services, first-responders and volunteers. Since 2-1-1 approval in 2000, 2-1-1 call centers in cities throughout the US have held key roles in successful disaster response, management, and recovery from natural disasters such as hurricanes, tornadoes, blizzards, mudslides, floods, and wildfires as well as man-made disaster management for chemical spills, “haz-mat” events, “Miracle on the Hudson,” and the H1N1 epidemic (2-1-1 US 2013; Bame and Arlikatti 2014).

4 Methods

We analyzed calls recorded by the Texas 2-1-1 Network during the study period August 1, 2005 through December 31, 2005. These calls were coded and analyzed by type of need according to location and disaster phase. We examined calls for transportation needs: 1) spatially in terms of a) volume of Texas 2-1-1 transportation unmet needs per Texas county (n=254 counties) and b) number of these needs adjusted by population size; and 2) longitudinally as daily transportation need demands received during the 5-month study period and compared by disaster phase. By analyzing these calls for unmet transportation needs over location and time, we can determine where help was needed to overcome access barriers in relation to the counties impacted by the disasters, and which phases of the disasters had greater barriers to transportation access. While Hurricanes Katrina and Rita impacted other states outside of Texas, most notably Louisiana, we only analyzed calls from the Texas 2-1-1 Network due to data reliability in terms
of coding consistency, completeness, and uniformity. Additionally, some of the 2-1-1 call centers in Louisiana had closed during some of the time periods under investigation whereas the Texas 2-1-1 Network was able to maintain 24/7 operations statewide regardless of disaster location.

4.1 Study Population and Time Frame

The study population consisted of all 2-1-1 calls logged in the twenty-five Texas regional Area Information Centers (AICs) during the study period. This study period included a four-week baseline phase prior to Hurricane Katrina, evacuation and landfall phases for each Hurricane, a one-week emergency response period following landfall of each Hurricane, then recovery phase up to the end of the calendar year. In winter of 2006, the AICs submitted their call data to headquarters of the 2-1-1 Texas Information and Referral Network (TIRN) where the electronic files and paper data logs were redacted, stored, and then given to the researchers upon Department of Homeland Security funding in 2008.

4.2 Data Collection and Coding

Texas 2-1-1 services are available “24/7,” with telephone rollover capability among the AICs during disasters to meet caller needs regardless of call timing or location. Local community and emergency services information and referrals are accessible throughout the State via the 2-1-1 Texas Network. Throughout the study period, trained 2-1-1 staff entered data directly into their own AIC’s software databases. During the surge of disaster calls, the Texas 2-1-1 Network captured all calls on a first-available rollover basis, with additional volunteer help to answer and log calls at their local AIC. Volunteers entered 2-1-1 call information onto paper logs or free-form notes. Upon receiving the data, the research team converted the electronic databases to a consistent file format and coded the paper data into the same format. After validating 100% of the data, the twenty-five AIC databases were merged.

4.3 Variables

Three variables were collected consistently by the Texas AICs: 1) location, 2) date, and 3) unmet need(s). Location of where the caller was looking for information or referral help was triangulated to improve accuracy using city, zip code, and/or
county information, then aggregated to the county level. If the call was from out of state, the state name was recorded. Next, call date was automatically coded by default of the 2-1-1 software in the AIC’s electronic databases and date was logged on most of the paper records. However, paper data from four AICs were missing call dates; hence, there is a bias underestimating number of calls from these evacuation destinations when analyzing over time. However, because of roll-over capabilities of the 2-1-1 Texas Network, other AICs handled calls that would be indicative of callers’ timing, location, and needs from those AIC regions with missing date data. Last, caller’s needs were coded in real time using the national 2-1-1 taxonomy of needs or paraphrasing the requests close to verbatim. During the periods of call surge, details of caller need(s) were often lost with barely time to log major type of need, e.g., “fuel” vs. “transportation.” When possible, the research team retrieved more detail about the needs from the type of information or referral given. Only the subset of call data with transportation-related needs was used for this analysis. Other unmet basic disaster needs, such as housing, shelter, health services, and food, have been reported elsewhere (e.g., Bame et al. 2012; Bame 2013).

4.4 Analysis

First, a qualitative examination was done of the types of unmet transportation needs encountered during the 5-month study period. Second, demand for unmet transportation needs was mapped according to: a) volume of 2-1-1 calls for these needs and b) ratio of unmet transportation needs per population size measured as number per 100 households per county. Expected ratios were estimated from average statewide 2-1-1 call-rates prior to the 2005 hurricane season. Less than expected ratio of calls per county was \( <0.5 \) and greater than expected ratio was \( >0.5 \) calls per 100 households. Last, longitudinal variation in the volume of transportation needs was described, spanning from a 4-week baseline prior to Hurricane Katrina, evacuation and landfall of both hurricanes, immediate recovery, through 3 months recovery post-Rita until the end of the calendar year.

5 Results

A total of 635,983 Texas 2-1-1 calls were recorded during the study period. Four percent of the total 2-1-1 calls, \((n=25,205)\) included unmet needs for transportation access or services. Although the proportion of transportation-related calls
was relatively small compared to disaster needs for shelter and housing (28%), health and safety (18%), food and water (15%), this was a sizeable number of the population encountering access barriers in managing transportation during the disasters.

Almost two-thirds (63%) of transportation-related needs were logged simply as “general transportation,” likely due to limited ability of 2-1-1 staff and volunteers to document detailed needs during the surge of calls occurring prior to and following landfall. Next, twelve percent of unmet transportation needs were regarding those with disabilities to get access or accommodations to transit, particularly for evacuation. Seven percent of callers needed help with evacuation and another seven percent needed fuel often related to evacuation. Other types of unmet transportation needs included transportation needed to shelter (3%), directions during evacuation (2%), financial help for fares or repairs (2%), deliveries (2%), bus-related (0.5%), transit to appointments (0.4%), and road conditions (0.2%). Calls were not classified based on importance or severity of the need due to lack of information in the 2-1-1 dataset.

5.1 Spatial Patterns of Unmet Transportation Needs

Spatial patterns of calls for unmet transportation needs revealed differences in demand across Texas counties that were strongly associated with population size. Over 99 percent (n=25,032) of transportation-related calls were from within Texas and only 0.69 percent of these calls (n=173) were from out-of-state. Out-of-state 2-1-1 calls originated from 25 states and Washington, DC. The greatest proportion was from Louisiana, accounting for over 50 percent of out-of-state calls, followed by adjacent states Oklahoma and Arkansas. This small proportion of calls from outside of Texas was not included in our spatial analysis by Texas county.

Mapping transportation unmet needs by county highlighted variations in the distribution of demand for help during the disaster period, as well as showing evacuation routes and destinations throughout Texas (see Figure 1 and Table 1). The highest volume of transportation-related unmet needs were from the State’s largest metropolitan areas: Harris County (Houston), Dallas and Tarrant Counties (Dallas-Fort Worth), Bexar County (San Antonio), and Travis County (Austin), accounting for 66 percent (n=16,513) of transportation unmet needs. The highest number of calls for transportation help was from Harris County, accounting for almost a third (30 percent; n=7441) of all transportation-related calls recorded in the State. The other four large metropolitan counties each reported over 1000 calls, accounting for 36 percent of total calls. Twenty-three smaller urban and suburban counties comprised 24 percent of transportation calls in Texas, with
Figure 1: Spatial Distribution of 2-1-1 Calls by County for Unmet Transportation Needs (August 1 – December 31, 2005).

Table 1: Frequency of 2-1-1 Calls for Unmet Transportation Needs in Texas, Fall 2005.

<table>
<thead>
<tr>
<th>Range of Calls/County</th>
<th>Minimum No. of Calls</th>
<th>Maximum No. of Calls</th>
<th>No. of Counties</th>
<th>Percentage of Counties</th>
<th>No. of Calls</th>
<th>Percentage of Calls</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;5000</td>
<td>7441</td>
<td>7441</td>
<td>1</td>
<td>0.39%</td>
<td>7441</td>
<td>29.73%</td>
</tr>
<tr>
<td>1000 to &lt;5000</td>
<td>1177</td>
<td>3433</td>
<td>4</td>
<td>1.57%</td>
<td>9072</td>
<td>36.24%</td>
</tr>
<tr>
<td>100 to &lt;1000</td>
<td>107</td>
<td>649</td>
<td>23</td>
<td>9.06%</td>
<td>5969</td>
<td>23.85%</td>
</tr>
<tr>
<td>10 to &lt;100</td>
<td>10</td>
<td>94</td>
<td>65</td>
<td>25.59%</td>
<td>2204</td>
<td>8.80%</td>
</tr>
<tr>
<td>1 to &lt;10</td>
<td>1</td>
<td>9</td>
<td>102</td>
<td>40.16%</td>
<td>346</td>
<td>1.38%</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>59</td>
<td>23.23%</td>
<td>0</td>
<td>0.00%</td>
</tr>
<tr>
<td>Sum</td>
<td>254</td>
<td>25,032</td>
<td>100.00%</td>
<td>100.00%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
each county receiving from 100 to 1000 calls. Sixty-five counties received at least 10 calls, accounting for 9 percent of total calls. Among the remaining mostly rural counties in the state, 102 received from 1 to 9 calls, and 59 counties did not receive any transportation-related calls.

The large proportion of transportation unmet needs reported from the greater Houston area was not surprising given that it was most directly impacted by the influx of evacuees from Hurricane Katrina and three weeks later by early evacuation from the threat of Hurricane Rita. The number of transportation unmet needs reported from other large metropolitan areas in the State were also high as expected, given that these were major evacuation destinations for both hurricanes. It is interesting to note that the volume of 2-1-1 transportation-related calls followed major evacuation routes; there was a cluster of calls for transportation help along the corridor from Beaumont/Port Arthur to Tyler in northeast Texas and radiating northwest from Houston towards the Interstate 35 corridor where the other three major metropolitan areas are located (see Figure 2). Although the majority of calls were reported east of the I-35 corridor, there were surprising clusters of transportation needs reported from smaller, distant metropolitan areas in western Texas (i.e., Abilene, Amarillo, Lubbock, Midland-Odessa). State

Figure 2: Major Highway Evacuation Routes.
and national emergency management had bused or flown Katrina evacuees to these more remote destinations to get them out of harm’s way as Hurricane Rita approached the Gulf Coast. Few or no transportation-related calls were reported in most rural counties in West Texas and the Panhandle region.

5.2 Spatial Patterns Adjusted by Population Size

Although large metropolitan areas received the bulk of transportation-related calls, demand for community transportation resources in rural counties were strained to a greater degree since they had fewer resources to handle disaster needs than urban counties. To determine the demand on rural counties, we analyzed spatial patterns adjusted by population size, calculated as the ratio of calls per 100 households per county (Table 2 and Figure 3). By controlling for urban/rural bias, the adjusted call rate reflected the location of populations at greater risk for access barriers to transportation services. Seventeen counties had adjusted call ratios greater than 0.5, comprising 47.5 percent of transportation-related calls. These areas at greater risk for vulnerable populations experiencing unmet transportation needs included the rural counties in Southeast Texas along the Louisiana border, urban Harris County (Houston), and the coastal metropolitan areas of Beaumont-Port Arthur and Victoria, comprising those areas closest to the impact of the Hurricanes. Other at-risk counties were scattered in the interior part of the State, highlighting smaller evacuation destinations not equipped to handle evacuees’ demands for unmet needs. Even after controlling for population size, these areas were overwhelmed with unmet transportation needs due to access barriers to available or affordable transportation support and services. Most of the rest of the State (52.5% of counties; n=173) had a fewer than expected rate of transportation-related calls after adjusting for population size. Fifty-nine counties, mostly rural counties in

Table 2: Ratio of 2-1-1 Calls for Unmet Transportation Needs Adjusted by Population Size Per County in Texas, Fall 2005.

<table>
<thead>
<tr>
<th>Range of Call Ratios/County</th>
<th>Min. Ratio Per 100 Households</th>
<th>Max. Ratio Per 100 Households</th>
<th>No. of Counties</th>
<th>Percentage of Counties</th>
<th>No. of Calls</th>
<th>Percentage of Calls</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥0.5</td>
<td>0.521</td>
<td>1.319</td>
<td>17</td>
<td>6.7%</td>
<td>11,902</td>
<td>47.5%</td>
</tr>
<tr>
<td>&gt;0 to &lt;0.5</td>
<td>0.006</td>
<td>0.484</td>
<td>178</td>
<td>70.1%</td>
<td>13,130</td>
<td>52.5%</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>59</td>
<td>23.2%</td>
<td>0</td>
<td>0.0%</td>
</tr>
<tr>
<td>Sum</td>
<td>254</td>
<td>100.00%</td>
<td>25,032</td>
<td>100.0%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
west Texas and the Panhandle region, did not report any transportation-related unmet needs during the 5-month study period.

In sum, the spatial analysis showed that the volume of transportation-related unmet needs were concentrated in the major metropolitan areas of Texas, particularly the Houston area. However, after adjusting for population size, it was evident that the more vulnerable counties for unmet transportation needs were the areas where resources were strained by the Hurricanes’ impact: the Houston and Beaumont-Port Arthur metropolitan areas and the surrounding rural counties. While disaster response resources were mobilized to the hurricane landfall location, counties adjacent to the landfall area were not adequately able to keep up with the transportation needs of evacuees and needed outside assistance and support for evacuees beyond what could be normally provided. Further, urban counties quite distant from the disaster site but serving as evacuation
destinations also had higher than expected unmet transportation needs and needed additional outside assistance.

5.3 Longitudinal Patterns of Unmet Transportation Needs

In addition to spatial analysis, longitudinal patterns of unmet transportation needs were examined. In Figure 4, the number of calls for unmet transportation needs was plotted per day throughout the 5-month study period. A distinct weekly pattern can be observed, with calls peaking at the start of a work-week, tapering off, with an abrupt drop in calls during the weekends. This pattern was largely consistent except during the immediate disaster period and matched typical weekly patterns of 2-1-1 calls for other types of needs. Although 2-1-1 operates “24/7,” call center staff speculated that callers typically wait until social support services are open during the work-week.

There was a relatively consistent low number of calls during the four-week baseline period prior to Hurricane Katrina landfall. After Hurricane Katrina victims were being transferred to Texas following the first few days of immediate disaster response in New Orleans, the demand for help with transportation unmet needs rose sharply. The volume of unmet transportation needs following Hurricane Katrina kept increasing into the second week as evacuees tried to mobilize

![Figure 4: 2-1-1 Calls Per Day for Unmet Transportation Needs in Texas. (August 1 – December 31, 2005).](image-url)
to get disaster resources and temporary housing as shelters began to close. Calls seeking transportation help from Katrina victims peaked at 1183 calls on September 6, 2005. There was still high demand for unmet transportation needs into the third week post-Katrina. Just as transportation-related 2-1-1 calls began to taper off, evacuation from Hurricane Rita began.

Calls for unmet transportation needs peaked again during evacuation just before Hurricane Rita’s landfall, with 1383 calls (5 percent of the total 2-1-1 calls for transportation). There was a drop in demand for the few days of immediate disaster response post-Rita landfall, then unmet transportation needs spiked again into the second week post-landfall. This surge coincided with shelters closing. Hurricane Rita evacuees began returning home and Katrina evacuees were yet again seeking temporary housing and disaster recovery resources. When the immediate disaster threat and response was over, the volume of calls began to wane back towards the baseline level.

During the high-demand disaster period from about September 1 to October 1, there were at least 200 calls per weekday with approximately half of the weekdays reporting over 500 calls per day. During disaster management for Hurricane Katrina evacuees in Texas, unmet transportation needs remained high and extended for the three weeks until Hurricane Rita hit. Compounding local evacuation from Rita with evacuating Katrina victims yet again, unmet transportation needs spiked. Throughout Hurricane Rita disaster response from September 22 to October 1, call volume remained consistently high, including the weekends. These patterns for transportation 2-1-1 calls were largely expected and reflected disaster and evacuation patterns in other locations (Bame et al. 2012).

6 Discussion

This study of 2-1-1 transportation-related calls during Hurricanes Katrina and Rita revealed important insights about unmet transportation needs during disaster using real-time data. We examined unmet transportation needs in two dimensions, spatially across the state of Texas and longitudinally across all phases of the Katrina and Rita Hurricane disasters. Conducting these analyses allowed for the comprehensive examination of unmet transportation needs in both the disaster site and the evacuation destinations in Texas, and showed where and when access barriers to disaster and community support services were most acute. Using this study as a model, analysis of real-time 2-1-1 data can be used to plan and monitor efficient allocation of resources and support services for transportation during disaster periods to enhance resiliency of populations and regions.
The spatial analysis showed that the highest volume of calls were concentrated in the five largest metropolitan areas in Texas, correlating with population size as well as major evacuation destinations. Houston was particularly hard hit with calls requesting transportation services, given its role in hosting Hurricane Katrina evacuees, and then a few weeks later evacuating in the threat of approaching Hurricane Rita. The spatial analysis also showed concentrations of calls along major evacuation routes radiating from Houston and Beaumont-Port Arthur along the Louisiana border. However, adjusting for population, it is evident that higher than expected call volumes were reported in rural counties in east Texas near the Gulf Coast and the Louisiana border, signifying “hot spots” where emergency resources and support were strained beyond capacity. This highlights the vulnerability of smaller communities located in rural areas near the epicenter of the disaster.

Analysis of calls over the disaster phases showed considerable differences in call volume between routine baseline levels and acute disaster phases. The volume of calls remained relatively low and consistent from the beginning of the study period until the relocation of Katrina victims into Texas when the demand for transportation needs increased over ten-fold. A week after the closure of emergency shelters and the departure of first responders and volunteers, the volume of unmet transportation needs increased sharply again as victims turned to community services that were not adequately prepared to handle the large demand for transportation needs. Although there was a steady decrease in unmet needs following this first week, the demand remained high until faced with evacuation yet again.

Hurricane Rita showed a different pattern in demand for transportation help, with unmet needs surging as millions of residents in the Houston and Galveston area evacuated early. Calls requesting transportation related services peaked right before Rita’s landfall then dropped to a moderate level during the emergency response phase. Demand for transportation needs rose sharply after a few days post-landfall as shelters began to close and Texan evacuees began to return home, leaving Katrina evacuees to relocate into temporary housing. The considerable disaster resources that became available after approximately a week post-Rita seemed to quell demand for unmet transportation needs, with the volume dropping precipitously and then remaining steady at a low rate through recovery until the end of the year.

Our findings illustrate the importance of 2-1-1 call centers assisting disaster victims in addressing their unmet transportation needs. Analyzing spatial patterns of call demand showed that the distribution of disaster resources should not only take into account the number of disaster victims but should be allocated in a manner that would alleviate the burden of communities most impacted by the
disaster, particularly rural communities with limited local resources for addressing transportation needs of evacuees. Analyzing calls for unmet transportation needs over time highlights the importance of monitoring changing needs over the course of the disaster, as high-risk counties were especially vulnerable close to landfall and during the immediate recovery phase of the disaster.

6.1 Limitations of the Data

As with any analysis of tertiary data, there were limitations regarding the detail and scope of existing data as well as lack of controls during data collection. Compounding these typical constraints was the fact that data were collected at 25 autonomous sites, each with its own practices of handling 2-1-1 caller inquiries and documentation and further complicated by adding volunteers during periods of call surge. However, reliability and validity were assumed to be adequate as there were standardized Texas 2-1-1 Network protocols to follow by all call centers during disaster management, 2-1-1 accreditation promotes staff compliance with standardized data collection and recording practices, and a nationwide 2-1-1 taxonomy of needs is used to document caller needs. External validity of the number and types of callers and unmet needs remains unknown as demographic data of 2-1-1 callers were not collected; hence, no comparison could be made regarding representativeness of callers to evacuees nor community populations. As 2-1-1 had become statewide in Texas only a year earlier, it was expected there would be a bias regarding who would be motivated to call 2-1-1, made familiar with this service through social support services, disaster announcements and resources, or word-of-mouth among family/friend networks. Because of these limitations, the findings remain a case study of one state’s experience with two sequential devastating hurricanes. Nevertheless, this unique analysis of unmet needs gathered in real-time over the duration of a disaster and across a broad geographic scope could set a baseline to empirically build a conceptual framework of unmet transportation needs in other disaster scenarios and for other locations.

7 Policy Implications and Conclusions

Since Hurricanes Katrina and Rita in 2005, there has been increasing attention to examine the impacts of natural disasters on transportation infrastructure. Furthermore, there have been recent efforts to implement best practices based on disaster management experiences to improve transportation resilience. A 2006
report by the U.S. Department of Transportation identified many lessons and best practices based on experiences in Texas and other Gulf Coast states, such as developing statewide hurricane evacuation and shelter plans, addressing fuel availability on evacuation routes, and developing contraflow plans and other mobility solutions to improve congestion (US DOT 2006). The evidence suggests that some of these best practices have been implemented since Katrina and Rita, demonstrated by the more effective emergency response during Hurricane Sandy due to better emergency plans and improved infrastructure (Powell et al. 2012; O’Neil 2014). However, in terms of non-emergency needs, there still remains a gap, as our understanding of managing transportation needs and access barriers during disasters remains limited.

Based on the results of this case study analyzing Texas 2-1-1 data of unmet transportation needs during and following Hurricanes Katrina and Rita, the following strategies and policies are recommended for mass evacuation and transportation support services. First, greater access to transportation services is needed in locations where evacuees are sheltered near large metropolitan areas and disaster sites. Access barriers to transportation services were clearly evident in large urban areas near the disaster site as well as rural counties. While large metropolitan areas were mostly able to absorb the needs of the evacuees that relocated there, smaller communities impacted by the hurricanes were particularly strained in terms of disaster support, as shown in the spatial analysis of calls for unmet transportation needs. Second, our case study highlights the need to provide better transportation services to persons with disabilities, based on the relatively high percentage of calls requesting information about this unmet need. Given that this segment of the population is most vulnerable in disasters, along with the elderly, 2-1-1 and disaster management officials could coordinate with local and regional transportation services such as taxis, shuttles and buses, and rental car facilities to expand access to transportation services. Third, based on calls requesting information about evacuations, disaster management could focus on increasing the availability of transportation services along evacuation routes to provide support to those evacuating by private vehicle and may require roadside assistance due to breakdowns and vehicles running out of fuel. However, one caveat is that additional public transit and emergency vehicles may have the unintended consequence of increasing congestion on evacuation routes. Fourth, based on the calls requesting information on transportation to shelters, area shelters could coordinate with transportation services to help evacuees get from their current location to a shelter where they could receive needed supplies and services during the disaster and help to make the transition to temporary housing.

In terms of addressing unmet transportation needs, the coverage of 2-1-1 call centers has expanded considerably since 2005. Based on the increasing number
of calls received during the past decade (in 2013, 2-1-1 services in the US answered more than 15.6 million calls), it appears that the goals of 2-1-1 are being met. In our case study, 2-1-1 played an instrumental role in providing non-emergency assistance to Katrina and Rita evacuees, evidenced by the wide coverage of calls throughout the state of Texas, and the large number of calls received from the Houston-Galveston area and rural counties near the Louisiana border. In addition to coverage and volume of calls, the 2-1-1 call data provided insights on the types of unmet transportation needs, although somewhat limited in details due to documentation constraints while handling calls during massive call surges prior to and during disasters. Future disaster studies could provide more detailed insights in transportation unmet needs in addition to their correlation with other needs such as housing/shelter, food/water, and health/safety. A unique advantage of 2-1-1 data is that it is collected in real-time using a standardized taxonomy of needs, containing data for analysis over time and location. Combining these tertiary data analyses with survey follow-up could further enhance our understanding about the types of calls for assistance, the types of assistance provided, and assessing the impacts of calls on local communities as well as the individual caller.

References


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