Hurricane Isaac Power Outage Impacts and Restoration

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Abstract: In August 2012, Hurricane Isaac made landfall twice in Louisiana. Cumulatively, over 1 million customers lost electricity as a result of the hurricane, some for more than 10 days. As a disaster, Hurricane Isaac is relatively unique because of the opportunity to largely isolate impacts and decisions directly associated with the electricity outage and restoration from cascading impacts related to direct flood or wind damage. Louisiana emergency managers, business representatives, and public officials were interviewed to develop and analyze a case study of the outage and restoration event. Interviewees were asked about (1) the significant impacts from the outage, (2) what (if any) lasting effects would result from the outage, (3) the relative performance of power restoration, (4) the effectiveness of communication between stakeholders, and (5) factors influencing the public and political perception of restoration performance. Other collected data included content from news media, government documents, press releases, situation reports, and publicly available quantitative data. Results suggest that there were few long-term impacts from the outage, and restoration performance was not unusually slow. Even so, the electricity service provider was the subject of vocal criticism. The findings of the case study highlight the importance of all aspects of communication and awareness raising before, during, and after power outages, as well as further research to facilitate this. The study reinforces the need to improve power continuity using a wide range of technical, political, and organizational strategies. Research and policy development is particularly needed for improving continuity of transportation, health care facilities, and gasoline provision. Understanding of the sociotechnical role of electricity outages within broader disaster contexts can only be improved through further interdisciplinary research. **DOI: 10.1061/(ASCE)IS.1943-555X.0000267.**

Introduction

Electricity is generated and delivered using what is arguably the most technically complex system in existence. Power systems are the epitome of a sociotechnical system because the physical systems and their functioning are embedded within social and economic demands for services that are organizationally and politically managed or regulated (Feinstein 2006; Graham and Marvin 2001). Similarly, restoration of electricity is a sociotechnical process involving decision making, political context, interorganizational dynamics, and conflicts between interest groups (Kormos and Bowe 2006; Murphy 2001). The complexity of restoration increases several magnitudes in the context of organizational culture, government regulations, public-private relationships, communication difficulties, and resource constraints (Feinstein 2006).

Miles et al. (2014) observed that power restoration protocols and planning cannot be effectively optimized without understanding the impacts of nontechnical contextual issues, as well as the technical ones. Similarly, elected officials and regulatory authorities cannot create effective, reasonable, and feasible restoration policies without understanding the sociotechnical contexts of power restoration faced by utility providers, as well as the perceived versus actual impacts of increasing restoration times for different types of customers. The same is true for customers' and emergency managers' ability to effectively plan for, respond to, and cope with power outages.

This paper describes the electric power outage, restoration, and related impacts associated with Hurricane Isaac (August 2012) in Louisiana—specifically Orleans, Jefferson, Plaquemines, and St. John the Baptist Parishes, which were the areas that suffered the most and highest percentage of outages. In the four-parish case study area, Hurricane Isaac had relatively minor impacts other than damage to the electricity distribution network and subsequent loss of electricity. There were many large and relatively densely populated areas that lost electricity for a significant duration but suffered no flood or wind damage. This allows for the relative isolation of the specific impacts and responses to the power outage and restoration. This isolation provides the opportunity to more easily see the linkages between electrical network disruption, dependent sociotechnical systems, and impacts and responses that might be obscured or overlooked in larger, more complex disasters (Miles et al. 2014). This knowledge is critical for the development of disaster planning practices that consider infrastructure interdependence. It can also help to more precisely characterize functional relationships for developing and refining electric power restoration and loss models.

This paper extends the reporting of Miles and Jagielo (2014) to provide a more detailed synthesis of the event and, more importantly, analysis of key observations to inform recommendations for both research and practice. In the following section, the method used to develop the case study is reviewed. Following this, the events of the Hurricane Isaac electricity outage and restoration are described. In the subsequent section, lifeline and socioeconomic impacts of the outage are presented. The paper concludes with a discussion of the significant sociotechnical lessons learned and recommendations for research and practice.

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Note. This manuscript was submitted on December 16, 2014; approved on June 9, 2015; published online on July 16, 2015. Discussion period open until December 16, 2015; separate discussions must be submitted for individual papers. This paper is part of the ***Journal of Infrastructure Systems***, © ASCE, ISSN 1076-0342/05015005(9)/$25.00.

Data Collection and Synthesis

The majority of data collected for this case study were derived from in-depth interviews with politicians (or their representatives), emergency managers (or people with an emergency management role during the disaster), and business representatives in Jefferson, Plaquemines, St. John the Baptist, and Orleans Parishes. Two representatives from Entergy Services were interviewed: one from legal services and one from transmission and distribution operations. Interviewees were identified using existing contacts, news stories, situation reports, and snowball sampling. Thirty-three participants from 19 different organizations were interviewed across 19 meetings (i.e., all organizations were interviewed separately): Entergy Services (two participants), Greater New Orleans (two), Jefferson Parish Economic Development Commission (one), Jefferson Parish Council (two), Jefferson Parish Sewerage Department (one), Jefferson Parish Emergency Management (one), Jefferson Parish President's Office (three), Louisiana Business Emergency Operations Center (three), Louisiana Department of Health and Hospitals (two), Louisiana Public Services Commission (one), New Orleans Office of Homeland Security and Emergency Preparedness (three), New Orleans Department of Human Services (two), New Orleans City Council (two), New Orleans Health Department (two), Plaquemines Association of Business and Industry (one), Plaquemines Parish Council (one), Plaquemines Parish Office of Homeland Security and Emergency Preparedness (two), Plaquemines Parish School Board (one), and St. John the Baptist Parish Long-Term Recovery Group (one). All but one meeting was conducted face to face and occurred during the second and third weeks of November 2012. The interview with Energy Services representatives occurred over the phone 3 months after the fieldwork.

Participants were asked five open-ended questions about (1) the significant impacts from the outage, (2) what (if any) lasting effects would result from the outage, (3) the relative performance of Entergy's restoration, (4) the effectiveness of Entergy's communication, and (5) factors influencing the public and political dissatisfaction with the restoration performance. The representatives from Entergy Services were willing to discuss the corporate structure of Entergy entities, their general approach to restoration, and their planned improvements for communication with customers and emergency managers that were motivated by Hurricane Isaac. Other collected data include content from news media, government documents, press releases, situation reports, and publicly available quantitative data (e.g., from the U.S. Department of Energy). These qualitative and quantitative data were synthesized to develop a comprehensive understanding of the event and identify significant themes to guide future research and inform future research and practice.

Outage and Restoration

Hurricane Isaac became a Category 1 hurricane a few hours before it made landfall in Southeast Louisiana. Although the hurricane was small, it had several unique characteristics (Berg 2013). Hurricane Isaac made landfall twice in Louisiana. The first landfall was in Plaquemines Parish, occurring on the evening of August 28, 2012; the second was on the following day, just west of Port Fourchon. Isaac lingered over the greater New Orleans area with winds over 48 km/h (30 mi/h) for up to 54 h (Entergy Services 2013a). This is as much as twice as long as what has been experienced with other hurricanes in the state.

Within the case study area of Orleans, Jefferson, Plaquemines, and St. John the Baptist, severe flooding was concentrated in less populated areas of the region. Flooding was limited for the most part to the Lake Pontchartrain shore around Laplace in St. John the Baptist Parish, along the east bank of Plaquemines Parish from Braithwaite southward to White Ditch, and in Jefferson Parish's Jean Laffite, as well as the immediate areas around it (Berg 2013). These severely flooded areas were outside of the federal levee system. Floodwaters around Laplace overtopped I-10, resulting in its temporary closure. Two flood-related deaths occurred in the case study area: a couple died in their Braithwaite home. According to FEMA building inspections, only approximately 4,000 homes suffered substantial or major damage across the entire four-parish case study area (GOHSEP 2012b).

According to interviews, residents in the four parishes have historically evacuated for hurricanes and were not accustomed to experiencing, and thus preparing for, extended electricity outages. Most electricity customers experienced the full duration and impact of the outage because they did not evacuate for Hurricane Isaac and did not experience flooding. In general, customers chose to stay home because of the storm's Category 1 rating and confidence in the newly renovated federal levee system. There were only a few mandatory evacuations, occurring in areas outside of the federal levee system.

In Louisiana, Hurricane Isaac left nearly 900,000 (43%) customers without power, with the peak occurring on August 30, 2012 (USDOE 2012). This number is comparable to the power outages in Louisiana resulting from Hurricane Katrina in 2005 (800,000) and Hurricane Gustav in 2008 (1.1 million) (USDOE 2009). Multiple parishes had 90% or more customers without power. In some locations, customers were without power for more than 10 days. Plaquemines, St. Bernard, Assumption, Jefferson, and Orleans Parishes experienced the highest percentage of customers without power for the longest number of days, with Jefferson Parish experiencing the most customers without electricity. By September 4, 2012, less than 5% of the state remained without power.

Entergy Corporation (Entergy) was the electricity service provider most affected by Hurricane Isaac. Hurricane Isaac resulted in the fourth largest power outage event for the organization. In Louisiana, Isaac affected 53 parishes served by Entergy. Fifty-nine percent of Entergy's customers lost power (787,116) (Entergy Services 2013a). The majority of Entergy's outages occurred in Louisiana, exceeding 707,000 customers. Entergy has three entities serving Louisiana: Entergy New Orleans (ENO), Entergy Louisiana (EL), and Entergy Gulf States Louisiana (EGSL). ENO serves customers on the east bank of Orleans Parish. EL serves the west bank of Orleans Parish and the other parishes in the study area for this paper. The service area for EGSL spans the area between the Texas-Louisiana state line to Baton Rouge.

This study focused on Orleans, Jefferson, St. John the Baptist, and Plaquemines Parishes. EL serves the latter three parishes and a portion of Orleans, whereas ENO serves the rest of Orleans Parish. These parishes experienced widespread outages with respect to number and percentage of customers without power: 161,802 (86%), 176,978 (85%), 19,443 (98%), and 11,870 (95%), respectively (USDOE 2012). The longest power outage occurred in Plaquemines Parish, the southeastern tip of Louisiana.

Activation and Mobilization

On August 25, 2012, Hurricane Isaac was predicted to make landfall in Florida. The Entergy system command center (SCC) was activated the same day and began making logistical preparations and securing preplanned resources (Entergy Services 2013a).

The forecast on August 26, 2012 projected landfall farther west near Mobile, Alabama. Later that day, Isaac was projected to make landfall even further west at the Louisiana-Mississippi border. As Isaac's path shifted west, ENO and EL transitioned from providing mutual aid to receiving it (Entergy Services 2013a).

Entergy utilized over 12,000 utility workers and 4,000 support personnel to restore electricity across their system (Entergy Services 2013a). Restoration crews from 25 states, including 20 mutual aid companies and 138 contractor companies, deployed crews and other resources to Louisiana to assist with Hurricane Isaac restoration. The SCC initially requested approximately 4,000 mutual aid workers based on storm forecasts and damage modeling. As Hurricane Isaac slowed, damage models predicted higher damage, requiring more mutual aid. The SCC subsequently requested two additional waves of roughly 3,000 mutual aid workers to assist in restoration activities.

When Isaac shifted west to Louisiana, resources that would have arrived from their home states over a period of days arrived much closer together—within 12–16 h of each other. This led to difficulties receiving and processing crews. The secured check-in site was set up at Slidell, Louisiana (St. Tammany Parish) on I-10 near the I-10/I-12 interchange. On August 30th, the Slidell check-in site flooded. Crews were rerouted to a backup site east of New Orleans. Approximately 60% of mutual aid workers arrived from the east because they were initially routed to Florida. This coincidence proved to be a good situation because of the flooding and closing of the Lake Pontchartrain Causeway Bridge due to high winds, preventing crews from accessing New Orleans from the west and north.

Two representatives interviewed from Jefferson Parish mentioned that Entergy did not plan well for mutual aid crews. Four interviewees mentioned that Entergy did not expect to feed and lodge mutual aid crews. In the end, the housing for mutual aid crews was a great distance from the restoration sites and, according to a Jefferson Parish elected official, roughly 4 h were lost each day bussing crews to and from the sites. The same official offered Entergy the use of a local hotel to reduce the commute, but Entergy declined the offer.

Initial scouting of impacts on Entergy systems began prior to winds dying down to inform damage models and initial restoration planning (Entergy Services 2013a). Sustained winds greater than 48 km/h (30 mi/h) lasted for approximately 56 h. This resulted in a roughly 2.5-day delay before restoration efforts could begin. Federal law prohibits use of service truck buckets above the truck vendor's bucket wind rating. The buckets on Entergy's trucks were rated at 56 km/h (35 mi/h) if workers did not have tools with them and 48 km/h (30 mi/h) if they did.

On the morning of August 30, 2012, when wind conditions permitted, damage assessments began in full force (Entergy Services 2013a). Damage assessment results were reported to the SCC for determining restoration priorities and were completed on September 2, 2012. The poststorm damage assessment allowed Entergy to adjust for discrepancies between the damage model predictions and the actual damage to modify resource allocation as necessary. Aerial bucket trucks and crews were fully staged before winds dropped below 48 km/h (30 mi/h) and damage assessments were complete. Bucket trucks were first used to make repairs on August 30, 2012. No fatalities or injuries of workers resulted from damage assessment and restoration activities.

Restoration

Across all entities and service areas, Entergy Corporation's total cost of restoration is estimated between $400 and $500 million (Entergy Services 2012). The total cost of restoration for EL was $216.8 million (Entergy Services 2013b). The restoration costs for ENO was $45.8 million. The total cost of restoration for EGSL was $68.5 million.

Entergy restored power to roughly 85% of Louisiana customers 5 days after winds dropped below 48 km/h (30 mi/h) (Entergy Services 2013b). A common industry benchmark for restoration is 70% of customers within 5–7 days. This benchmark was met if the 2.5-day delay in restoration activities due to high winds was not considered.

At the end of the first day of restoration, customer outages in Orleans Parish were reduced from 158,134 to 145,652 (Entergy Services 2013a). Notably, the New Orleans central business district, which includes the French Quarter, never lost power. This greatly simplified restoration needs. By the end of September 3—the fifth day of restoration—95% of customers in Orleans Parish were restored. On September 3, 2012, 69% of customers in Jefferson Parish had power restored, leaving 63,906 customers without electricity. Service was restored to 99% of customers in Jefferson Parish by September 5–1 week after restoration began. In St. John the Baptist Parish, power was restored for 67% of customers by September 3, 2012, meaning 6,558 customers still had no service. Electricity was completely restored in the parish by September 6, 2012. In Plaquemines Parish, electricity was restored to 30% of customers (8,742 without service) by September 3, 2012. A decommissioned power plant was brought back online in Plaquemines Parish to temporarily restore electricity to the southern end of the parish. By September 6, 2012 service was restored to 77% of customers (2,848 customers). Restoration took up to 2 weeks in the severely flooded but sparsely populated areas between Braithwaite and White Ditch on the east bank of Plaquemines Parish.

Entergy experienced several challenges with the restoration process. First, few residents evacuated Entergy's service areas. Entergy was not accustomed to having the public around during large-scale restoration efforts. The presence of the public added to traffic congestion caused by road closures and high volumes of mutual aid workers on the road. (Many residents drove their cars to make use of air conditioners or purchase food and supplies.) Entergy also had difficulty accessing distribution lines in the back of customers' properties in Jefferson Parish.

Throughout the restoration process, Entergy executed a diverse public communications campaign. Entergy opened 21 customer information centers (CICs) to facilitate communication with customers (Entergy Services 2013a). There were 16 CICs open in Louisiana. Entergy's CICs answered over a million calls. The CICs made over 2 million calls to customers, sent roughly 1.4 million text messages, interacted with over 32,000 customers via social media (Facebook and Twitter), and responded to more than 500 questions through e-mail. Entergy had an interactive restoration map on their website (a feature of their outage management system), which experienced heavy use during the outage. Press releases and outage updates were provided to local media outlets.

Based on interviews, Entergy did not effectively communicate their problems concerning lingering high winds and why restoration activities were delayed, although ENO's chief executive officer (CEO) gave very long estimates for restoration times to perhaps avoid high expectations. As a result, many customers in multiple jurisdictions complained about repair trucks and mutual aid crews sitting idle as Entergy waited for winds to die down. According to Plaquemines Parish officials, parish residents saw hundreds of trucks sitting idly and were unaware of Entergy's constraints and restoration plan. Jefferson Parish–elected officials and business organizations received complaints from residents and businesses

about trucks staged just outside the parish for a long period of time.

The need for Entergy to improve their communications and public information during their next power outage was mentioned in 13 of the 19 meetings for this study. The public received information before the storm from the media, but not from Entergy. The ENO CEO provided regular restoration updates in the media once electricity was out, but EL did not provide similar updates. In general, customers did not understand that there were two different service providers (ENO and EL) and that many updates only applied to ENO customers. Multiple interviewees mentioned frustrations with Entergy's Web-based restoration map. For example, a New Orleans emergency manager said that distribution lines would "flicker on and off again" when the Web page was refreshed. Information on Entergy's website and social media streams did not reach many residents because of poor access to the Internet (not related to the power outage).

Participants in three of the five meetings with elected officials or their representatives felt that Entergy's communication with government officials was poor during Isaac. Entergy had a representative in the City of New Orleans Emergency Operation Center (EOC). Two city emergency managers felt that Entergy's representative was unable to adequately answer questions about restoration activities and plans. When requested, Entergy told the city's EOC that they could not determine the status of an individual customer's electricity service. Restoration statuses were available by substation, which was unsatisfactory to some emergency managers interviewed. A different city emergency manager mentioned that they did not have enough information from Entergy for "evidence-based decision making." The interviewee noted that Entergy's Web map only displayed distribution lines—not customer locations. It was particularly important for them to know the power status at specific addresses to determine if patients could be sent home.

Impacts

The overall impacts from Hurricane Isaac are reflected by the estimated $2.35 billion cost of damage across the affected states in the southern United States (Berg 2013). Approximately $970 million in losses were insured. These figures are approximately half of those associated with Hurricane Gustav in 2008, which was a Category 2 by the time it hit Louisiana (Beven and Kimberlain 2013). Peak unemployment claims in Louisiana were similar to those after Hurricane Gustav—approximately 10,000. Approximately half of the Hurricane Isaac unemployment claims came from the four parishes focused on for this study. Across Louisiana (21 parishes), over 263,000 U.S. Department of Agriculture Disaster Supplemental Nutrition Assistance Program (DSNAP) cards were issued, exceeding a value of $103 million. This total was approximately one-third less than that associated with Hurricane Gustav. Approximately 50% of residents in both Plaquemines and St. John the Baptist received DSNAP benefits.

Hurricane Isaac damaged or destroyed over 4,500 distribution poles, 2,000 distribution transformers, 95 transmission lines, and 144 substations across the Entergy network (Entergy Services 2013a). Approximately 11,404 cross arms were damaged or destroyed across Entergy's region—more than any other storm (Entergy Services 2013a). Hurricane Isaac damaged 90% of the conductor miles on the east bank of Orleans Parish (ENO's service area) and 97% of the conductor miles on the west bank (EL's service area).

The significant impacts described later are synthesized from interviews with study participants. In other words, the significance of impacts was determined for this case study based on the results of the interviews. Interview synthesis resulted in the emergence of three broad themes: lifeline infrastructure impacts, business impacts, and health care impacts.

Lifeline Infrastructure

There are a large variety of lifeline infrastructures that are functionally dependent on electricity and, thus, have potential to be negatively impacted by a power outage (Miles et al. 2014). These include transportation, fuel, domestic water, wastewater, and communications. Of all impacts, transportation was mentioned as the most significant in the highest number (10) of meetings (five with emergency managers, three with political representatives, and two with business representatives).

Transportation

There was significant traffic congestion during the power outage, as suggested earlier. Interviewees estimated that trips took 3–4 times longer than normal. Multiple interviewees noted that this was because the public, who did not evacuate for the most part, drove their cars to stay cool using air conditioning, search out operating gas stations, purchase food and supplies, or view damage from the storm. In all parishes, traffic light outages contributed to traffic congestion. Many large intersections with traffic light outages required reallocation of law enforcement, which accrued overtime costs for each government. Two participants attributed the increased traffic to poor planning and management around disaster food distribution centers. A local emergency manager said that congestion slowed portable generator delivery. The manager suggested that this also slowed restoration because of the difficulty in moving replacement poles through traffic. One local elected official was frustrated with the difficulties caused by traffic congestion in making deliveries of food and other supplies to nursing homes and assisted living facilities. Transit systems were only moderately impacted. For example, Jefferson Transit did not resume normal schedules until September 4.

Fuel

A significant impact raised by most study participants was limited access to gasoline during the power outage. Emergency managers, business representatives, and elected officials noted that almost all gas stations were without electricity and backup generators. This meant that nearly no station within the study area could operate pumps. A state emergency manager said that a significant cost to the state was acquiring and delivering generators to gas stations. No interviewee indicated that government agencies were significantly impacted by poor access to gasoline from private gas stations.

When asked what one lesson should be taken from the disaster in regards to lifeline infrastructure, multiple participants mentioned the need for improved access to gasoline after a future outage. An elected official, as well as a business representative, expressed exasperation about the problem because the state had previously provided financial incentives for gas station owners to purchase generators. The business representative had run multiple workshops in the past to demonstrate generators to businesses and inform them of the incentive program. The incentive program proved unpopular and unsuccessful. A state official vowed to push to require gas stations to purchase generators in the future.

Water and Wastewater

There were few impacts to domestic water systems. Within the parishes studied, there were no boil-water advisories related to the outage (loss of water system pressure due to disrupted pumps). Government interviewees attributed this to lessons learned from recent hurricanes. For example, Jefferson Parish had equipped each water pump station with a generator and a safe house to shelter one on-site employee.

Impacts to wastewater systems were mentioned in six meetings (four with emergency managers and two with elected officials). According to a representative in the Jefferson Parish Public Works Department, the power outage disabled 75% of the 550 sewer lift stations in the parish. Two lift stations in Jefferson Parish were inoperable because of not having a backup generator and not receiving a portable generator. The sewage from these stations overflowed into streets and was temporarily pumped into a nearby canal. The wastewater system of the Sewerage and Water Board of New Orleans performed well overall, with one instance of a faulty generator that led to discharge of untreated wastewater. New Orleans has a unique power source not available to other parishes: a 100-year-old 25-cycle diesel power plant. This was used to provide power continuity to water and sewer systems.

A Jefferson Parish emergency manager said that the impacts from the loss of electricity to the wastewater system were reduced based on lessons learned after Hurricanes Katrina and Gustav. For instance, unlike during prior events, wastewater system managers knew ahead of time what size and types of generators were appropriate for each of the 550 sewer lift stations. Preexisting contracts with area electricians were also in place as a result of Gustav. Jefferson Parish leased generators to operate the sewer system during the power outage. After delivery, these generators were used for roughly 2 weeks. Portable emergency pumps had also been recently purchased for use at sewer lift stations. Plaquemines Parish leased 125 generators from the state to power their sewer lifts.

Communications

Cellular phone service was minimally impacted because of extensive successful use of backup generators and batteries. AT&T did experience some cellular tower outages from either a lack of backup generators or generators not working (GOHSEP 2012a). The Plaquemines Parish School District interviewee said that their AT&T service, including short message service (SMS), was unreliable during the outage. There was minor disruption to 911 services in the small service areas associated with these generator problems. Plaquemines Parish had some difficulty keeping their communication sites operational because of an inadequate preevent supply of propane for generators (GOHSEP 2012a). Further, during the outage, they had trouble accessing additional propane supplies. Only one participant, a state-level emergency manager, stated that the lack of cable and Internet service was hard on businesses. This person suggested that there was poor communication between Entergy and the cable/Internet service provider. The minimal impacts to communication described by interviewees are consistent with similar observations by Kwasinski (2013).

Businesses

Four major themes on the topic of businesses and the economy in the case study area were prominent across the study interviews. The identified themes relate to lessons about business continuity, business assistance programs not being utilized, impacts of school closures, and the likely lack of long-term economic or business impacts.

Business Continuity

The JEDCO representative noted that the power outage hit small businesses the hardest—in particular, those without backup generators or business interruption insurance. Gas stations were the most heavily impacted business sector in Jefferson Parish, according to local elected officials. Another business sector heavily impacted because of lack of generators was grocery stores and other food-related businesses. Area grocery stores lost at least $10 million, according to an elected official. Small businesses in Plaquemines Parish generally did not have generators, according to a local economic development director. A Greater New Orleans (GNO) representative thought that area big businesses were more prepared with respect to data backup and business continuity than for Hurricanes Katrina and Rita, suggesting a lesson learned. For example, area refineries successfully used on-site backup generators to ensure continuity of life safety and critical process operations.

Business Assistance

In Jefferson Parish, the Small Business Administration (SBA) business recovery center was open for 3 weeks, but there was reportedly no overwhelming need for it. The Louisiana Business Emergency Operation Center (LA BEOC) was active for 9 days for Hurricane Isaac, giving some indication of the period of greatest need for Louisiana businesses. JEDCO offered site-selection assistance for businesses within the parish to permanently or temporarily relocate. Only one business that suffered moderate wind damage took advantage of their offer. A business recovery center was set up in St. John the Baptist Parish. The manager of the center said few businesses took advantage of the recovery center. However, a couple weeks after the center closed, several businesses complained to the same emergency manager that they did not have the resources they needed to recover.

According to SBA data, businesses across the four-parish case study area received $4.7 million in economic injury disaster loans (EIDLs). EIDLs provide support to businesses unable to meet obligations and to pay ordinary and necessary operating expenses, regardless of damage to contents or real estate. EIDL amounts totaled approximately $2.8 million, $934,000, $560,000, and $439,000 for Jefferson, St. John the Baptist, Orleans, and Plaquemines Parishes, respectively. It is impossible to determine what amount of these loans is specifically related to the power outage. However, SBA data do not show any approved EIDL for businesses in the area that did not also receive loans for damaged contents or real estate. This suggests that few, if any, EIDLs were requested specifically to assist with loss of electricity.

School Closures

School closures were the chief complaint of GNO member businesses because of the child care complications created. Schools operated by Orleans Parish School Board were reopened by September 4, 2012 after closing August 27, 2012. Schools in the southern end of Plaquemines Parish were closed for 10 days. Most Jefferson Parish schools were closed until September 6, 2012, with four closed until September 10. Several schools used mobile generators on tractor-trailers leased and arranged by FEMA. This was not arranged ahead of time. Schools could not reopen immediately after service was restored because mold remediation was required first. Many families in Plaquemines Parish temporarily enrolled their students in other schools. This was encouraged by the school district. Preemptive measures taken by Plaquemines School Board were examples of lessons learned from Katrina and Rita. When Hurricane Isaac was approaching, the district shipped food from schools to a centrally located refrigerated facility for safekeeping and immediately threw out dairy products. There were plans in place to serve nonperishable lunches if needed.

Long-Term Impacts

While many interviewees brought up issues surrounding business impacts and operations, most felt that the outage had little to moderate impact on businesses overall. Although several interviewees noted severe short-term impacts to gas stations and food-related businesses—one interviewee mentioned the finance sector, as well—none felt there would be long-term effects on the economy. Publicly available annual sales tax statistics from each of the four case study parishes do not show any decreases in revenue from 2012 to the time of writing this paper. This supports the predictions of few long-term economic effects, at least at the temporal and spatial scale of the data. A St. John the Baptist emergency manager was the only interviewee who said that there were still businesses struggling to get back on their feet at the time of the interview. However, it was not clear that he was referring to businesses only impacted by electricity loss—the parish suffered more flood impacts than any of the four parishes in the case study.

A GNO representative said that none of their member businesses reported severe impacts from the power outage, and the representative did not think there would be any long-term consequences related to the extended loss of electricity. This is somewhat related to the New Orleans central business district not losing power. The GNO study participant did express concern that reoccurring outages from hurricanes may make it less attractive for outside businesses to move to the area. A New Orleans emergency manager predicted there would be no long-term impacts to individual businesses within the parish, and noted that the New Orleans Office of Economic Development had not expressed concern. The interviewee from JEDCO did not report any major impacts to area businesses, primarily just complaints about seeing idle repair crews. The JEDCO representative said they did not expect any long-term impacts to businesses or the Jefferson Parish economy. An elected official from Jefferson Parish countered that many complaints from businesses were received, with several saying they will leave the parish if they lose electricity frequently. An interviewee from the Louisiana Business Emergency Operations Center stated that elected officials are generally overaggressive in their critique of Entergy's restoration efforts. A representative of a different Jefferson Parish elected official agreed with this assessment, saying that not all council members felt that constituent concerns warranted politicians making vocal public complaints about Entergy.

Health Care

A third major area of impacts described by study participants relates to health care facilities and services. Hospitals in New Orleans remained open but, in many instances, discharged patients with less serious conditions (GOHSEP 2012a). New Orleans emergency rooms saw an increase in volume during the power outage. Some of the increased volume was related to people who rely upon powered medical devices and were seeking assistance.

For the most part, health care facilities faired much better in Hurricane Isaac than they did in Hurricanes Katrina, Rita, or Gustav, according to interviews. In this case, there was far less physical damage to facilities. However, as a result of less damage and the fact that there was not a large-scale evacuation, more electricity-related issues arose or were perceived. Acting on lessons learned from past hurricanes, there was a nursing home coordinator at Louisiana's Department of Health and Hospitals (DHH) during the outage, as well as within the City of New Orleans EOC. These coordinators facilitated communication and helped identify resource needs for impacted nursing homes.

The aspects of health care mentioned by participants include hospitals, nursing homes, assisted living facilities, and home health care. Two major themes were identified by study participants and are described in turn in the following sections: backup generators and facility evacuation.

Backup Generators

The use of existing generators within hospitals was generally successful. Hospitals were prepared with 2–3 days of fuel to power backup generators prior to Hurricane Isaac making landfall. According to DHH representatives, area hospitals anticipated a loss in electricity due to Isaac and so started up their generators before the hurricane hit, avoiding, for the most part, loss of service. The delivery of a portable 10-mW generator by DHH was required to deal with a failed generator at a Tier 1 hospital in the study area. Several Tier 2 hospitals did not have generators to power their HVAC system and thus were not occupiable during the outage.

DHH stated that 59 (21%) of the state's nursing homes, with over 6,000 residents, relied on backup generators for some period. In New Orleans, at least two required evacuation as a result. By September 5, 2012, all nursing homes had returned to normal electricity operations. Similarly, 36 hospitals used backup generators and, as a whole, were back to normal operations by September 3, 2012. In the media, the mayor of New Orleans explicitly expressed concern about the lack of adequate generators or generator fuel for Tier 2 hospitals, nursing homes, assisted living facilities, and low-income senior housing.

Reportedly, few assisted living facilities had generators during Hurricane Isaac. Of nursing homes with backup generators, several had generators that were not adequate for operating their air conditioning systems. Interviewees said that several nursing homes and assisted living facilities requested backup generators from local officials. Once generators were acquired, lack of fuel became a problem because few facilities had fuel contracts in place prior to the outage. Multiple study participants pointed out that the lack of air conditioning due to the outage was problematic in nursing homes and assisted living facilities, particularly in high-rise residences. Of nursing homes with backup generators, several did not have ones that could support the load of their air conditioning systems or that ran out of fuel.

After Hurricane Katrina, lower-tier health care facilities—nursing homes, outpatient, and assisted living facilities that do not have emergency services—were encouraged by emergency managers and Entergy to purchase generators. Multiple interviewees—elected officials, emergency managers, and Entergy representatives—said that many such health care facilities had not purchased generators by the time Hurricane Isaac occurred. As a result, several of these facilities requested and received portable backup generators from FEMA or DHH during the outage.

Private dialysis centers typically have no requirements for backup electricity. However, private dialysis centers did well in Hurricane Isaac, according to New Orleans Department of Health. Dialysis centers registered their patients and were aware of their individual needs. Based on past hurricane experience, many centers performed *predialysis* before the storm to allow people to go without power for a little longer. Employees from the dialysis centers worked extra shifts to get patients in and out efficiently prior to landfall. Last, dialysis centers tend to be near hospitals and had service restored quickly.

Evacuation

For Hurricane Isaac, 10 hospitals were evacuated. The storm led to the evacuation of 21 nursing homes and hospitals in total, affecting nearly 1,100 patients (Greenstein 2012). The majority of the evacuations took place before the storm. The state (DHH) opened five medical special needs shelters during Hurricane Isaac that served over 400 residents (Greenstein 2012). The special needs shelters

run by New Orleans Department of Health served 143 residents. None of the shelter occupants were the result of health care facility evacuations.

Although many hospitals and nursing homes had evacuation plans, executing the evacuation was still complicated, as told by state and local health officials. It took time to determine what types of patients were at each facility, how the patients and staff would be transported, and whether the receiving facility could accommodate the increased patient load or had electricity.

Nursing homes worked together to track evacuation needs and, in some instances, procure supplies. Many nursing homes in Plaquemines Parish did not have generators and were evacuated. The nursing home residents in Plaquemines Parish evacuated to a naval base 1–2 days after the storm hit. In New Orleans, the fire department attempted to help nursing homes evacuate, but many residents stayed and suffered the heat, according to local emergency managers. DHH representatives said that no nursing homes evacuated to state-designated special needs shelters.

The likelihood that many owners of assisted living facilities did not take appropriate action prior to or following Hurricane Isaac, such as evacuation planning and assistance, was mentioned in a majority of the study meetings. Several assisted living facilities did not evacuate and ran out of generator fuel within 2 days. In New Orleans, many assisted living facilities refused help from the fire and health department to evacuate. In Jefferson Parish, high-rise assisted living facilities were evacuated and one resident died from heat stroke, based on the account of one local elected official. Health officials said that many dialysis centers set up mutual aid agreements to facilitate patient transfers.

A public health emergency manager noted that many people did not have medical emergencies appropriate for emergency care facilities; they had "power emergencies." During the power outage, many electricity-dependent individuals left their personal homes and attempted to claim admittance to hospitals and emergency rooms to operate their medical devices. Notably, hospitals do not receive revenue for sheltering people and often lose money from admitting large volumes of people to power medical devices.

During the outage, libraries were used as electricity shelters for people to charge their oxygen and other medical devices. This was done to lessen the need for evacuation, as well as the burden on emergency room and ambulance operators. Unfortunately, the idea of library charging centers came about near the end of the outage. People were also encouraged to use Red Cross shelters during the day to charge devices.

Discussion

Synthesis of the previously described Hurricane Isaac case study results in several significant observations and potential lessons. These are relevant for researchers, decision makers, emergency managers, and electricity service providers. Key observations from this case study are extracted and discussed in this section.

The power outage, restoration process, and impacts described earlier led to broad, vocal criticism of Entergy and, in turn, the two service providers in the study area: ENO and EL. The criticism is interesting given the responses by interviewees for this study. Interviewees repeatedly mentioned three major impacts from Hurricane Isaac related to lifeline infrastructure, businesses, and health care. Overall, lifeline impacts were relatively small. Long-term business and economic impacts were not a major concern of interviewees. Health care impacts related to backup electricity and evacuation were somewhat significant. However, this was not a common public complaint by customers or elected officials after the storm based on interviews and news media coverage. Emergency managers and elected officials interviewed from several jurisdictions had wide-ranging recommendations for Entergy to improve their restoration process. Based on this study, it is hard to fully support an argument that Entergy restored electricity unusually, negligently, or adversely slow. Conversely, it is easy to justify an argument that their coordination and communication of their restoration plans and activities with elected officials, emergency managers, and customers had significant room for improvement to increase awareness and reduce inconvenience.

Most of all, this case study reinforces the critical nature of communication between electricity service providers, decision makers, and customers. Although there were some notable impacts from the power outage—remembering that impacts were caused nearly exclusively by the outage—interviews, after action reports, and constituent email correspondences provided by elected officials focused most on aspects of communication. The relative lack of fervor on the part of interviewees while they enumerated impacts from the hurricane was somewhat surprising. There seemed to be an attitude that the tangible impacts caused by the outage were less of an issue than simply having to go without electricity and the consequent inconveniences and disruptions to daily activities.

There was some dissatisfaction expressed by several interviewed emergency managers and elected officials in regards to Entergy's communication with them or information provided to them. Given that there have been multiple major outage events in the area over the past decade, it is perhaps surprising that this issue persists—at least to the degree suggested. It appears that the most frequent complaint had to do with timing, clarity, and detail of restoration time estimates, as well as responsiveness to requests for prioritization of specific critical facilities. Emergency managers relied on information from Entergy's outage management system (OMS) as it was delivered via their interactive Web-mapping system. Although Entergy's OMS is among the most popular systems commercially available, there was notable dissatisfaction by users of the system other than Entergy.

The issue of idle repair trucks and the appearance of inactivity by Entergy stood out as the largest factor in people's negative perception of the power restoration. There was a commonly shared opinion that Entergy did not do anything when repair crews had to wait for winds to die down. When asked what Entergy could do better in the future, multiple interviewees said that Entergy should have been doing damage assessment during that time. According to Entergy (and government reports), they were doing damage assessment (to the extent legally possible) during that time. In a report to the Louisiana Public Service Commission, Entergy lamented in retrospect that their scouting vehicles were not marked clearly enough for the public to realize damage assessments were taking place early on. Something as simple as large decals on vehicles could have reduced the perceived impacts or inconvenience of the power outage and restoration time (Entergy Services 2013a).

Another subtle but important example of crossed wires between Entergy and customers is the arithmetic used in calculating outage times and, thus, restoration performance. Entergy and the U.S. DOE touted the restoration response as better than industry standard, calculating restoration times from the point that work crews could go up in buckets to make repairs. Entergy informed the media that the Hurricane Isaac restoration was their fastest and safest restoration to date for any major outage. The Deputy Assistant Secretary for Infrastructure Security and Energy Restoration of the DOE also publicly stated that Entergy's restoration speed was "unbelievable." In recognition of this, Entergy received the 2012 Emergency Response Award from the Edison Electric Institute (Entergy Services 2013a).

The math used by Entergy and the DOE to arrive at the award-winning restoration speed was not the same math used by decision makers and customers. The time to restore electricity was calculated by customers based on the entire length of the experienced loss. Those experiencing the outage saw restoration as taking at least 2.5 days longer than publicly communicated by Entergy. Although it is true the 2.5-day delay was out of the control of Entergy, few people seemed to understand this. Had Entergy been more clear and descriptive of the challenges while they were occurring, customers may have been more accommodating. Such misunderstandings can have real impacts on power companies, such as large fines and pressure for upper-level management to resign.

Entergy did eventually realize the need to improve their communications with all parties. This was acknowledged during interviews for this study and in their reports to both the Louisiana Public Services Commission and New Orleans City Council. Immediately after restoration was completed, Entergy representatives met with business groups to explain what happened and what Entergy and their customers could do in future disasters. Interviewees felt that these efforts were very successful and well received. It remains to be seen whether Entergy will maintain this outreach strategy. However, they certainly understand the effectiveness of it and can serve as a model for other power companies. At least one local emergency manager interviewed was committed to ensuring Entergy continue what the manager saw as a critical practice.

Entergy intended to gather additional input on the most effective ways to communicate with customers using surveys, focus groups, and neighborhood meetings with a broad range of people. Entergy stated that they would distribute prestorm plans more widely to regulators, elected official, EOCs, and the media in the future. Entergy interviewees realized that public communications in advance of an anticipated storm are especially important when there is no mandatory evacuation.

Recommendations

Several lessons and recommendations can be drawn from this case study, which are highlighted in the following paragraphs. The overarching lesson should be that evaluating the observed impacts of electricity outages and restoration performance from past disasters pays off. Nearly all of the study participants argued that the New Orleans area was better prepared to deal with Hurricane Isaac in general, and specifically the loss of electricity, because of experiences from Hurricanes Katrina, Rita, and Gustav. Even though residents did not evacuate, as many have for recent past hurricanes, the impacts of being without electricity for several days were not large.

The major themes identified for this case study relate to lifeline infrastructure, businesses, and health care. Apparently, the most frustrating lifeline impact for political representatives and emergency managers was the resultant increase in traffic congestion. Avoiding or reducing postevent traffic congestion requires traffic management planning and measures that assume customers will use their private vehicles to improve their comfort and access resources during events where large-scale evacuations are not mandatory. Hurricane Isaac also highlights the need to improve electricity continuity using a wide range of technical, political, and organizational strategies. In the context of Hurricane Isaac and other studied outages, improving power continuity for health care facilities, private gas stations, and food-related businesses seems to be a priority area for policy development (Miles et al. 2014; Davies Consulting 2012). The findings of this case study illustrate the importance of all aspects of communication and awareness raising before, during, and after power outages.

The issue of gas stations and lack of access to fuel is a common refrain during power outages. Miles et al. (2014) noted a similar problem for the 2011 San Diego outage, as well as the 2011 Great East Japan earthquake. Based on interviews related to the San Diego case study, the most unexpected and unplanned-for impact was related to access to gasoline and the serviceability of gas stations. Miles et al. (2014) recommended offering incentives for gas stations to purchase backup generators. The Hurricane Isaac case reveals it may not be that simple, because such an incentive program had been offered in Louisiana and was largely unsuccessful. As a less-expensive option, quick connects for portable generators could be required by the state to reduce the difficulty in installing portable backup generators delivered during an outage. Additionally, preexisting contracts could be required for generator delivery in the case of disasters. Of course, this approach would increase competition for backup generators at a time when critical facilities are in need. However, the level of disruption caused by lack of access to gasoline may warrant such measures. Regardless, the critical role of fuel in the immediate aftermath of a disaster is such that jurisdictions need to prioritize efforts to promote power continuity at private gas stations.

Nursing homes potentially need to upgrade their generators and have more fuel for their generators. Backup generators need to handle the appropriate load to ensure that facilities are more functional, such as the operation of HVAC systems. Unfortunately, according to public health emergency managers, health care and other critical facilities in New Orleans should assume electricity might be out for approximately 2 weeks during any year; they should plan and prepare accordingly. New programs or regulations specific to assisted living facilities are needed. Interviewed public health emergency managers said this would be a priority for them following Hurricane Isaac. Financial incentives could be offered to nursing homes and assisted living facilities to purchase backup generators. However, past success with incentives for gas stations suggests such incentives would have to be part of a broader strategy. In addition, or alternatively, regulations or best practices for improved evacuations and patient transport for certain types of facilities can be put in place to reduce and centralize demands for generators. Whether for health care facilities, gas stations, or other types of businesses, concerted policy research can play a large role in understanding how to improve the likelihood that key business sectors have sufficient capacity or access to backup power during severe outages.

The practice of temporary *electricity shelters* or collective charging stations is worthwhile for emergency managers and hospitals to develop further. Offering such shelters for the public to recharge devices could reduce unnecessary burdens on health care facilities. These types of practices could be analyzed and promoted in the future by researchers, service providers, and emergency managers.

Research is needed to understand the needs of emergency managers and customers and how outage management systems can be improved with respect to what information is provided and how. For example, the spatial resolution of restoration data provided to emergency managers was cited as a frustration, as well as the reliability of the system itself. If it is technically feasible for Entergy and other companies to provide higher spatial resolution, it is hard to imagine why this should not be done. If it is not technically feasible (or is undesirable), this needs to be clearly explained to decision makers well ahead of a disaster.

Similarly, the ability of power companies to prioritize particular areas or facilities is often constrained by characteristics of the power system (e.g., location of power generation and configuration of the distribution network) or restoration protocol (e.g., complete all damage assessment prior to any repairs). Entergy and electricity

service providers in general need to ensure two-way communication to explain what is possible and acknowledge efforts to address prioritization requests. Entergy's experience suggests that service providers can do more to educate customers and decision makers, including emergency managers, about how power systems function, what is possible in the restoration period (e.g., technical and legal constraints), their preevent plans, and descriptive updates of challenges and progress during the restoration period. This is not an uncommon situation across the power industry. Davies Consulting (2012) notes that "customers, elected officials, and other external stakeholders have not been adequately educated on restoration practices or engaged in developing restoration priorities" (p. 64).

The time to educate customers about technical and legal details is before a disaster, rather than during. For example, customers need to understand that unnecessary use of roads can lengthen their loss of electricity. Targeted public awareness campaigns can help customers understand what to expect when they experience extended loss of electricity, as well as what restoration entails and requires on the part of electricity service providers and emergency managers. Research into how customers and political leaders are impacted by, perceive, and react to major outage events and the restoration activities associated with them can help emergency managers and service providers design and conduct their messaging and awareness-building efforts, whether before or after an event.

The final recommendation apparent from this case study is the need for additional and more wide-ranging research on large-scale electricity outages and restoration, whether due to technical failure, terrorism, or natural hazards. Many of the aforementioned recommendations will be difficult to achieve without both qualitative and quantitative data collection, analysis, and cross-case synthesis. Perhaps most critical is the need for social scientists to engage the subject from a sociotechnical perspective, particularly in the context of interdisciplinary research with engineering scholars.

Acknowledgments

This work was supported by National Science Foundation Infrastructure Systems Management and Extreme Events Rapid Response Research (RAPID) Award #1313597.

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