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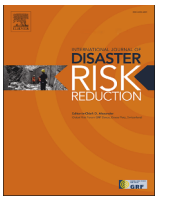

# Far from home: Infrastructure, access to essential services, and risk perceptions about hazard weather events

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ABSTRACT

This study explores the role of access to essential facilities and emergency services during hazard weather events in shaping individuals' risk perceptions. We develop a framework in which residents' views of required actions facing extreme weather are influenced by their level of access to essential facilities to obtain medical and emergency services. The effect of access is complemented by perceptions about the status of local infrastructure conditions as enabling access. Using a sample of Texas residents collected during April 2021, we demonstrate the role of restricted access and views of local infrastructure conditions as important predictors of increased concerns during natural disasters. The results demonstrate the effects of factors such as access and status of local infrastructure on the risk assessments of individuals in vulnerable communities who face increased risks from extreme weather. Accordingly, the findings advance our understanding of the unexplored relationship between access of essential facilities and risk perceptions, and could inform disaster managers and public officials regarding the importance of evaluating access as an element of public risk perceptions facing extreme weather events.

## 1. Introduction

The year 2021 was particularly deadly for Americans dying from extreme weather events, as indicated by 538 people having lost their lives (National Center for Environmental Information, NOAA website[1]). During extreme weather, the ability to access emergency and essential services is critical. An October 2021 threat assessment report from *First street foundation* (a nonprofit organization dedicated to increase the visibility of climate risks) detailed how risks to Americans during extreme weather events are exacerbated by inadequate infrastructure conditions. In their assessment, the authors of the report highlight that limited access to utilities, emergency services and transportation increase the dangers to victims, who in turn view those services as providing important and essential protection.[2]

At their core, hazardous events place substantial stress on citizens due to risks from extreme weather. Barriers to obtaining help when needed, or accessing essential services further amplify those concerns. In this research, we explore an under-studied aspect that drives public risk attitudes and behaviors during natural hazards - the degree of access victims have to essential services during an extreme weather event. We focus on access and investigate how limited access, and the related inadequate infrastructure conditions, af-

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[1] https://www.ncdc.noaa.gov/billions/summary-stats/US/2021, Website Accessed December 16th, 2021.
[2] https://www.bloomberg.com/graphics/2021-flood-risk-critical-infrastructure/, Website Accessed December 18th, 2021.

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fect residents' risk perceptions regarding required actions when severe weather strikes. Using a public opinion survey of Texans collected in April 2021, we test how variations in residents' access to essential services lead to different risk assessments for engaging in life-saving actions facing natural hazards. Given Texans' exposure to major extreme weather events (such as Hurricane Harvey and Winter Storm Uri) over the past five years, this study region provides a proper context for data collection and analysis.

Our empirical approach leverages both perceptual type measures regarding the status of infrastructure conditions, as well as objective indicators of access to emergency and essential services. In the empirical analysis, we explore how those factors influence the views of residents about essential actions such as getting to the pharmacy, or more emergency type actions such as getting to a hospital or evacuating if necessary. We also conduct an in-depth investigation of vulnerable individuals who may face more restrictions in terms of access, and compare their views to those individuals in less at-risk communities.

Our results suggest that access to services and views of the status of existing infrastructure are important elements in the development of extreme weather-related risk attitudes. In particular, those who face greater limitations in access, such as living in areas with lower availability of essential services, are substantially more concerned about their ability to rely on those services during extreme weather scenarios. These effects are more intense among the highly-vulnerable citizens who report greater difficulties in accessing essential services, and who consider the local infrastructure conditions as inadequate. For these individuals, the degree of concern about getting to a hospital or evacuating can be 25–35% higher than citizens in less vulnerable communities.

The results demonstrate the importance of underlying factors such as access and the status of infrastructure conditions in driving public risk attitudes. Our findings offer important theoretical contributions to the literature that explores the social and behavioral angles of natural hazards. In addition, we point to areas that governments should consider additional investment in to reduce the risks for residents, and enhance communities' resilience in the face of growing number of regional hazard events.

## 2. Societal risks and infrastructure disruptions

Research on societal vulnerability and infrastructure in the context of natural hazards explores both technical and behavioral aspects. On the engineering side, scholars explore various services and their underlying dependencies, offering methods to improve their ability to withstand disasters [1–4]. From a social-behavioral standpoint, researchers investigate disruptions of infrastructure services and how those lead to the emergence of risks for individuals, primarily among vulnerable populations [5–12].

One of the most important drivers of variations in vulnerability to risks during natural hazards is preparedness. Studies demonstrate how low preparation by various population groups increase the risks for being harmed due to disruptions to infrastructure services [6,13,14]. In order to capture variations in risks, previous researchers developed measures like the *Social Vulnerability Index (SoVI)* which shows how factors such as socioeconomic status and demographic variables affect the degree of risk some groups face [15]. In recent work [16], develop the *Disruption Tolerance Index (DTI)* that offers a spatial measure for residents' susceptibility to infrastructure services' disruptions. Beyond these types of measures, studies have shown that vulnerability to infrastructure disruptions is associated with multiple demographic and socioeconomic factors [17–19].

## 3. Hazard events and risk perceptions: an infrastructure-centric approach

One aspect that supports the expansion of research on the societal aspects of infrastructure disruptions is the integration of citizens' risk perceptions into the analysis. For instance, recent work [19] accounts for the gap between expectations of infrastructure services, and their actual performance during hazard events. The analysis demonstrate how demand for services, preparedness level, past experience and risk-related information acquisition drive variations in public views during high-risk scenarios (see also, [20].

We propose an approach that accounts for some of these factors, but places more focus on an area that has received less attention - citizens' access to essential services during high-risk scenarios such as floods, storms, etc. The vast majority of work in the context of infrastructure access and hazard events address the spatial distribution of services by answering technical questions about proximity to important services (hospitals, grocery stores, gas stations) and the roadway grids that lead to these locations. Researchers develop models of the environment with the objective of offering solutions to improve accessibility and thus, reduce risks and vulnerabilities [21,22].

The concept of *access* in hazard events refers to the ability of residents to rely on existing infrastructure to reach essential facilities and obtain services such as health care, fuel, and groceries. In the literature, the social aspect of access is explored within the framework of equitable access as crucial to developing *community resilience* facing exacerbating risks due to climate change [23–27].

In our view, the role of infrastructure is even more critical. In every citizen's daily life, deficient infrastructure that creates access delays or hardships is a nuisance. However, hazard events constitute a risk amplifier and increase citizens' concerns about infrastructure capacity and access, primarily to emergency services. We propose that individuals' perceptions about storm-related risks are shaped by their degree of access to critical and emergency facilities and essential services. In other words, those who face more challenges in terms of access are more likely to express higher levels of concern about their safety during hazard events, including safe access to emergency services or being able to evacuate if necessary.

According to this view, access to emergency and/or essential services is one central factor that drives risk perceptions during hazard events. A complementary element that shapes individual perceptions is views about the *status of existing infrastructure*. By status, we refer to a qualitative evaluation of the infrastructure as enabling access, and the capacity of these services to meet demands or expectations [19].

In public policy research, citizens' opinions of government services are an important factor. Many studies test public assessment of services using the citizen satisfaction framework that includes clear evaluation of services [28–30], or using the Expected-Disconfirmation model (EDM) in a variety of services [31,32,33,65]. We expect citizens' views of the status of infrastructure services

to be an important predictor of their levels of concern. Primarily, those who view the existing infrastructure as lacking or ill-equipped to handle disruptions such as strong weather systems are likely to report increased concern with respect to required actions such as getting to a health care facility or evacuating to safety.

## 4. Modeling access and status into risk perceptions

We propose an approach that combines the effect of two infrastructure related factors: access and status. Therefore, residents who face challenges in access to essential services, and view the status of infrastructure as poor are likely to be more concerned during high-risk conditions. Those individuals would be mostly worried about their ability to engage in potential live-saving behavior such as obtaining essential and emergency services, and in more extreme cases, evacuating to safety.

While our model emphasizes the role of access and status of infrastructure services in shaping risk perceptions, we account for two additional factors that are important in the natural hazards literature. First, *personal/past experience*. The logic behind this factor is that living in an area with frequent natural hazards, or having experienced hazard events personally make the issue more salient and increase individuals' concerns and willingness to act. Studies have shown the effects of personal experience on general attitudes with respect to climate change [34–36], risk perceptions and actions due to climate concerns [37–39], and natural hazards in particular [17,40–42]. For our purposes, we expect that personal experience further exacerbates concerns about infrastructure access and poor status facing natural hazards.

Second, as our model explores citizens' views of public policy, trust in government is a critical component [43,44]. As a whole, citizens' evaluations of public actions are often contingent on their level of trust in government [45,46]. During hazardous scenarios, this effect is magnified [47,48], and we expect that those who trust the government to care for their needs would display lower levels of concern even when facing restricted access and negative views of infrastructure status. As a summary of our conceptual model, Fig. 1 below provides an illustration of the various drivers of risk perceptions facing extreme weather events.

### 4.1. Measuring public services

Research on public policy and services assess their quality by focusing on performance measures [49]. While some focus primarily on perceptual measures of performance [50], others use objective indicators [28,29,51]. In this context, some researchers suggest using an integrated approach that relies on both objective and subjective measures as a way to overcome risks of self-reporting, social desirability, positivity and common source bias [52,53,63,64]. Our approach borrows from this latter view and we use both perceptual and objective measures. In particular, we use survey responses regarding views of the status of local infrastructure in the context of hazard events, highlighting the most glaring problems. In addition, we rely on measures that fit the objective type by asking respondents to report the duration of drive time from their place of residence to local essential services and facilities.

## 5. Research design

We assess public views and risk perceptions in the context of infrastructure and access using a public survey of 610 Texas residents administered on April 2021.[3] In terms of demographic and individual characteristics, our sample consists of 49.6% men and 50.3% women, and the average age is 52 years old (most respondents are between 40 and 65 years old, the IQR). Most of our respondents (72%) hold either a bachelor's or some college degree, and 19% have a high school diploma. 40% of the respondents rated themselves as somewhere on the conservative scale, 33% are moderates and 23% fit to different liberal categories. From a partisan preference, 48% are republicans and 47% are democrats.[4]

Texas has experienced multiple extreme weather events (such as 2017 Hurricane Harvey, 2019 Tropical Storm Imelda, and the 2021 Winter Storm Uri) during the past five years; thus, it provides a suitable study region to examine our research questions. By exploring the relationship between various measures of access and perceptions about status, we show the critical role played by these factors on citizens' risk perceptions regarding natural hazards.

### 5.1. Dependent variable: individual risk perceptions

In our main analysis, we evaluate citizens' risk perceptions about their ability to obtain essential and emergency services. Measurement of risk perceptions is debated at length in the literature, as scholars highlight the multi-dimensional nature of the concept [54–56].[5] One central dimension is consequences – the negative outcomes of something of value given exposure to a hazard [56]. We follow this approach as our focus is the effects of access and infrastructure conditions on the behavioral consequences of a hazard event. In that sense, we measure risk perception by highlighting the views about required behavior following an exposure to a hazard (see also [57,58]).

Considering our approach to measuring risk perception, we rely on several indicators from the survey. The survey items ask respondents how likely they think several disaster-related actions/services in their community will be available to them in emergencies. Responses are given on a 1–4 scale (from "Not likely at all" to "Very likely"). As our focus is emergency-type services, we leverage

[3] Ipsos Public Affairs (Ipsos) conducted this Texas public opinion survey of adults 18 years and older. The survey was in the field from April 26, 2021 through May 6, 2021. The sample was drawn from Ipsos' web-enabled KnowlegePanel®, a probability-based panel designed to be representative of the U.S. population. The survey was offered in English. The survey consisted of 147 question-items. A total of 1200 surveys were fielded. The completion rate of 51% yielded 610 completed surveys. The median survey completion time was 15.65 min (full details on recruitment of participants is available in Appendix C in the online supplementary files).

[4] Full details of all sample characteristics are provided in Table 1A in Appendix A of the online supplementary files.

[5] Dimensions explored include probability, severity, vulnerability, susceptibility and more.

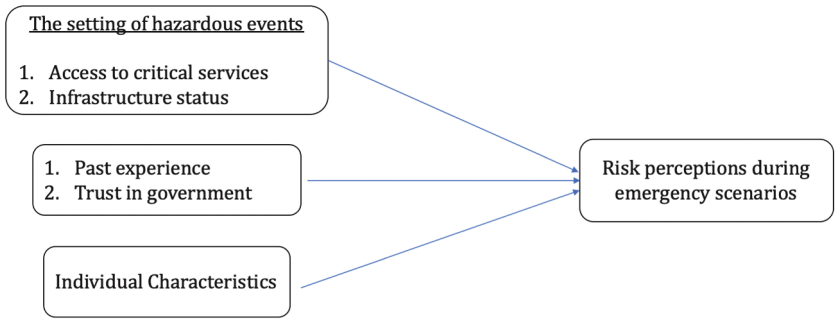


**Fig. 1.** Conceptual model.

items that ask about needing to evacuate, emergency services response, and being able to reach essential facilities such as a hospital and a pharmacy.

### 5.2. Independent variables: access and status

The central explanatory factors are the extent of access to emergency services or facilities, and the status of local infrastructure. We employ both objective and subjective type measures in order to conduct a broader test of our theoretical concepts. We measure the access concept with objective-type items from the survey. Our objective measure asks respondents how long it takes them to travel to certain locations from their residence. Responses are measured in minutes. We collect information about the *duration of travel* to two critical locations: the closest pharmacy, and health care facility. To reduce concerns about potential bias of this measure, we ask respondents for the duration of travel on a *routine daily* drive, not during emergencies. This offers an objective proxy for access from respondents' residence to different services and locations.

We account for the concept of status of local infrastructure using subjective measures. Those are survey items that ask respondents how much do certain aspects cause *infrastructure disruption* in their community (thus restricting access to essential services). Responses are measured on a 1–4 scale (from "Not a problem at all" to "Very serious problem"). In order to capture the important role of status in this context, we focus on two evaluative aspects: the level of infrastructure maintenance, and its capacity to deal with the demands of severe weather events. Focusing on these two aspects tap into the role of local infrastructure as enabling or limiting access during emergencies such as natural hazard events.

### 5.3. Control variables

Previous research on public policy demonstrates that citizens' opinions on government issues (such as infrastructure quality) depend on their level of trust in government. Such a factor may play a more important role in high-risk situations such as natural hazards. Therefore, we control for this factor using survey items that ask respondents to rate their levels of trust in the local (state) and federal government. Responses are rated on a 1–5 scale (from "Strongly distrust" to "Strongly trust").

We also control for personal or past/prior experience of hazards. We measure it using a survey item that asks: "Over the past five years, have you experienced any flooding in your area?". Responses are binary (either "Yes" or "No"). As a complement to the survey item, we add spatial data from FEMA and USGS [59] that indicate whether the local area (measured at the census tract level) was inundated during hurricane Harvey (summer 2017). We match this information to respondents' location and use a binary indicator *Harvey Affected* ("Yes" or "No").[6]

Lastly, we control for a host of individual factors that can shape public views about natural disasters. Primarily, we control for respondents' age, education level, gender, income level, political ideology and partisan preference.

## 6. Results

In the empirical analysis, we use a variety of items from the survey to assess our main question: do changes to the degree of access to emergency services lead to variations in the level of concern regarding obtaining these services during hazard events?

First, we present the variables used in our analysis. Table 1 displays the summary statistics of all indicators used, by their type.

### 6.1. Natural hazards and infrastructure access and status

In the main analysis, we explore how access, as well as public views of the status of local infrastructure, shape respondents' concerns about the risks and disruptions during hazardous events. We assess the effects of our *access* and *status* independent variables on the risk perceptions of survey respondents regarding several infrastructure disruptions. We employ OLS regression models with all the

[6] This measure is viewed as complementary as it accounts for the local census tract (area) and is not necessarily an indication that a certain survey respondent experienced damages, only the area in which she/he resides.

**Table 1**
Summary statistics.

| Variable | N | Mean | Median | SD | Min | Max |
|---|---|---|---|---|---|---|
| **Dependent Variables** | | | | | | |
| Concern: Evacuate | 604 | 2.634 | 3 | 0.832 | 1 | 4 |
| Concern: Delay emergency response | 607 | 2.815 | 3 | 0.793 | 1 | 4 |
| Concern: Get to pharmacy | 608 | 2.520 | 3 | 0.855 | 1 | 4 |
| Concern: Get to healthcare facility | 604 | 2.618 | 3 | 0.817 | 1 | 4 |
| **Independent & Control Variables** | | | | | | |
| Access: Travel time to pharmacy (min.) | 596 | 8.513 | 5 | 7.853 | 0 | 120 |
| Access: Travel time to healthcare facility (min.) | 599 | 13.382 | 10 | 9.505 | 0 | 70 |
| Status: Inadequate maintenance | 606 | 2.982 | 3 | 0.793 | 1 | 4 |
| Status: Insufficient capacity | 605 | 2.863 | 3 | 0.823 | 1 | 4 |
| Past experience | 608 | 1.586 | 2 | 0.493 | 1 | 2 |
| Harvey Affected | 610 | 0.250 | 0 | 0.433 | 0 | 1 |
| Trust: local government | 606 | 2.901 | 3 | 0.927 | 1 | 5 |
| Trust: federal government | 605 | 2.759 | 3 | 1.037 | 1 | 5 |

relevant factors, results are displayed in table 2.[7] Overall, across all four model specifications, we find evidence for the effects of both objective and subjective measures of access and status on the degree of concern with regard to infrastructure disruptions during emergency scenarios.

**Table 2**
Natural hazards risk atttiudes - OLS Regression models.

| | Dependent Variables: Concern during hazard events | | | |
|---|---|---|---|---|
| | Pharmacy (Model 1) | Hospital (Model 2) | Emergency Services (Model 3) | Evacuation (Model 4) |
| *Access: Time to pharmacy* | **0.022***** (0.004) | **0.013**** (0.004) | **0.017***** (0.005) | 0.007 (0.005) |
| *Access: Time to healthcare facility* | 0.005 (0.003) | **0.015***** (0.004) | 0.001 (0.003) | **0.007*** (0.004) |
| *Status: Maintenance* | **0.173***** (0.048) | **0.132**** (0.046) | **0.202***** (0.046) | **0.12**** (0.048) |
| *Status: Capacity* | **0.117**** (0.044) | **0.147***** (0.043) | **0.137***** (0.042) | **0.162***** (0.045) |
| *Past Experience* | **0.273***** (0.068) | **0.279***** (0.065) | **0.126*** (0.064) | **0.199***** (0.068) |
| *Harvey Affected* | **0.244**** (0.076) | 0.116 (0.073) | **0.214***** (0.072) | **0.253***** (0.076) |
| *Trust: State Govt.* | **−0.084*** (0.038) | **−0.071*** (0.037) | **−0.107***** (0.036) | −0.059 (0.038) |
| *Trust: Federal Govt.* | **0.084*** (0.037) | 0.057 (0.036) | **0.071**** (0.035) | **0.136***** (0.038) |
| *Age* | **0.004*** (0.001) | **0.004**** (0.002) | −0.001 (0.001) | **0.003*** (0.002) |
| *Education Level* | −0.041 (0.038) | −0.026 (0.037) | 0.013 (0.036) | −0.02 (0.038) |
| *Gender* | 0.096 (0.064) | 0.099 (0.062) | 0.002 (0.062) | **0.155***** (0.065) |
| *Income* | 0.006 (0.021) | −0.001 (0.021) | −0.007 (0.021) | −0.012 (0.021) |
| *Political Ideology* | −0.015 (0.032) | −0.001 (0.031) | −0.043 (0.031) | **−0.068**** (0.032) |
| *Partisanship* | −0.01 (0.022) | 0.001 (0.022) | **−0.038*** (0.021) | **−0.057**** (0.022) |
| *Constant* | **1.312***** (0.358) | **1.363***** (0.342) | **2.047***** (0.338) | **1.548***** (0.352) |
| *Observations* | 579 | 576 | 580 | 576 |
| $R^2$ | 0.229 | 0.23 | 0.198 | 0.189 |

Notes: *p < 0.1; **p < 0.05; ***p < 0.001.
Standard errors in parenthesis.

We begin with the less extreme scenario and assess how measures of access and perceptions of status shape residents' views with regard to their ability to get to the pharmacy (model 1). The objective measure of drive time (access) to the pharmacy is positive and significant suggesting that the longer is the routine commute to the pharmacy, the higher is the level of concern about getting to the pharmacy under dangerous weather conditions. We find that the level of concern increases by more than 4% when the drive time doubles from five to 10 min. This rate of increase in concern doubles again (to 9%) when drive times extends from 10 to 20 min to the closest pharmacy.

We also find strong effects for the perceptual measures of the status of local infrastructure. For example, when views regarding *Inadequate maintenance* shift from "Not a problem at all" to "A very serious problem", the level of concern about being able to reach the local pharmacy increase by 24%. Even a less extreme shift on maintenance views, from "Not a problem at all" to "Somewhat of a problem" triggers a 16% increase in concerns about disruptions that limit access to the pharmacy.[8]

[7] Recent studies [60] suggest that despite the ordinal nature of survey responses, OLS models offer many benefits when studying survey-based risk attitudes. To complement the main analysis, we run a set of robustness tests by replicating all four models using an ordered logit model specification. Overall, results are consistent., see Table 2A in Appendix B of the online supplementary files.

[8] Shifts in views along the other perceptual measure (the Insufficient capacity item) also demonstrate substantial increases in concern about being able to access the pharmacy.

In model 2, we explore the effects of the access and status indicators on residents' concerns about disruptions that restrict their ability to reach a local health care facility. This model tests a more dangerous scenario in which residents may sustain physical harm and are in-need of medical help. As in model 1, we find that both objective and perceptual measures shape degrees of concern. First, both drive time measures are positive and significant pointing to growing concerns about getting to a hospital for those who face longer drive times to a local pharmacy and/or a nearby health care facility. For instance, when the routine drive time to the local health care facility increases three-folds, from five to 15 min, the associated increase in concern about getting to a hospital during an emergency is more than 6% higher. In other words, a prolonged drive time predicts increased concern regarding risk-related disruptions that make it harder to get to a hospital when needed.

Second, the perceptual measures of status are also positive and significant suggesting that among residents who view the infrastructure as needing greater attention, the concern about relying on such services to reach the hospital is higher. For example, when views regarding *Insufficient capacity* shift from "Not a problem at all" to "A very serious problem", the level of concern about being able to reach the closest hospital increases by almost 19%. The results of models 1 and 2 demonstrate that both access and status are central to residents' perceptions in the more common scenarios when residents need to use essential services facing hazardous weather events.

Models 3 and 4 explore more severe cases, when victims of natural hazards require the assistance of emergency services or must evacuate due to extreme conditions. For both of these models, the objective measures are less powerful. Results show that reported drive time to the pharmacy predicts variations in the level of concern about emergency services being able to reach individuals' residence. Drive time to health care facility has a weak ($p = 0.09$) positive effect on concern regarding evacuation.

The perceptual measures of infrastructure status are significant and positive. With regard to emergency services, when views of insufficient maintenance change from the lowest value (" Not a problem") to the highest (" Very serious problem"), the level of concern about emergency services being able to reach a resident's house increases by over 25%. The increase in concern is about 16% when assessing views regarding the capacity of local infrastructure. These results suggest that individuals who perceive increased risks due to infrastructure disruptions during hazardous events are substantially more concerned about the ability of emergency services helping them if the situation requires it.

Model 4 accounts for difficulties to *evacuate* when necessary. In this extreme case, the subjective measures offer stronger predicted changes in residents' risk evaluations. In particular, the more concerned individuals are about the status of local infrastructure, the more worried they are about the prospect of evacuation. The weaker effects in model 4 can be a function of the unique nature of an emergency action such as evacuation. Nevertheless, the persistence of the effects of both objective and subjective measures in more extreme cases (as in models 3 and 4) increase our confidence in the argument that the conceptual factors of access and status play a prominent role in determining citizens' concerns facing severe weather scenarios.

Taken together, the results of the main analysis suggest that residents' risk perceptions facing hazardous events are influenced by underlying factors such as the extent of access and status of (enabling) infrastructure. The less confident individuals are of the capacity of local infrastructure, the more concerned they are about a variety of behavioral consequences they may need to undertake facing extreme weather conditions.

### *6.2. Past experience*

Research on natural hazards has shown a substantial role for past exposure to hazardous events as driving the views of individuals. In our analysis, we include a dichotomous variable that indicates whether respondents experienced a flooding event in their area of residence.

The effect of this factor is consistent across all four models. Having suffered through a hazard event has a strong positive effect on citizens' concerns. With respect to emergency actions such as getting to the pharmacy or a hospital, those with no past experience report a concern level which is between 11 and 12% lower than respondents who experienced a hazard event in the last five years. For the more extreme actions like evacuation, having previous experience of extreme weather event increases one's reported concern by approximately 8%. We added to our survey the *Harvey Affected* binary indicator (based on spatial data on the census tract area suffering damages during hurricane Harvey). The results of this measure are consistent across most models and show that residents in areas that were inundated report higher concerns about behavior during and post-hazard events.

### *6.3. Trust in government*

Our analysis demonstrates the crucial role that access and views of local infrastructure have on public concerns during emergencies such as natural hazards. While these factors play a central role in driving public opinion, research also suggests that when citizens need public services, their degree of trust in government also affects their perceptions. The main expectation is that those who place greater trust in the government to provide required services when needed will be less concerned during times of emergency.

Our empirical analysis accounts for this factor by including measures of trust in local and federal governments in all models. The results are significant in their effects but mixed in terms of direction. As such, we discuss each level of government separately. First, in three of the four models, the coefficients for trust in local government (defined as 'state government') are negative indicating that those who trust local government services are less concerned during hazard events. At the same time, for three of our models, the effect of trust in federal government has the inverse effect. Trust in federal services (e.g. agencies such as FEMA) is associated with an

increase in concerns about behavior during risky scenario. It is possible that past events in which federal agencies appeared less than competent drive these reactions.[9]

Finally, we also control for individual demographic characteristics. Overall, few factors display consistent effects. Age is positive (albeit small in size) suggesting older respondents are more concerned about their expected behavior during risky situations. This makes sense as older residents may find it harder to evacuate and act quickly in times of need. We find additional effects in the evacuation scenario (model 4). First, gender has a positive effect indicating that women report higher levels of concern when it comes to severe actions such needing to evacuate. Second, when contemplating the need to evacuate, conservatives and republicans report lower levels of concern compared to liberals and democrats. Those results fit with general views of climate change-related issues which are less of a concern among conservatives and republicans [36].

## 7. Limited access: An in-depth investigation

The main analysis demonstrates the effect of access and status of infrastructure on residents' concerns about the availability of services during an emergency scenario. While the effects are prevalent throughout the population, it makes sense that these effects would be enhanced among the more vulnerable residents, those who live further away from emergency and essential facilities.

To test this proposition, we split our respondents' sample and explore the views of those who are likely to have more challenges to obtain emergency services. We focus on our two central objective access measures - drive time to a pharmacy and to a health care facility. To identify our vulnerable respondents' sub-sample (those most likely to face access challenges), we focus on respondents whose drive time to either facility surpasses the 75th percentile in the data. As such, our sub-sample consists of 73 respondents who reported drive times that are longer than 10 min to the closest pharmacy, and 15 min to a nearby health care facility. To further amplify the effect of limited access and problematic status of the existing infrastructure, our analysis investigates the average levels of concern for each of our dependent variable indicators only among those who perceive infrastructure status problems as either "Important" or "Very important".

Fig. 2 displays the mean level of concern across all four actions (evacuation, emergency services arrival, getting to the pharmacy and a hospital) for those who rate the status of *Inadequate maintenance* as either important or very important. In each of the panels, we add a dashed line to represent the mean value of concern for this action among the less vulnerable respondents (the rest of the sample). The most evident finding in this figure is that the average level of concern among the more vulnerable group (those who are more restricted in access to essential and critical services) is higher across all emergency actions.

We calculate the difference between the average concern in our vulnerable and less-vulnerable sub-samples and find substantial differences. For instance, among those who rate the status of infrastructure as "Important", their average level of concern is between 14 and 18% higher than the less vulnerable sub-sample for the less severe actions (getting to the pharmacy/hospital).

These differences are larger for those who see inadequate maintenance to infrastructure as "very important". Among respondents of the 'more vulnerable' sub-sample, the level of concern for critical actions such as evacuation and arrival of emergency services is about 20% higher. The gaps are larger for the actions of getting to the nearest pharmacy (27% higher) and hospital (approximately 33%).

We run a similar analysis for the status item of *Insufficient capacity*. The results are depicted in Fig. 3. The four panels display the mean level of concern across the different actions facing hazard event (including the dashed lines for mean value in the less vulnerable sub-sample). The results of this analysis complement and support the previous one. Citizens that face more restricted access and lower availability of essential and emergency facilities report increased concerns compared to the full sample.

We calculate the gaps in reported concern and find, similar to the analysis in Fig. 2, that residents with limited access report concern levels that are 20–26% higher for actions of getting to a pharmacy and hospital. For the more extreme actions of evacuation and arrival of emergency services, reported concern is 8.5% and 16.3% higher respectively.

## 8. Discussion

The empirical analysis leverages both subjective and objective measures to assess the effects of infrastructure-related disruptions on public views of the risks during hazard events. In particular, we focus on the effects of access and infrastructure services status (or conditions) to explore how both shape the risk perceptions of citizens in the face of severe weather scenarios, and if they would need to engage in actions such as getting to essential or emergency facilities, and even evacuate.

Our data included objective measures of access - the duration of drive time from a resident's home to the nearby pharmacy or health care facility. We find that this factor is significant and shapes perceptions. Primarily, individuals whose residence is further away and they face more challenges to access essential services are more concerned about being able to rely on such services when needed. The results are consistent and meaningful across various types of behaviors including getting to the pharmacy or a hospital, as well as emergency services being able to reach to individuals' premises. We find that when the estimated drive time to a facility doubles in duration, there is an associated increase in risk perception regarding the capacity to obtain emergency services. The results of the objective indicators are important and add to recent work that rely on such measures to study public policy [29,52].

To complement the objective measures, we use subjective items that account for views about the status of the infrastructure. We focus on description of deficient maintenance or inadequate capacity to deal with extreme weather. Our results indicate that those who view the infrastructure in bad shape are more worried about the various actions needed during a natural hazard. Across all mod-

[9] For example, one can imagine that citizens are worried that by the time federal services such as FEMA will arrive on the scene, it will be too late for a safe evacuation.

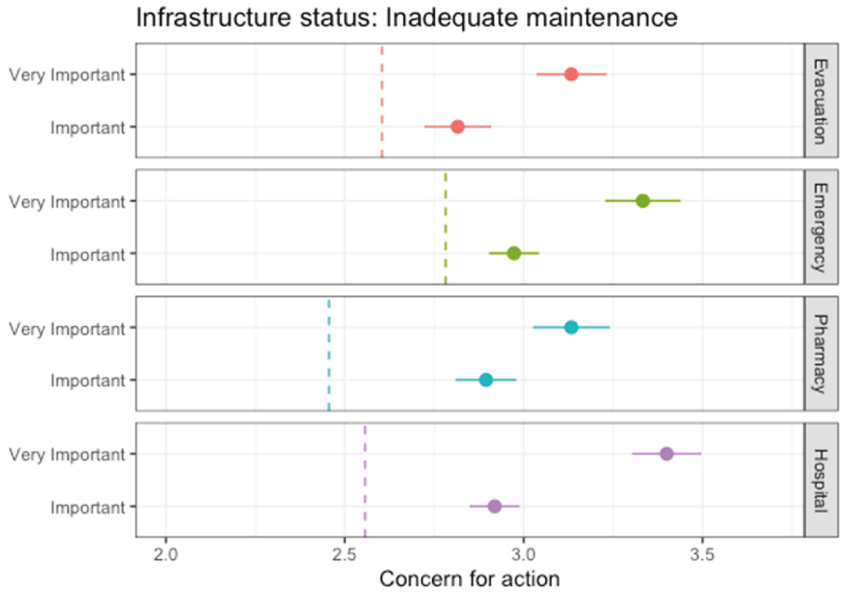


**Fig. 2.** Infrastructure disruptions risk attitudes facing hazard events – comparing vulnerable and less vulnerable sub-samples (a).

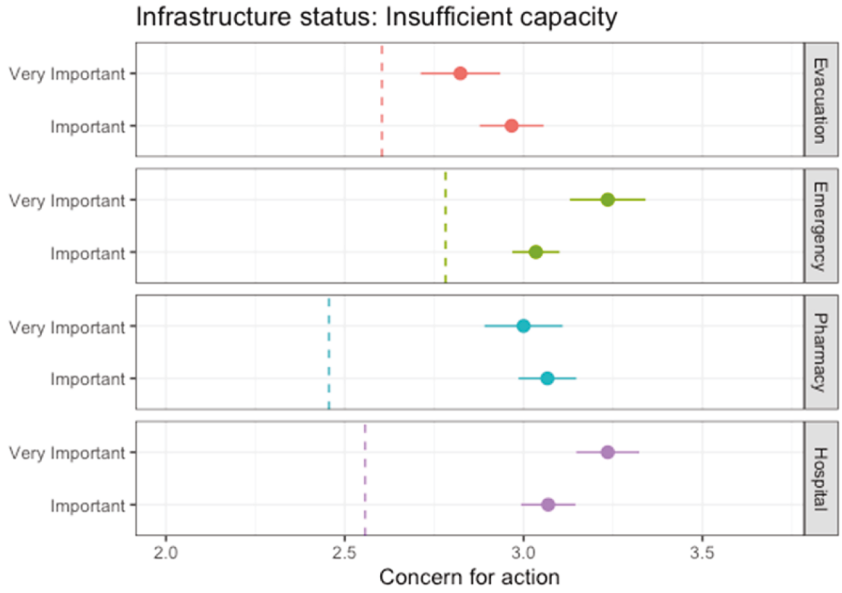


**Fig. 3.** Infrastructure disruptions risk attitudes facing hazard events – comparing vulnerable and less vulnerable sub-samples (b).

els, when views of infrastructure conditions shift from low to high, the associated concern increases by values that range from 14% to 25%. The findings for both types of measures point to the need to place more emphasis on issues of enabling or facilitating access in the context of community resilience [24,27]. In addition, we provide a social-behavioral angle that complements the extensive work on the infrastructure accessibility [21,22].

The analysis in this study provides evidence for the relationship between infrastructure conditions and access and public opinion during hazard events. We go beyond these general findings and conduct an in-depth analysis of a more vulnerable portion of the population by exploring the views of those who face greater challenges in terms of access to essential and emergency services. We test the risk-related views of residents who are in the top 25th percentile in terms of limited access (drive time to services is longer) and compare them to the less at-risk portion of the sample. Our findings reveal the enhanced effect of restricted access. Residents who live in these areas, and view infrastructure conditions as inadequate are more likely to be concerned about their actions during a risky scenario. The higher levels of concern are anywhere from 10% to 12% to as high as 33% higher reported concern than the less vulnerable sub-sample. These findings provide further support for the important role that proper access and infrastructure maintenance have on public views in the face of natural disasters.

While our study places most emphasis on the role of access and status of infrastructure, we also account for two other central factors that drive public views in the context of hazard events. First, we find a substantial effect for past experience that increases risk perceptions for both extreme actions such as evacuation, and less so like getting to the pharmacy. As a whole, our findings correspond with most of the literature about the role that past experience plays in shaping public opinion with regard to natural hazards [17,34–36,40,41].

Second, our analysis also demonstrates that trust in government has a role in public views. We distinguish between two levels of government and show that trust in local leadership reduces concerns, while higher levels of trust in the federal government increase concerns. These results point to the separate roles that citizens see for local and federal officials when addressing natural hazard events. Mostly, the local level is more relevant for such scenarios while federal agencies may be involved only in very extreme situations. That gap may be part of the explanation for the variations we find in public reactions.

## 9. Conclusions

In this study, we expand the research on natural hazards and public attitudes regarding the risks associated with a hazardous event by focusing on an under-explored element - the ability of residents to reach essential and emergency services as reflected in the concept of access. We also discuss the status of local infrastructure and demonstrate that those who face more challenges in the sense of access are prone to display higher risk perceptions during extreme weather situations.

We complement the analysis by showing that those views are exacerbated among individuals who judge the status of local infrastructure as inadequate or poorly maintained. Our analysis also shows that the more vulnerable residents display substantially higher concerns about required actions such as getting to the nearest pharmacy or hospital. These views hold and are more profound for more extreme actions such as the need to evacuate facing severe weather conditions.

The results of our study have several implications to research on the behavioral aspect of natural hazards. From a theoretical standpoint, our emphasis on factors such as access and status of infrastructure complements the literature by highlighting the role of implicit elements that are rarely viewed as central until disaster strikes. We show how living in locations where availability of essential services is restricted underlie public attitudes in the sense of becoming more worried when hazard events transpire, making it a critical aspect for future research. Second, we follow work in public administration and integrate subjective and objective measures of access and status into the analysis of risk attitudes. The consistency of the results based on both types of measures provide stronger validity to our research design and reduces concerns about potential biases for studies that primarily rely on perceptual measures for assessing risk attitudes. Third, the vast majority of work in the context of infrastructure and natural hazards explore technical angels. We complement those studies by focusing on the behavioral-social aspect of infrastructure and access in shaping public view of risks when facing hazard events.

The study also has practical implications for policymakers. In particular, it points to the need of local governments to invest in infrastructure maintenance and ensure sufficient capacity to deal with hazard events such as severe floods and storms. Facing poor conditions, residents become very concerned if/when they need to rely on essential services. This is even more profound for the vulnerable portion of the population who reside in more remote locations and whose life rely more directly on adequate infrastructure. Our survey analysis also shows that trust in local government is essential to reduce those concerns and thus local officials should increase efforts to design policy solutions that mitigate those public concerns.

Despite the encouraging results of our work, there are a few limitations that future studies can improve. Primarily, our survey data was collected in Texas. The ramifications of extreme weather are not unique to Texas, and we discuss hazard events that are common across the US, therefore the results should be generalizable for the average American. In addition, recent work on natural hazards use similar type of samples [19,41,61,62,67]) and those studies offer important insights on public views of extreme weather. Nevertheless, a broader sample which covers multiple US states can offer more benefits and more generalizable results, and future studies should study issues of access and infrastructure using a national sample of Americans.

The year 2021 was a very deadly one for Americans dying from natural hazard events (more than 530 fatalities)[10]. The conditions of local infrastructure are a critical underlying factor in public views of the risks and concerns about their ability to rely on these services in weather-related emergencies. This research has shown that even a basic aspect such as access to essential and emergency services is a critical driver of public attitudes during such emergencies. As governments shift plans to place more emphasis on solutions to reduce the risks from climate change, investing in adequate infrastructure and ensuring safe access to all citizens is important for life-saving actions when hazard events take place.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

[10] USA_today November 2021. Link: https://www.usatoday.com/story/news/nation/2021/11/09/u-s-weather-deaths-2021-deadliest-year-since-2017/6353312001/

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## Appendix A. Survey items text

Table 3 below present the text of all survey items used in this study. We also present the proportions and frequency of responses (by categories).

**Table 3**
survey items text, proportions and frequencies

| Variable type | Text in survey | (1) Not likely at All | (2) Not so likely | (3) Somewhat likely | (4) Very likely | Did not answer |
|---|---|---|---|---|---|---|
| Dependent Variable | In a storm related emergency, how likely do you think it is that each of the following will happen in your community? - Difficulty getting to a pharmacy | 10.8% (66) | 39.3% (240) | 36.3% (222) | 13.1% (80) | <1% (2) |
| | In a storm related emergency, how likely do you think it is that each of the following will happen in your community? - Difficulty getting to health care facilities | 7.8% (48) | 35.5% (217) | 42.1% (257) | 13.4% (82) | <1% (6) |
| | In a storm related emergency, how likely do you think it is that each of the following will happen in your community? - Delays in emergency response | 5.9% (36) | 24.4% (149) | 51.3% (313) | 17.8% (109) | <1% (3) |
| | In a storm related emergency, how likely do you think it is that each of the following will happen in your community? - Difficulty evacuating | 7.0% (43) | 37.8% (231) | 38.3% (234) | 15.7% (96) | <1% (6) |
| | | (1) Not a problem at all | (2) Not so much of a problem | (3) Somewhat of a problem | (4) A Very serious problem | Did not answer |
| Independent Variable - Status | How much of a problem do you think the following potential causes of infrastructure disruptions are in your community? - Inadequate maintenance | 3.6% (22) | 21.3% (130) | 47.7% (291) | 26.7% (163) | <1% (4) |
| | How much of a problem do you think the following potential causes of infrastructure disruptions are in your community? - Insufficient capacity | 4.7% (29) | 27.0% (165) | 44.4% (271) | 22.9% (140) | <1% (5) |
| | | 25th percentile | Median (50th percentile) | 75th percentile | Maximum Value | Did not answer |
| Independent Variable – Access (min.) | About how many minutes does it typically take to travel one-way between your home and the closest Pharmacy | 5 | 5 | 10 | 120 | 2.2% (14) |
| | About how many minutes does it typically take to travel one-way between your home and the closest Healthcare facility | 6 | 10 | 15 | 70 | 1.8% (11) |

| Variable type | Text in survey | Yes | | No | | | Did not answer |
|---|---|---|---|---|---|---|---|
| Control variable – Past Experience | Over the past five (5) years, have you experienced any flooding in your area? | 41.3% (252) | | 58.3% (356) | | | <1% (2) |
| | | (1) Strongly distrust | (2) Distrust | (3) Neither distrust nor trust | (4) Trust | (4) Strongly trust | Did not answer |
| Control Variable - Trust | How much do you distrust or trust the following types of organizations? State Government | 6.2% (38) | 26.8% (164) | 39.1% (239) | 24.5% (150) | 2.4% (15) | <1% (4) |
| | How much do you distrust or trust the following types of organizations? Federal Government | 13.4% (82) | 24.5% (150) | 36.8% (225) | 20.9% (128) | 3.2% (20) | <1% (5) |

## Appendix BSupplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijdrr.2022.103185.

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