THESIS

# EFFECTS OF WEATHER-RELATED DISASTERS ON U.S. HIGHWAY, STREET AND BRIDGE CONSTRUCTION SECTOR LABOR MARKETS

Submitted by

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## ABSTRACT

# EFFECTS OF WEATHER-RELATED DISASTERS ON U.S. HIGHWAY, STREET AND BRIDGE CONSTRUCTION SECTOR LABOR MARKETS

The U.S. has been experiencing the increasing effects of disasters, both in frequency and economic losses. Disaster damages to U.S. transportation infrastructure systems cause hundreds of millions in direct and indirect economic losses annually. Hundreds of miles of highways, streets and bridges are damaged every year due to severe storm events and are particularly vulnerable to flood damage. The urgency to repair and reconstruct these road networks after disasters creates a sudden demand shock for construction industry services and labor. The term demand shock is used throughout this thesis to indicate changes in the demand for labor due to exogenous factors like weather-related disasters. The researcher hypothesizes that the rapid increase in construction labor demand after disasters influences labor wages within the highway, street, and bridge construction sector (NAICS 237310) labor market. Specifically, this study proposes to answer the following research questions:

*RQ1: How does post-disaster labor demand shock affect the highway, street, and bridge sector?*

*RQ2: How do State-level socioeconomic conditions influence post-disaster labor demand shock?*

*RQ3: How can the highway, street and bridge sector anticipate post-disaster labor demand shock?*

This research provides the quantitative assessments of how post-disaster demand for construction services can influence labor market wages in the highway, street and bridge construction sector. Results indicate labor costs spike after disasters, information that could help

local and state governments to plan for post-disaster reconstruction project costs. This research can also help contractors bidding on roads and bridge reconstruction projects to include more accurate costs for labor wages. The study of labor demand helps in assessing the current status of labor market and its capacity in supporting the post-disaster reconstruction.

# ACKNOWLEDGEMENTS

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Thank you

Sudip Shrestha

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Weather-related Disasters: Weather-related disaster events are the destructive events caused due to the natural processes of the earth and through indirect environmental impacts of human actions. For example, flood, tsunami, storms, hurricanes, fires, snowstorms, etc. Specific weather-related disasters selected for this research and the process are explained in the methods section of this research.

Demand Shock: A sudden change, either increase or decrease, in the demand of goods and services because of an external event is known as demand shock.

Labor Demand Shock: Labor demand shock, in this research, refers the strain in the labor market of a particular state due to external factors. External factors in this research are the weather-related disaster events.

State-Level Socioeconomic Conditions: This terminology is used in this research to broadly incorporate the factors that indicate the existing socioeconomic and demographic circumstances of the state. The specific parameters for this research are selected based on the literature review. For e.g.: GDP, Population, Unemployment rate, etc.

# 1 INTRODUCTION

The U.S. has been experiencing the increasing effects of weather-related disasters, both in frequency and economic losses (Hopkinson, 2019a; Olsen & Porter, 2013). Public transportation infrastructure systems are particularly susceptible to damages caused by floods, hurricanes and severe storm disasters (National Research Council, 2008; US EPA, 2016). In addition to direct damages (e.g., the cost to repair or replace damaged infrastructure components), communities suffer widespread indirect economic losses (e.g., business interruption, decline in revenue collection) when transportation infrastructure systems are closed or inaccessible after a disaster (Gall et al., 2015; Simpson, 2014). Thus, the swift recovery of transportation infrastructure systems, including highway, street, and bridges, is vital for post-disaster community economic redevelopment and recovery (Boyd et al., 2014).

However, more than a decade after the Great Recession of 2008, the U.S. construction industry is still experiencing labor shortages. The lack of skilled workers available to fill open job positions is one of the greatest challenges facing the U.S. construction industry (Goodrum 2004). In fact, about 80% of the construction firm respondents reported difficulty finding craft workers in the recent 2019 survey by the Associated General Contractors (AGC) and Autodesk (AGC & Autodesk, 2019). According to the Bureau of Labor Statistics (BLS), the U.S. construction industry had over 200,000 unfilled positions as of December 2019. The number of open jobs in construction has been growing over the past decade and is expected to be more than 747,000 by 2026.

The effects of construction industry labor shortages are exacerbated by the increasing annual frequency and severity of severe weather-related disasters occurring throughout the U.S. (Doyle, 2017). Demand for construction services rapidly increases after disasters, but infrastructure repair and replacement work must be completed by the limited supply of construction contractors in the labor force (Arneson et al., 2020). Although the speed and cost of post-disaster reconstruction depends on the regional availability of labor, material and capital resources (Arneson et al., 2020), post-disaster project costs are driven primarily by the price of labor rather than the market price of materials (Olsen & Porter 2011).

The urgency to repair and reconstruct transportation infrastructure systems after disasters creates a positive demand shock for labor in the construction market (Chang-Richards et al., 2015). In this thesis, the term 'demand shock' is used to indicate changes in the demand for labor due to exogenous factors like weather-related disasters. Demand shock causes additional stress on the construction industry which is already facing a labor supply deficit. This increase in the labor demand sometimes results in increased labor wages (Pelling et al., 2002). In addition to the rising wages, labor force deficits may cause project schedule delays, indirectly increasing the cost of post-disaster reconstruction.

Because of the seemingly important role of the labor market in post-disaster reconstruction, Olsen & Porter (2011) suggested that our collective understanding of why the cost of construction increases after disasters can be explored with improved quantitative analysis of post-disaster labor markets. However, a review of the literature indicates that nearly all studies of labor markets in post-disaster reconstruction have focused on the residential construction sector. Few if any studies have provided a quantitative analysis of post-disaster labor markets for the U.S. highway, street, and bridge construction sector.

## 1.1 Problem Statement and Research Gaps

- Existing literature on post-disaster labor markets focuses almost exclusively on residential housing reconstruction and the residential construction sector.

- Some researchers have analyzed pre-disaster unemployment rates in relation to post-disaster labor wage changes. They recommend analyzing other variables such as disaster relief funding, gross domestic product, and consumer expenses when studying labor market phenomenon after disasters.
- With uncertainty in the labor market behavior in the wake of a disaster, projects are often over budget and reconstruction costs are increasing every year. A study of labor market behavior after disasters would help provide more accurate estimates for future post-disaster construction projects.

## 1.2 Research Questions

Based on the existing gaps in the literature, this thesis addresses the following three research questions.

*RQ1: How does post-disaster labor demand shock affect the highway, street, and bridge sector?*

*RQ2: How do State-level socioeconomic conditions influence post-disaster labor demand shock?*

*RQ3: How can the highway, street and bridge sector anticipate post-disaster labor demand shock?*

## 1.3 Thesis Organization

This thesis is organized into five chapters. Chapter 1 includes an introduction, problem statement, research gaps, and research questions. Chapter 2 is a literature review which explores the background on weather-related disasters, disaster damages, the reconstruction process in the U.S., and post-disaster funding mechanisms for public highway, street and bridge projects. Although this research focuses specifically on post-disaster labor demand shock within the highway, street and bridge construction sector, much of the literature about demand shock is pulled from the broader body of knowledge about transportation systems. Chapter 3 includes a description of the research methodology, data sources, and the data analysis process. Results are presented in Chapter 4 and the thesis concludes with Chapter 5.

# 2 LITERATURE REVIEW

## 2.1 U.S. Disasters and Damages

The U.S. has been experiencing the increasing effects of weather-related disasters, both in frequency and economic losses (Hopkinson, 2019a; Olsen & Porter, 2013), as presented in Figure 1. In fact, there is a 5% increase in aggregate disaster losses every year (A. B. Smith & Katz, 2013). Every year, the U.S. is struck by weather-related disasters that cause direct infrastructure damages and indirect economic losses worth billions of dollars. The National Center for Environmental Information (NCEI) data shows that the U.S. was hit by approximately 285 severe weather and climate disasters since 1980 to 2019 which caused direct damages of more than $1 billion individually (NCEI, 2019) adjusted for inflation with CPI, 2019.

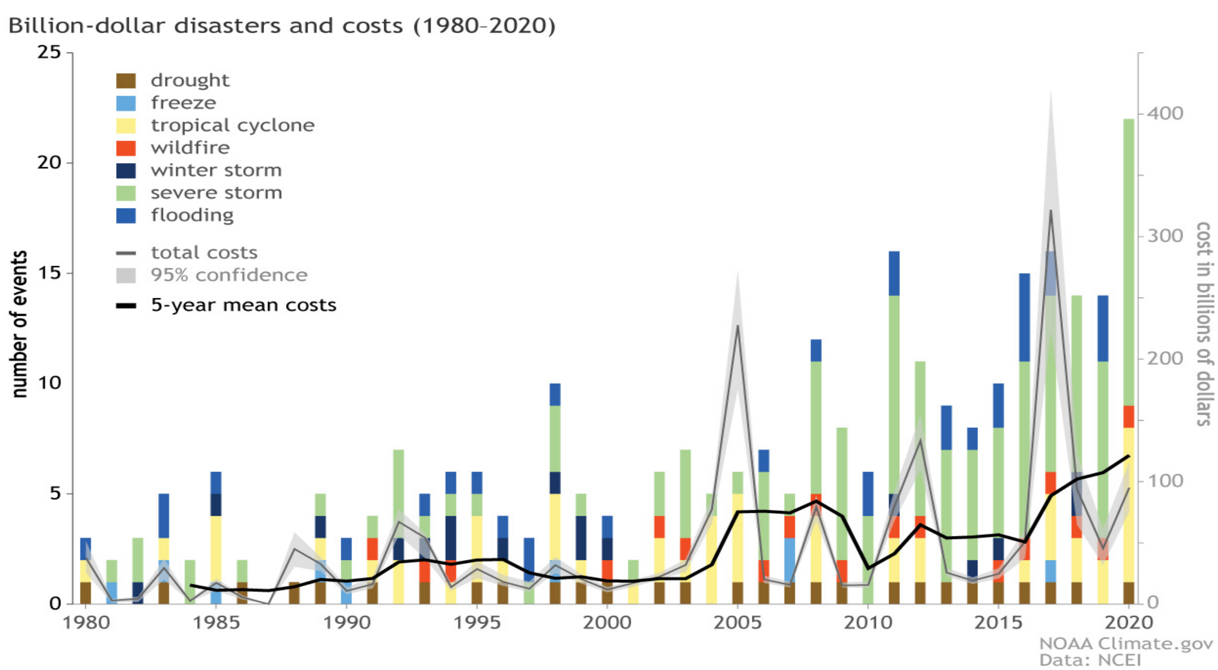


*Figure 1: Number of disasters (left), Total annual damage (right) by year from 1980 to 2020 (data including only billion-dollar disasters) source: https://www.ncdc.noaa.gov/billions/*

These same records show that the average frequency of billion-dollar weather and climate disasters has increased from 3 per year in the 1980s to 12 per year in this decade as summarized in Table 1 (NCEI, 2019). These billion-dollar disasters accounted for 80% of the direct damages from weather-related disasters during the 30-year period, even when accounting for inflation (A. B. Smith & Katz, 2013).

*Table 1: Damages by billion-dollar disaster events in the U.S. (Adjusted for Inflation)*

| Decade | No. of events | Total cost of damage | Average no. of events per year | Average annual direct damages |
|---|---|---|---|---|
| **1980s** | 29 | $171.1 billion | 2.9 | $17.1 billion |
| **1990s** | 53 | $274.0 billion | 5.3 | $27.4 billion |
| **2000s** | 62 | $519.0 billion | 6.2 | $51.9 billion |
| **2010s** | 119 | $810.5 billion | 11.9 | $81.0 billion |

### 2.1.1 Impact of Disasters on the U.S. Highway, Street and Bridge Construction Sector

Weather-related disasters frequently damage U.S. transportation infrastructure systems, including highway, street, and bridge infrastructure assets. Although the U.S. road transportation system has a hierarchical mesh structure and is not highly susceptible to localized disruptions, highways and streets are much more vulnerable to wide-scale disruptions such as flood or hurricane disaster events. Additionally, the road transportation system is reliant on connecter infrastructure assets such as a bridges,  which are also prone to flood-related disaster damages (Rodrigue, 2020). Hundreds of miles of highways, streets and bridges are damaged by disasters every year, and are particularly vulnerable to floods, hurricanes and landslides (National Research Council, 2008; US EPA, 2016).

Disaster damages range from minor to catastrophic. Minor damages are limited to a partial or complete blockade of transportation networks for limited periods of time immediately after a disaster, with networks operational after debris removal. Catastrophic damages occur when transportation networks suffer severe damage or complete destruction, requiring millions of dollars for repair and reconstruction. Additionally, the time for reconstruction of transportation infrastructure tends to be slower than other infrastructure types such as telecommunication and electric power systems (Rodrigue, 2020). This time factor also plays an important role in evaluating the damage in transportation infrastructure systems and its indirect impact (Simpson, 2014). In addition to the direct damages to transportation infrastructure systems, network disruptions cause sustained economic losses for the surrounding disaster-affected region.

i. Direct Damages

Direct damages are the immediate losses due to disaster and include physical and structural impacts on the roads and bridge infrastructure systems because of earthquakes, floods, or hurricanes (Sarmiento & Miller, 2006). The total cost of damages by Hurricane Katrina in August 2005 is estimated to be $161.0 billion (CPI adjusted, 2021) (NOAA, 2021). This includes the physical damages caused by the disaster on buildings, infrastructure systems, agriculture products, etc. A more specific estimation shows that Hurricane Katrina damaged bridges of more than $1.4 billion, adjusted for inflation (Padgett et al., 2008). Similarly, Hurricane Florence in 2018 cost $476.1 (CPI adjusted) million in direct damages to transportation infrastructures in the state of North Carolina. Of that amount, $359.9 million was in highway, roads and bridges sector while the rest was in rail, ports and aviation (Cooper, 2018). In 1993, Midwest flooding caused over $250 million (CPI adjusted) of direct damages to roads and bridges (US FEMA & Galloway, 1994). These amounts show that flood and severe storm disasters cause a substantial damage to transportation infrastructure systems.

ii. Indirect Losses

Indirect losses are the delayed losses and secondary impacts caused by direct damage such as: business interruptions, decline in revenue collection, and disruptions to flow of goods and services (Gall et al., 2015; Simpson, 2014). Pelling et al. (2002) implies that there is fault in how the economic impacts of disasters are reported which mainly show estimates of direct costs as replacement value of damaged infrastructure systems but do not incorporate indirect economic impacts (Buckle et al., 2001; Vermeiren, 1989). An overall consideration of direct damages with indirect losses would amount to be much higher than expected (Simpson, 2014).

A study by Arkell & Darch (2006) on the impact of climate change on transport networks in London suggests that traffic disruptions caused by floods on main roads are estimated to cost £100,000 ($135,560) in indirect losses every hour during peak hours. Similar study conducted by Larry Wesemann et al. (1995) on the 1994 Northridge earthquake in California indicated that the indirect losses due to travel disruptions and delays in Los Angeles, CA amounted to more than $2.8 million per day (adjusted for inflation).

## 2.2 Post-Disaster Recovery Process for Highway, Street and Bridge Reconstruction

Restoration of transportation infrastructure systems is considered as an important aspect of post-disaster recovery plan including housing recovery, economic redevelopment, environmental restoration, social recovery, etc. (Boyd et al., 2014). The robustness and recovery of road transportation system depends on the performance of highway, street, and bridges. The recovery of the transportation systems after a disaster also aids in the economic recovery and social well-being of the community (Zhang et al., 2017). But the time for reconstruction of transportation infrastructure tends to be slower than other infrastructure types. For example, after the 1995 Kobe earthquake in Japan, telecommunication and electric power systems were restored in weeks while rail and road infrastructure systems took several month to years for full operation (Rodrigue, 2020).

Recovery of highway, street and bridge network is an important phase of emergency management of transportation infrastructure after a disaster including mitigation, preparedness and response (Baird, 2010). Post-disaster recovery is broadly defined as restoration of services, facilities, infrastructure and community to pre-disaster level or with further improvements to meet current standards and future demands (Baird, 2010; United Nations Development Programme, 2016). Specifically, for transportation sector, post-disaster recovery can be divided into three separate phases.

i. Short-term recovery lasting initial days which include clearing primary transportation routes for access in and around disaster areas.

ii. Intermediate recovery which lasts from few weeks to months and includes initial debris removal and planning immediate infrastructure repair and restoration.

iii. Long-term recovery lasting from few months to several years which includes rebuilding infrastructure to meet future community needs. This phase is also termed as permanent reconstruction phase (FEMA, 2011).

### 2.2.1 Post-Disaster Highway, Street and Bridge Reconstruction Funding

The U.S. adopts community-focused recovery model where partnerships at every level are supported by state and federal authorities and encouraged through two-way communication (FEMA, 2011), as shown in Figure 2.


*Figure 2: Community-focused recovery model*

In large scale disasters, local community government and industry have a critical role in implementing an inclusive, locally led recovery process. Local government has the primary role in planning and managing all aspects of community's recovery. They adopt and enforce the state and federal standards at the local level in order to be eligible for state and federal disaster funding. The federal government plays a facilitative role in the development of social and physical infrastructure by providing funding and other needed resources to state and local governments if the demand exceeds the capacity of states resources (FEMA, 2011). State governments lead the overall recovery process by managing and coordinating recovery activities including financial and technical support. They are also the channel for local governments to important federal funding and assistance programs (FEMA, 2017).

There are two major U.S. federal agencies which provide reconstruction funding to state and local governments for highway, street and bridge repair and reconstruction work – the Federal Emergency Management Agency (FEMA) and the Federal Highway Administration (FHWA).

i. Federal Emergency Management Agency (FEMA) Public Assistance (PA)

The Federal Emergency Management Agency (FEMA) is a federal agency of the U.S. Department of Homeland Security (DHS) with the main goal of coordinating with and assisting local and state agencies during disaster recovery phase in scenarios which overwhelm the available local resources. The FEMA Public Assistance (PA) is a reimbursement program that assists state agencies by providing federal funding to respond and recover from disasters. The funding provided under a PA program can be used by local and state agencies for recovery efforts which include debris removal, emergency protective measures, and permanent repair and reconstruction of public infrastructure systems. The permanent reconstruction of the damaged infrastructure is based on the pre-disaster function and design with conformity to current codes and standards.

After an event is declared as emergency or major disaster by the U.S. president, the declared state or local government submits an application for federal assistance. The Public Assistance program shares not less than 75% of the total applicable cost with the local government. FEMA believes that this cost sharing approach ensures local involvement and coordination during the administrative process.

ii. Federal Highway Administration Emergency Relief (ER)

The Federal Highway Administration (FHWA) is the federal agency under United States Department of Transportation (DOT) which overlooks federal-aid highways and federal lands highways. It oversees the funds, contracts, and construction standards for the transportation networks under the National Highway System. The goal of the FHWA Emergency Relief (ER) program is to supplement state and local resources, and funding from other Federal agencies to aid in the restoration of Federal-aid highway infrastructure systems and roads on Federal lands which are damaged from natural disasters or catastrophic failure events. Similar to FEMA PA funding, the ER program also works with cost sharing approach.

To be eligible for FHWA ER funding, a disaster event must have resulted in at least $700,000 in the federal share in damages. Similarly, for site eligibility, the minimum threshold is $5,000 in damage per site. Any damages under these minimum thresholds are generally considered as heavy maintenance.

The amount of the federal share depends on the type of repair, location, and the type of federal-aid highway. The FHWA ER program fully covers the required restoration and reconstruction costs such as restoring essential traffic and protecting the remaining facility from further damages within the first 180 days after the disaster. The 180 days criteria can be extended if a site is inaccessible to the State agencies for evaluation of damage and repair cost. For permanent restoration works after 180 days, the federal share is 90% for Interstate highways and 80% for all other Federal-aid highways.

### 2.2.2 Reconstruction Costs and Labor Market

Over the years, weather-related disaster damages have cost the U.S. Federal and State agencies billions of dollars in reconstruction funding. Olsen & Porter (2010) found that the cost of repairing a damaged infrastructure asset depends on the severity of the disaster. Even if the damage to the infrastructure asset is same, the repair cost will be higher if when the damages occur during a larger disaster with greater overall damage extents than if the damages occur during a smaller disaster, a phenomenon called demand surge. This indicates that the cost of various construction resources changes depending on the size of the disaster. Similarly, the cost of reconstruction is also increasing every year. Quarterly analysis reports by Verisk Analytics show a steady growth in reconstruction costs in the U.S. The annual growth in reconstruction cost is 3.7% and 3.9% in the two years from 2018 to 2020 in the third quarter (Hopkinson, 2019b, 2020). It includes the growth in cost of materials and labor.

Similarly, a detailed trend analysis of highway construction costs in Louisiana by Cheng & Wilmot (2009) shows up to 51% increase in construction costs of highway infrastructure in the short term (two quarters approximately) after hurricanes Katrina and Rita. The cost index includes the cost of labor, equipment, and materials. Even though the construction market is disrupted immediately following a disaster, the market of supply and demand stabilizes it into equilibrium over a period of two years (Cheng & Wilmot, 2009). They also found a significant statistical difference in the trend of construction costs of highway infrastructure between a disaster hit zone and a disaster unaffected zone in same state.

Although the above studies suggest the growth in reconstruction costs are influenced by two different mechanisms – annual cost increases over time and sudden cost increases after a disaster event – both mechanisms include labor and material in the calculation. Another study by Olsen & Porter (2011) concluded that the total cost of reconstruction is primarily driven by labor costs rather than the cost of materials. The authors also suggested that our collective understanding of why the cost of construction increases after disasters can be explored with improved quantitative analysis of post-disaster labor markets. This research is an attempt to fill that gap in research in the field of highway, street, and bridge construction.

## 2.3 Demand Shock and Supply Shock in Labor Market

In an ideal labor market, wage determination is done as a function of labor demand and supply. The intersection of demand curve and supply curve provides the equilibrium in the labor market and in-turn the labor wages ($W_1$) as shown in Figure 3. Demand curve ($D_1$) shows the relation of demand of labor by employers as a function of wages and is downward sloping. Supply curve ($S_1$) shows the supply of labor willing to participate in the market as a function of wages and is upward sloping. The point of intercection of these two curves represents the state of equilibrium in the labor market. Since wage is determined at the intersection of demand and supply curve, any changes in either demand or supply will affect the labor wages.

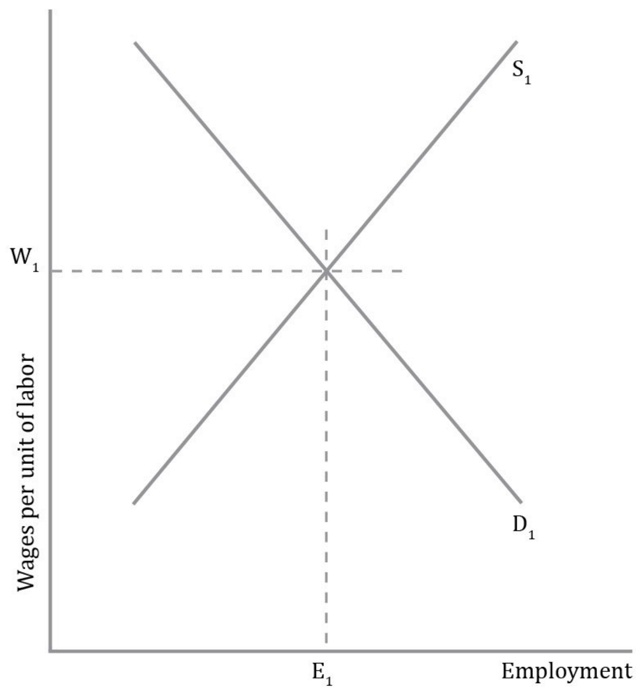


*Figure 3: Wage determination in labor market equilibrium*

An event such as weather-related disaster has multitude of effects on the local and neigboring labor market. It can cause out-migration from the disaster-hit area to the neighboring regions (Belasen & Polachek, 2009) while the attempt for recovery increases the demand for labor in the local market (Federal Reserve Board of Governors & Roth Tran, 2020). This sudden increase in the demand of labor is called positive demand shock. Similarly, the out-migration results in negative supply shock in the local labor market and a positive supply shock in the labor market of neighboring region. These behaviors in labor availability was studied by Belasen &

Polachek (2009) and the results are explained briefly in section 2.4.1. The sudden increase in demand and the reduction in supply has a tendency to directly have an impact on the labor wages

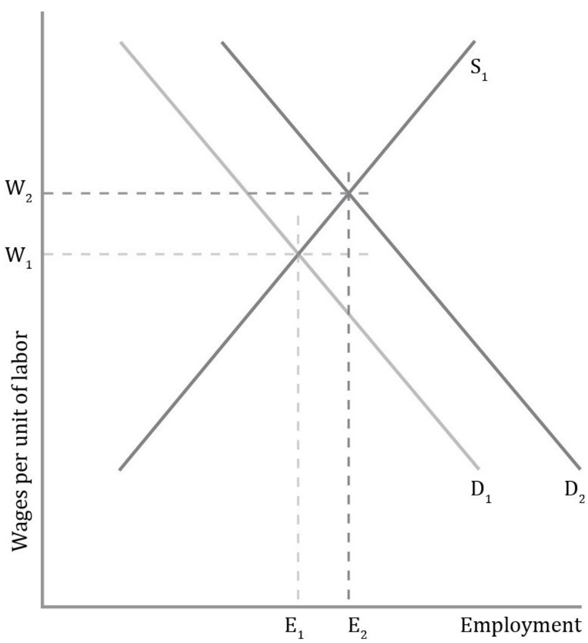


Figure 4: Effect of Positive Demand Shock on wages

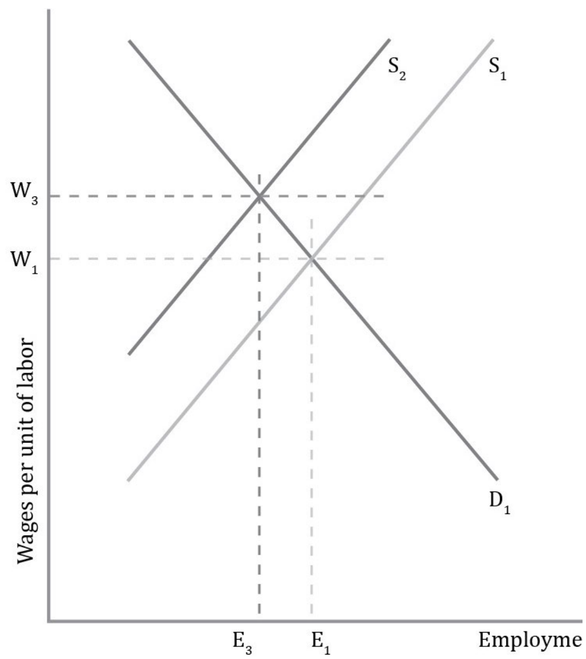


Figure 5: Effect of Negative Supply Shock on wages

as shown in Figure 4 and Figure 5. In both the cases, positive demand shock ($D_1 \rightarrow D_2$, Figure 4) and negative supply shock ($S_1 \rightarrow S_2$, Figure 5) in the local labor market, the pre-disaster wages ($W_1$) rises in value to $W_2$.

## 2.4 Disasters and the U.S. Labor Market

The labor market plays an important role in post-disaster recovery and supplies most needed human resources in the construction market. The supply capacity of labor market has a huge impact in both the duration and cost of post-disaster recovery. Disaster events also cause a regional migration of labor force within the U.S. impacting the local housing market. This movement of labor force affects the labor supply capacity within a region which also influences the cost of labor.

### 2.4.1 Effects of Disasters on Wages

The need for swift reconstruction of transportation infrastructure systems creates positive labor demand shock. In this thesis, demand shock is mentioned to indicate changes in the demand for labor due to exogenous factors like weather-related disasters.

Groen et al. (2017) studied the effect of Hurricane Katrina and Hurricane Rita on individual employment and earnings, using U.S. Census Bureau household survey data. They found that aggregate quarterly employee earnings across all industries declined the first year after a disaster and did not typically begin rising again until one-year post-disaster. Earnings, in this case, is defined as the function of wages and total hours. Workers with decreased earnings and delayed income opportunities were more likely to migrate to other areas, causing a long-term drop in the available labor supply. However, Groen et al. (2017) also found that the construction industry was a unique outlier in post-disaster labor market trends. Construction workers experienced an immediate and substantial growth in earnings after a disaster, due presumably to the high demand for construction services, in comparison to workers in other industries. In addition, workers in the construction industry saw more weekly work hours due to the increased demand for post-disaster construction work. Although, the increase is earnings could be due to the combined effect of weekly work hours and increased wage rates, the authors also found reports of employers offering wages much higher than pre-disaster levels.

Similarly, Belasen & Polachek (2009) compared employment trends in counties struck by a hurricane struck to all other unaffected counties in the same U.S. State. They found that employment in hurricane-stricken counties decreases while the neighboring counties experience an oversupply of labor because of out-migration. The hurricane-stricken counties had decreased labor availability and a 4.35% increase in wages, but wages decreased by 4.51% in neighboring counties with increased labor availability. The authors also suggested the use of other variables such as disaster relief fund, gross domestic product, consumer expenses, etc. to study this phenomenon of labor wage change after a disaster.

### 2.4.2 Labor Migration and Housing Market

When discussing migration after disasters, McCarty & Smith (2006)hypothesized that an unexpected increase in the frequency of disasters increases the out-migration of the labor force. If the frequency of disaster is within the expected frequency, it will not affect labor migration while a greater frequency of disasters will lead to the out-migration of labor. The hypothesis is based on individual preferences but proposes that disasters do cause migration. Not only disasters cause out-migration of labor for the short and long term but also attract skilled workers to the needed area from other regions (Hallegatte et al., 2008).

Even though many economists consider that the residents' aptitude to move and relocate to a new location for better employment is the U.S.'s greatest virtue for economic growth (Zabel, 2012), the decision to migrate is determined not only by the labor demand but also by the condition of the housing market. Also, Zabel (2012) found that housing prices respond to demand shocks. And, the local housing market elasticity affects employment and wages in the long term (Saks, 2008). Positive demand shock and in-migration increases the price of housing and eventually wages and employment. But on contrary to this, Boustan et al. (2017) found that housing prices and rent decreased up to 2.5-5% following a disaster in the U.S. Even though there is no research solving this duality of housing market condition after a disaster, these studies indicate the need to include the housing market parameter, such as average rent, median housing price or vacancy rates, in this research.

### 2.4.3 Pre-disaster Unemployment and Post-disaster Labor Wages

The unemployment level in the labor market indicates the supply capacity of labor market following a disaster. Lower unemployment rate and speed of reconstruction give bargaining power to the workers causing the wages to rise. Hallegatte et al. (2008) used macroeconomic modeling to assess how disasters influence regional economies and found that disasters are more disruptive during economic expansion than during a recession. Their research suggests that the higher unemployment rates associated with economic recessions create labor force availability, facilitating post-disaster recovery work and damping the disruptive effects of a disaster. The opposite happens during economic expansion because the labor force typically cannot meet demand and has unfilled job openings, and a disaster amplifies this existing disequilibrium. Similar results were found by Bartik (2015) indicating that, after a demand shock, the local economy with lower initial unemployment saw an increase in labor wages.

# 3 METHODOLOGY

Chapter 2 provided with historical analysis on direct damages due to weather-related disasters in highway, street and bridges, and descriptive analysis on the demand shock experienced in the labor market. Chapter 3 details the quantitative methodology for analyzing the effect of weather-related disasters in highway, street, and bridges. Figure 6 graphically represents the overall process of identifying, collecting, and analyzing data utilized for this research. The data collection process for this research relied on the availability of public data and demanded an extensive search for data from U.S. governmental datasets. The data analysis process involved cleaning and preparing the data for analysis and utilizing data analysis tools and statistical software to obtain results.

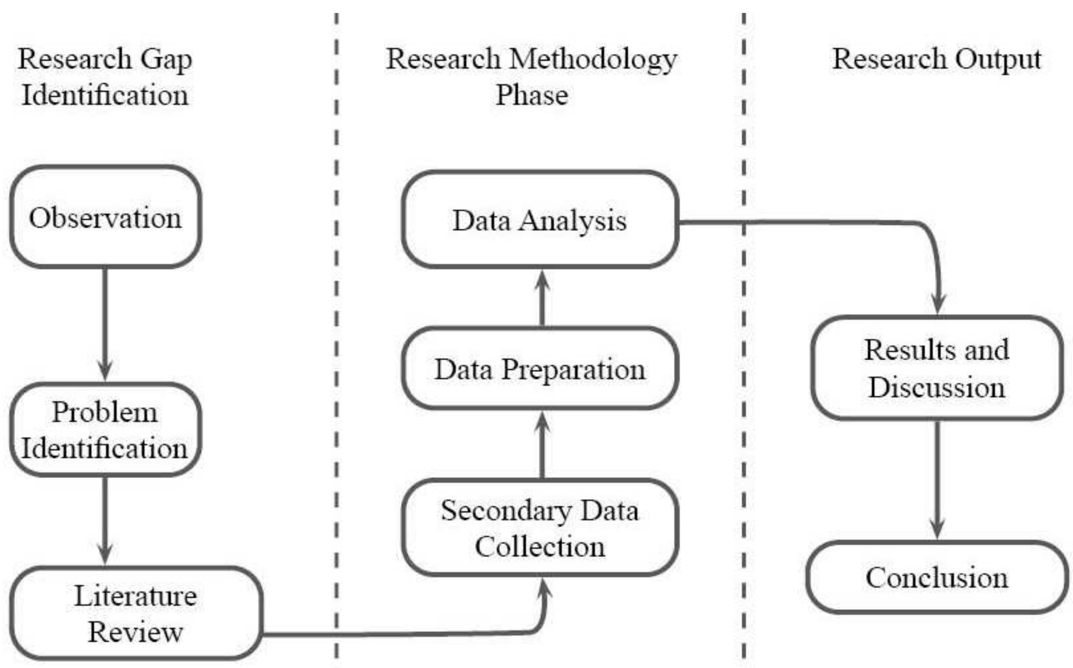


*Figure 6: Research Methodology*

## 3.1 Study Overview

This study employed descriptive and inferential statistics to answer the three research questions from Chapter 1.

First, this study explored *Research Question-1:*

*How does post-disaster labor demand shock affect the highway, street, and bridge sector?*

To answer the first research question, the research studied the trend of weekly labor wages in highway, street, and bridge construction sector in a post-disaster situation. The research looked into disasters within a certain timeframe and compared the percent change in weekly wages in highway, street and bridge sector in disaster hit U.S states with the disaster unaffected states and the average national percent change in weekly wages in the same sector in same timeframe to inspect unusual fluctuation in wages. In addition to this, t-tests were also computed to study if the difference in the behavior of labor wages these groups were statistically significant or not.

Second, this study examined *Research Question-2:*

*How do State-level economic conditions influence post-disaster labor demand shock?*

The concept of post-disaster demand shock in the construction industry has barely been explored, especially for the highway, street, and bridge sector. Therefore, previous studies on topics of labor market and disasters from other industries and business sectors were reviewed to inform this research.

Below is the list of variables identified during the literature review:

i. Unemployment rate

ii. Gross Domestic Product (GDP)

iii. Population

iv. Reconstruction Funding

v. Measure of highway, street, bridge infrastructures

Correlation tests were done to study the degree of association between the labor wages and these state level economic conditions.

Lastly, this study considered *Research Question-3:*

*How can the highway, street and bridge sector anticipate post-disaster labor demand shock?*

To answer this question, this research employed simple linear regression modelling. Using the statistical analysis software SPSS, this study assessed if state-level economic conditions and disaster damages are predictor variables for post-disaster labor demand shock.

## 3.2 Data Collection

This study utilizes records from U.S. government agencies and other public institutions as sources for secondary datasets. Data collection included searching publicly available datasets using web platforms and historical archives. Some required a direct inquiry with representatives from the related public institutions for data collection because of the lack of online archives. Table 2 below lists all the data sources used for this research including the specific variables extracted from each of them. Following section provide brief introduction to the data sources and their primary method of data collection.

*Table 2: Data Sources*

| Data Source Name | Source Institution | Obtained Variables |
|---|---|---|
| **Quarterly Census of Employment and Wages (QCEW)** | Bureau of Labor Statistics (BLS) | Average weekly wages, Employment numbers |
| **OpenFEMA Dataset** | Federal Emergency Management Agency (FEMA) | Disaster ID, Disaster date, PA Funding |
| **FHWA ER Allocation** | Federal Highway Administration (FHWA) | ER Funding |
| **Highway Statistics Series** | FHWA | Highway length by state |
| **Local Area Unemployment Statistics (LAUS)** | BLS | Unemployment rate |
| **Historical Population Change Data** | Census Bureau | Population |

### 3.2.1 Quarterly Census of Employment and Wages (QCEW)

The Quarterly Census of Employment and Wages (QCEW) is published by the Bureau of Labor Statistics (BLS) and includes industry-level data (e.g., number of business establishments, average weekly wages, and number of employed persons) for more than 95% of jobs in the U.S. (Trevino, 2021). The primary sources of data for QCEW are the Quarterly Contributions Report (QCR) submitted by private sector employers, as well as state and local government public agencies under the State Unemployment insurance (UI) program. The data from QCR is supplemented by the Annual Refiling Survey (ARS) and Multiple Worksite Report (MWR). These surveys contact around one third of all the private sector employers every quarter, collecting geographic and industry information such as individual business and industry-level employment and wage data (Trevino, 2021).

Data about the highway, street, and bridge construction sector was collected from the QCEW. The relevant construction industry data was identified using the North American Industry Classification System (NAICS). The NAICS classifies U.S. establishments and employees using a six-digit hierarchical numbering system. For example, NAICS 23 describes all establishments and employees working within the U.S construction industry while NAICS 237 represents heavy civil engineering and construction (NAICS-OMB, 2017). The authors collected data for NAICS 237310, which is comprised of business establishments and workers primarily engaged in highway, street and bridge construction work.

Specifically, the QCEW data for wages and employment for the NAICS 237310 sector was collected. This included: (1) wages – seasonally adjusted average weekly wages; and (2) employment – average number of employed workers.

### 3.2.2 OpenFEMA Dataset

Data about flood disaster damages was collected from the OpenFEMA Dataset: Public Assistance Funded Projects Details dataset, which contains information on Public Assistance projects. The dataset is obtained from FEMA's National Emergency Management Information System (NEMIS) and published in raw unedited format and is the most up to date and accurate disaster damage data available in the U.S. (FEMA, 2021).

The dataset contains a list of all public projects funded by FEMA and the details associated with each project (disaster number, disaster date, disaster type, damage category of project, geographical location, project amount, federal share obligated for the project amount and other related information). The disaster type classifies the project based on the cause of damage such as flood, severe storm, wildfire, earthquake, hurricane, etc. The damage category distinguishes the area of restoration to be funded by the obligated amount from FEMA, as shown in Figure 7 below.

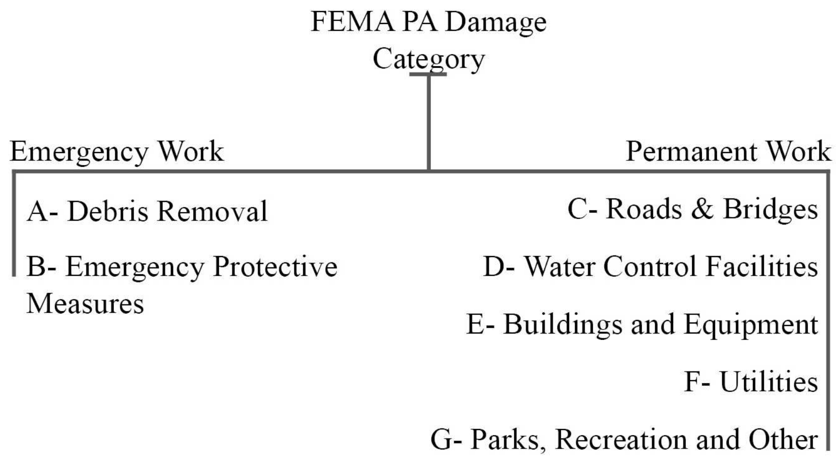


*Figure 7: FEMA PA damage category*

For this research, the author collected information about flood and severe storm disasters and funding for category C damage – roads and bridges. Specifically, the collected data included the type of disaster, date of disaster, state affected, and individual project amount and obligated federal share in category C.

3.2.3 FHWA ER Allocation

(Federal Highway Administration) FHWA maintains an online archive on its ER program but it only contains general information about the program. It also publishes ER allocation for every fiscal year but unlike OpenFEMA datasets, they only dated back to year 2017 at the time of data collection for this research.

The author contacted the Office of Stewardship, Oversight, and Management for the FHWA ER program who provided additional information about the reconstruction funding dating back to fiscal year 2000. The obtained dataset was summarized utilizing two different methods. The first dataset listed the states receiving funding and the year when the funding was allocated, but without any related information on the disaster events. The second dataset listed funding by disaster event, allocation date, and recipient state.

For this research, a second dataset was used because it contained information about the disaster events. Similar to OpenFEMA Dataset, the collected dataset included the information of disaster, state affected and the total federal funding under the ER program for the reconstruction of highways, streets and bridges damaged by a given disaster.

#### 3.2.4 Highway Statistics Series

The Highway Statistics Series is published annually by the FHWA Office of Highway Policy Information based on the data submitted to FHWA directly by individual states (FHWA, 2014). It contained statistical information on motor fuel, motor vehicle registrations, highway user taxation, highway mileage, travel, and highway finances. This study used the "Length by ownership" table indexed as HM-10 from the yearly published series for all years within the study timeframe. The table contained the total length of public road networks in individual states. This dataset provided the quantity of built physical infrastructure (e.g., the total miles of road) within highway, street and bridges sector that had a possibility of being damaged by a disaster in any given year.

#### 3.2.5 Local Area Unemployment Statistics (LAUS)

The Local Area Unemployment Statistics (LAUS) dataset is published by the U.S. Bureau of Labor Statistics (BLS) and contains the monthly estimates of total employment and unemployment numbers for the U.S. (U.S. BLS, 2018). This program is a federal-state cooperative effort under the BLS with the main goal of analyzing local economic conditions (U.S. BLS, 2020). The underlying concepts and definitions of LAUS data come from the Current Population Survey (CPS), which conducts household surveys for measuring the labor force of the

U.S. The LAUS produces monthly labor force, employment, unemployment, and unemployment rate from 1976 to present date categorized geographically (census regions and divisions, states, metropolitan areas, small labor market areas and likewise), smallest unit being counties, and cities of 25,000 population or more (U.S. BLS, 2020).

This thesis used the seasonally adjusted LAUS monthly state unemployment rate for the study timeframe. The overall unemployment rate for all industries from the LAUS was used under the assumption that the seasonally adjusted average data is the representation of the available labor force in the market.

## 3.3 Data Preparation

The raw data obtained from various sources had to be sorted and refined before conducting the quantitative analysis. The first step involved identifying types of disasters to be included in the study based on the extent of damage they caused on highway, street and bridge sector. After disaster selection, the appropriate timeframe was selected for the study based on the availability of datasets. Lastly, total funding for each disaster was aggregated from the FEMA PA funding and FHWA ER funding. This process and chronology of tasks performed during the data preparation phase is shown in Figure 8.

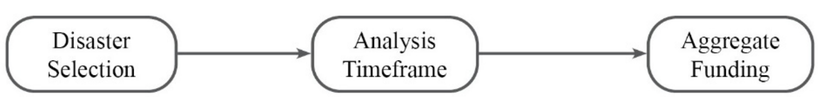


*Figure 8: Process of Data Preparation*

### 3.3.1 Disaster Selection

Not all disaster types cause large-scale direct physical damage to transportation infrastructure systems. Disasters like wildfires or drought cause minimal direct damage to highway, street, and bridges. For example, although tornadoes can be extremely destructive to residential housing, these powerful windstorms rarely undermine highway and street integrity.

Historically, floods, hurricanes and severe storm disaster events have caused the most significant physical damages to highway, street, and bridges infrastructure. The proportion of funding from FEMA and FHWA allocated for post-disaster reconstruction is also the highest for highway, street, and bridge repairs.

Figure 9 and Figure 10 below represent the total amount of FEMA funding allocated to public infrastructure damaged due to flooding from 2009 to 2019. It shows a large proportion of funds dedicated for Category C- Roads and Bridges permanent reconstruction. This indicates substantial damage to highway, street, and bridges due to flooding and severe storms.

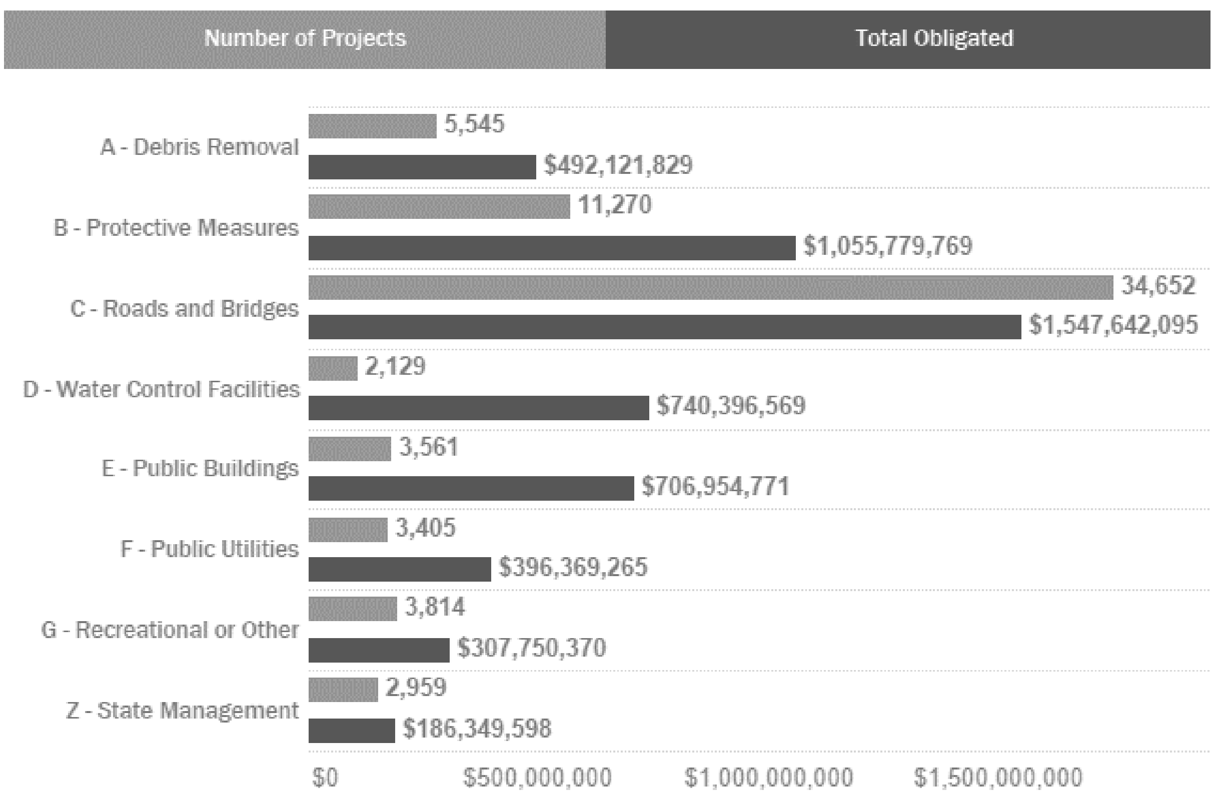


*Figure 9: FEMA PA funding for flood damages events from 2009 to 2019*

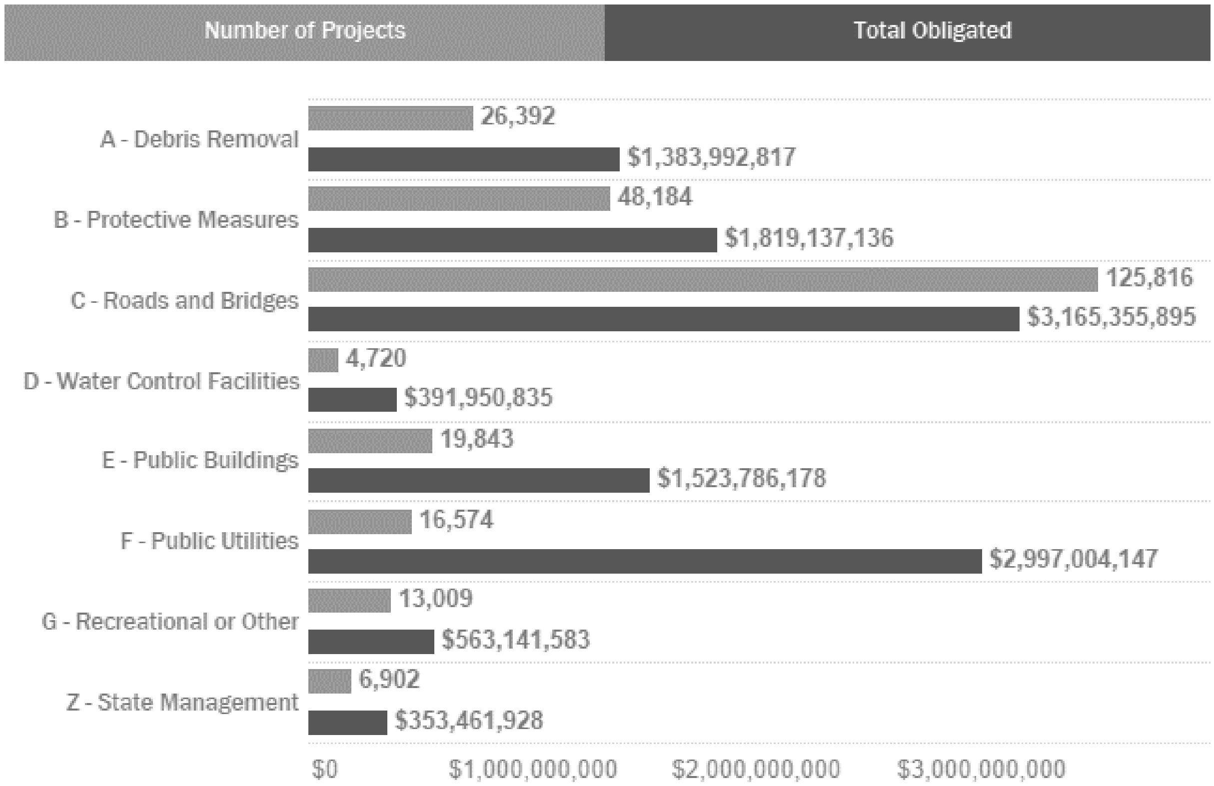


*Figure 10: FEMA PA funding for damages due to severe storm events from 2009 to 2019*

Similarly, the funding allocation of after a hurricane also showed a large share of it dedicated to the reconstruction of C-Roads and Bridges. Based on these observations, this study conducts analysis on the floods, hurricanes, severe storms, and severe snowstorms only. The time frame of year 2009 to 2019 does not represent the study timeframe for the overall research and is only used to analyze the typical allocation of funding after a disaster.

### 3.3.2 Study Timeframe

The timeframe selection for this study was controlled by the availability of historical datasets for the weekly wages and the state-level economic conditions intended to be used for the regression analysis. For the study, all datasets had to span over the same duration of time to facilitate a longitudinal analysis. However, the datasets covered different timespans. For example, the FHWA ER Allocation data was only available for the years leading back to 2000.

Therefore, the combined dataset used in this study had to be trimmed down to start in the year 2000 and continue to the most recent year with available statistics, thus ending in the year 2018.

Explained in later section (3.4 Data Analysis), some part of the study focuses on trend analysis of different variables before and after a disaster event. It looks at labor markets 2 years before and 2 years after a specific event for any unusual fluctuation. Because of this, disaster events from year 2002 to 2016 were taken into consideration which requires data from year 2000 to 2018

### 3.3.3 Total Disaster Funding

Although both the FEMA PA and the FHWA ER datasets maintained the records of disaster funding allocated per disaster event, they each used their own disparate system of nomenclature. FEMA used numerical digits to identify individual disaster events (i.e., disaster record 4085 represented Hurricane Sandy) while FHWA used state, year of event, and event number that year (i.e. CO201301 represented the first disaster event of 2013 in Colorado). The disaster identification in both systems had to be cross referenced and later added to obtain a total amount of funding in highway, street and bridges due to a disaster. Eventually, only those disaster events with total funding in highway, street and bridges amounting more than $100,000 were selected.

Based on this data preparation section, here are the three criteria for a disaster to be included in the analysis,

i. Flood, Hurricanes, Severe Snow/Storm events
ii. From year 2002 to 2016
iii. Total federal funding more than $100,000

## 3.4 Data Analysis

Various statistical analytical tools were employed for data analysis. Descriptive statistics were utilized to identify and understand the baseline patterns in labor wages in the highway, street, and bridges sector (NAICS 237310) after a given disaster. Inferential statistics were utilized to assess differences in labor wage trends in disaster-affected U.S. states in comparison to states not affected by disasters. In the final data analysis step, regression analysis was used to assess if post-disaster labor wage shock can be predicted based on state-level economic market conditions.

### 3.4.1 Descriptive Statistics

The first phase of study focused on trend analysis of labor wages before and after a disaster. For this, two different groups of data were created. One contained a pool of U.S. states affected by weather-related disaster (flood and severe storms) with corresponding weekly wages. The second group contained the list of states without any events (including hurricane, tornado, or any other incident with potential damage) that could cause immediate labor demand shock. The percent change in average weekly wage in disaster-hit states was compared against that of states without a disaster and also the national average. A sudden or unnatural change in labor wages would indicate exogenous effect on labor market due to a disaster. This process is represented graphically in Figure 11.

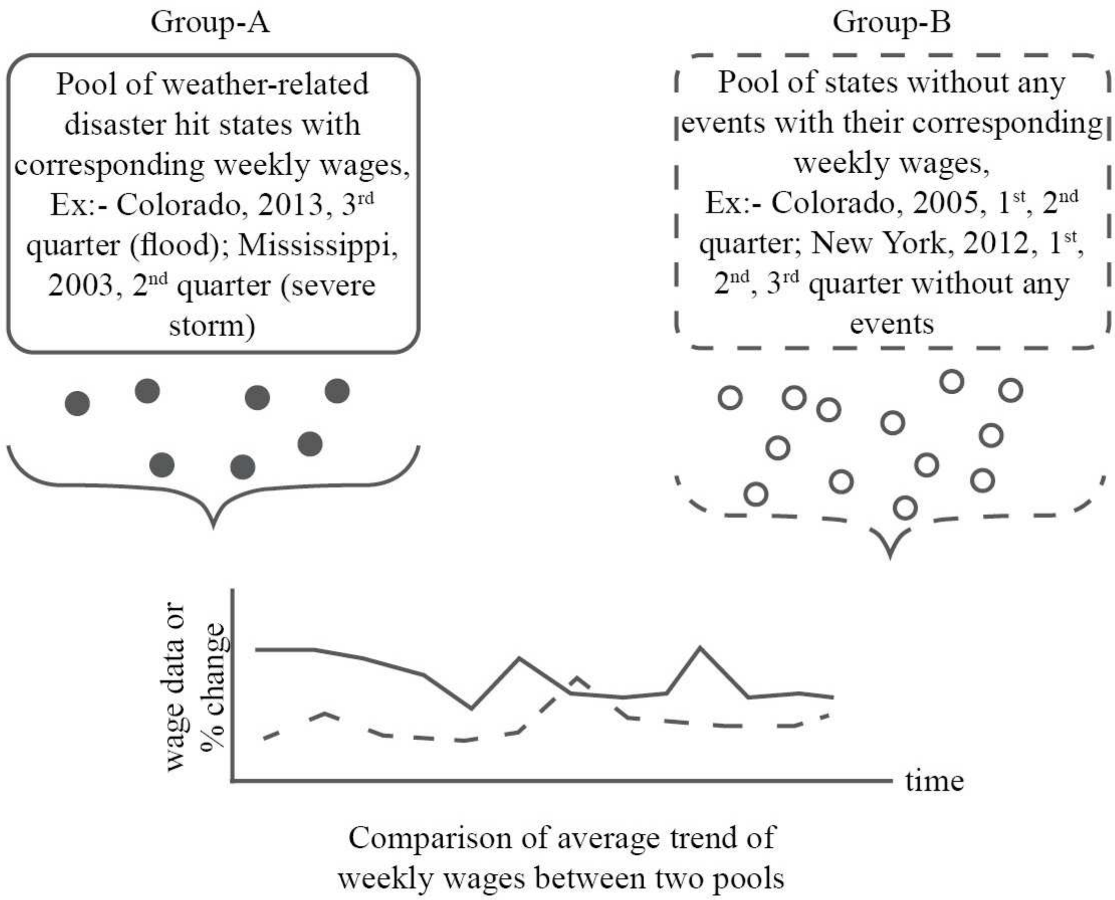


*Figure 11: Graphical representation of Descriptive statistics*

The comparison is done on percent change in average weekly wages after a year since a disaster event. Similarly, regional trend analysis was also done in four U.S. census regions to study how the wages change in those compare against each other. This trend study incorporated weekly wages data from BLS for 2 years before and after a disaster event. Figure 12 below shows the timeframe around the disaster event that is used for trend study of wages.

Where,

t = time of disaster event (quarter)

t-8 = eight quarters before disaster (2 years) t+8 = eight quarters after disaster (2 years)

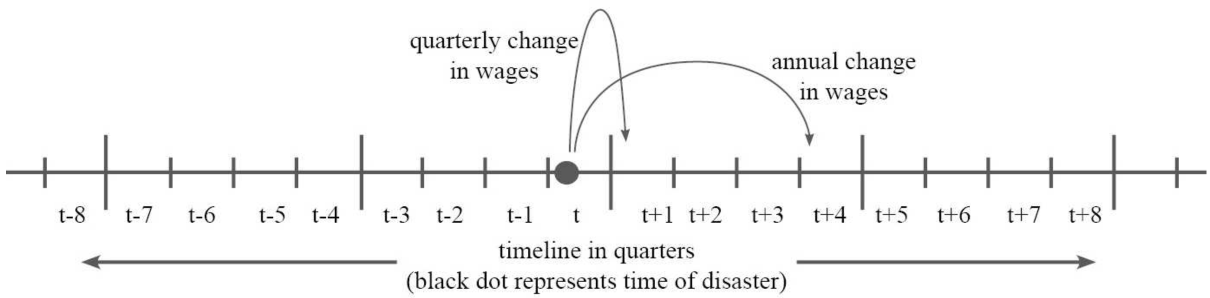


*Figure 12: Timeframe for wage trend analysis*

***How were the two pools of disaster hit and disaster unaffected states created?***

i. *The pool for the list of all federally declared disasters in the U.S. within the specified timeframe of 2000 to 2018 were obtained from FEMA PA dataset as mentioned in the data collection stage.*

ii. *The common smallest unit of time for all the datasets were set to be a quarter. Some data sources provided monthly data which were later converted to quarterly averages.*

iii. *Some states had more than one disaster events in a single quarter. This would cause the final data to have duplicates in it. So, any disasters occurring in a state within a same quarter were assumed to be a single event and the funding for them were aggregated as one. This reduced the pool of disaster hit states but avoided duplicates in the final data.*

iv. *Similarly, the pool of disaster unaffected states cannot include time periods immediate to the event. This list excludes all the disaster hit states plus an additional one year before and after the disaster event in an effort to minimize any inclusion of disaster affected data in the second data pool.*

### 3.4.2 T-test

A t-test is a statistical process to assess the probability that the mean of two population is statistically different (Lavrakas, 2008). It is often used as a hypothesis testing tool to determine whether two groups are different from one another. The hypotheses are stated below.

i. The null hypothesis ($H_0$) assumes that the two groups (annual percent change in weekly wages for employees working in NAICS 237310 in disaster hit states and disaster unaffected areas) have the same mean.

ii. The alternative hypothesis ($H_1$) assumes that the two groups have different means. This would indicate that annual percent change in weekly wages in disaster hit and disaster unaffected states are statistically different.

The p-value obtained from t-test is compared against a threshold of 0.05 for hypothesis testing to determine if the difference between the means of the two groups are statistically significant at the 5% level.

In this study, t-test was carried out between the same groups described in descriptive statistics process (Figure 11) to analyze whether the means of wages and the annual percent change in wages between two groups have significant statistical difference. Figure 13 below represents the process graphically.

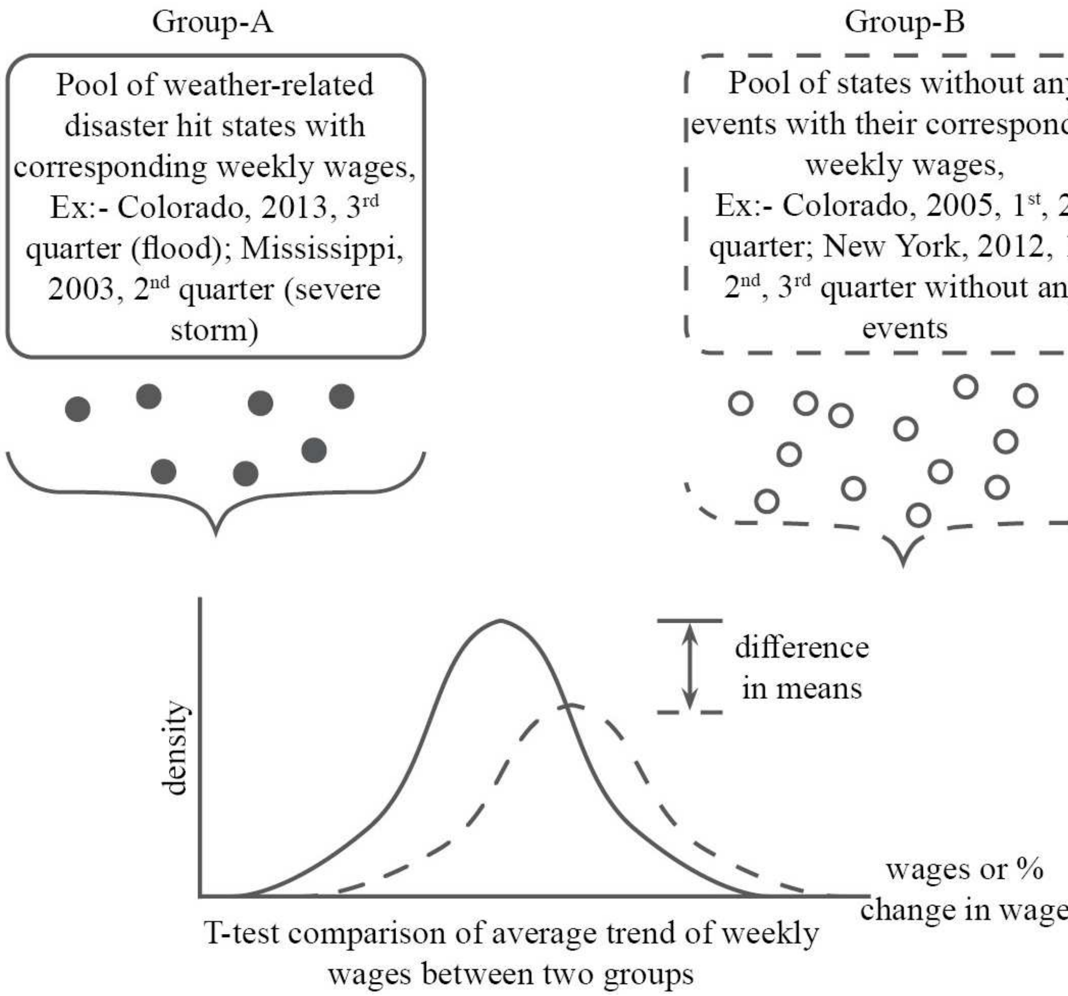


*Figure 13: Graphical representation of t-test*

### 3.4.3 Correlation Tests

Correlation test is the statistical method used to study the strength of association between two different variables. The strength of association is measured by a correlation coefficient, also called Pearson's correlation coefficient (r). The value of Pearson's 'r' coefficient can range from -1 to +1 with '0' showing no correlation between the two variables. A value closer to -1 represents a strong negative correlation while a value close to +1 represents a strong positive correlation.

T-tests and descriptive statistics in the previous steps help to study the variation in average weekly wages after a disaster event. Correlation test is done to study the strength of association between the change in average weekly wages and the state level economic conditions introduced in our data collection phase as shown in figure below.

The results from the correlation test would help in better understanding the change in average weekly wages and also contribute to the knowledge acquired during the literature review process. Building on the works on Hallegatte et al. (2008) and Bartik (2015) as mentioned in literature review, correlation rest can further explore the association of unemployment rate with labor wages specifically in highway, street and bridges sector.

### 3.4.4 Regression Analysis

Regression analysis is used to estimate the relationship between dependent variable and a set of independent variables. Correlation test in the previous step studies the strength of association between a set of variables including dependent variable and independent variable but a resulting correlation between variables does not imply a causality. The cause and effect between dependent and independent variable can be tested through a regression model study. Regression model will produce an equation that predicts dependent variable based on a set of independent variables. A sample regression model equation has a following form:

$$Y=a_1X_1+a_2X_2+a_3X_3+\ldots+K+e$$

Where,

K= constant

Y= independent variable

$X_n$= dependent variables

$a_n$= multipliers or coefficient, which indicate the extent of effect of each independent variable on the final dependent variable

e=error term

Along with equation, regression analysis also results in p-value for each independent variable and a $R^2$ value for the whole model. If the p-value of an independent variable is less than the significance level (0.05), this indicates a statistically significant relation with the dependent variable. Similarly, $R^2$ value also called coefficient of determination is the percentage of variation in dependent variable that can be predicted with the independent variables. Its value can be within 0% to 100%. Higher value of $R^2$ implies that the model can effectively predict the variability in the dependent variable.

In this research, dependent variable is the change in average weekly wages in disaster hit states while the independent variables include state level economic conditions such as unemployment rate, employment number, milage of roads, population, and disaster funding for reconstruction of highway, street and bridges. Regression analysis is the final step in answering the research questions put forward in the introduction section of this thesis.

# 4 RESULTS AND DISCUSSION

This chapter presents the results obtained after analyzing the impact of weather-related disaster events on labor wages in highway, street, and bridge construction sector (NAICS 237310). The first phase of the study focused on a trend analysis of post-disaster labor wages, by analyzing the average weekly wages after a disaster event. In the second phase of the study, t-tests were conducted to test for statistically significant differences in the means of the percent changes in weekly wages in disaster hit states vs disaster unaffected states. In the third phase of the study, correlation tests were performed to identify pre-disaster state-level socioeconomic factors that are correlated with post-disaster labor wage shock. The fourth and final phase of the study utilized linear regression analysis to study the relation between percent change in weekly wages of labor and state-level socioeconomic conditions and generate a prediction model. The sections below present the results of these statistical processes, as well as a discussion of the results.

## 4.1 Disasters in U.S. and FEMA Funding

This study focuses on the effects of flood-related disasters (e.g., flood, hurricane, and severe snow/storm events) that caused severe damage to highway, street, and bridge infrastructure systems. Disasters were only included in the study if they required a U.S. local or state government to seek post-disaster financial assistance of at least $100,000 for highway, street and bridges repair and reconstruction from the federal government (Federal Emergency Management Agency and Federal Highway Administration). There were 1,873 total federally declared disasters in the U.S. from 2002 to 2016. Out of those, local and state governments received financial support from the federal government (via FEMA and FHWA disaster funding worth at least $100,000) for highway, street, and bridges reconstruction in 773 disasters. Of those

773 disasters requiring federal (FEMA and FHWA) funding for reconstruction, 678 disaster events were flood, hurricane, and severe snow/ storms. As presented in the Table 3, this research covers almost 90% of all the federally declared disaster events during the study timeframe that caused significant physical damages to highway, street, and bridge infrastructure and almost all of the FEMA funding received for the same sector.

*Table 3: Counts of disasters and funding for reconstruction (only FEMA funding)*

| | Count | FEMA Funding |
|---|---|---|
| **All disasters with funding in highway, street, and bridge reconstruction** | 773 | $ 9.2 billion |
| **Flood, Hurricane, Severe Snow/ Storms** | 678 | $ 9.1 billion |
| **Percentage Covered** | 87.7% | 98.9% |

Additionally, some of the states were hit by flood, hurricane, and severe snow/storm events multiple times in the same quarter. But, as explained in the methods section, this study focuses on quarterly data as the smallest unit of time. Disasters in a state occurring in a same quarter cause duplicates in the final data. So, any disasters occurring in a state within the same quarter were assumed to be a single event. For example, 2009 Kansas flood in November and December are taken as 2009-4$^{th}$(quarter)-Kansas. This reduced the effective number of disaster events in the study timeframe from 678 to 535 but eliminated the chances of having duplicate datasets in the final data. The results presented in this section are based on the effects of these 535 disaster events in the labor markets of highway, street, and bridge construction sector (NAICS 237310).

### 4.1.1 Regional Statistics

Figure 14 below shows the number of weather-related disaster events in four different U.S. Census regions (Midwest, Northeast, South, and West) from 2002 to 2016. It includes flood, hurricane, severe storm, and severe snowstorm events. The majority of these weather-related disasters seem to be concentrated in certain geographic location depending on the corresponding weather conditions in each region, as shown in Figure 15. The Midwest and South regions each averaged more than 150 disasters during the study timeframe while the Northeast and West regions each had about 90 of those weather-related disasters.

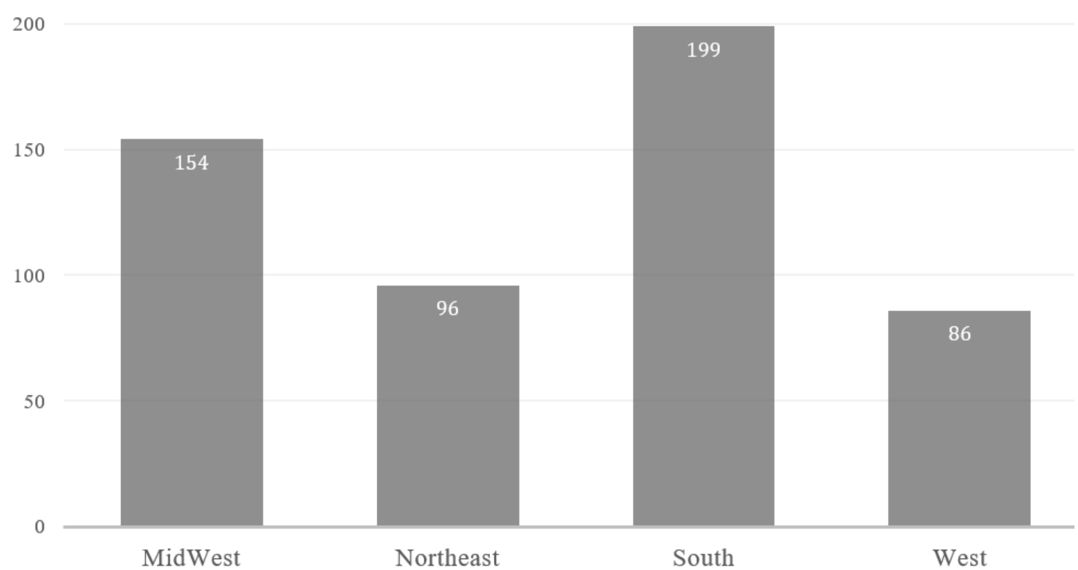


*Figure 14: Number of Flood, Hurricane and Severe Snow/Storm events by regions from 2002-2016 (out of total 535)*

With 199 disaster events, the South region received the largest amount of funding of $9.8 billion from the federal government (FEMA and FHWA aggregate) for the reconstruction of highway, street, and bridges. Northeast regions received the second largest federal funding at $4.0 billion dollars. Although only 20% of the disaster events in each of these regions are hurricanes, they account for more than 50% of the disaster funding as shown in Figure 16. This shows the severity of damages to highway, street and bridges caused by hurricane events.

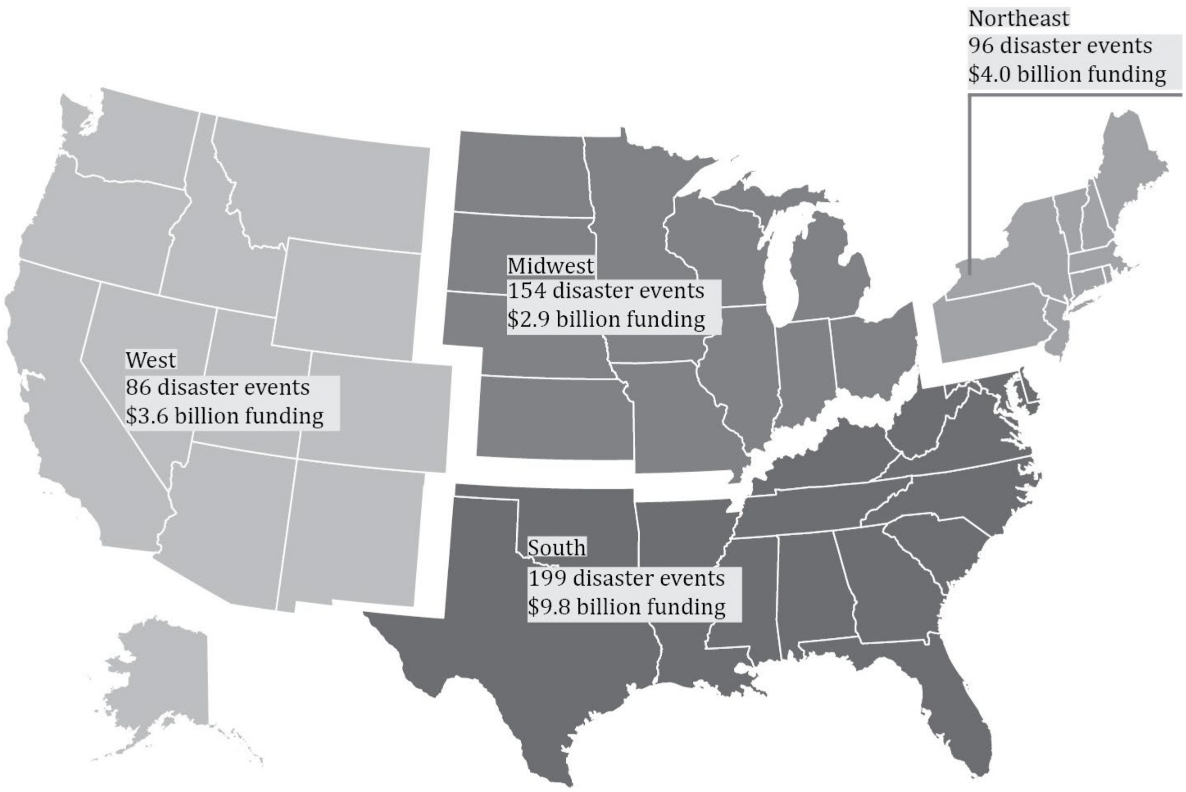


*Figure 15: Number of weather-related disasters and funding by regions from year 2002-2016*

Similarly, West and Midwest regions each received a federal funding of about $3.0 billion for the reconstruction of highway, street, and bridges. Unlike the South and Northeast, most of the funding in these regions is because of flood and severe storm disasters.

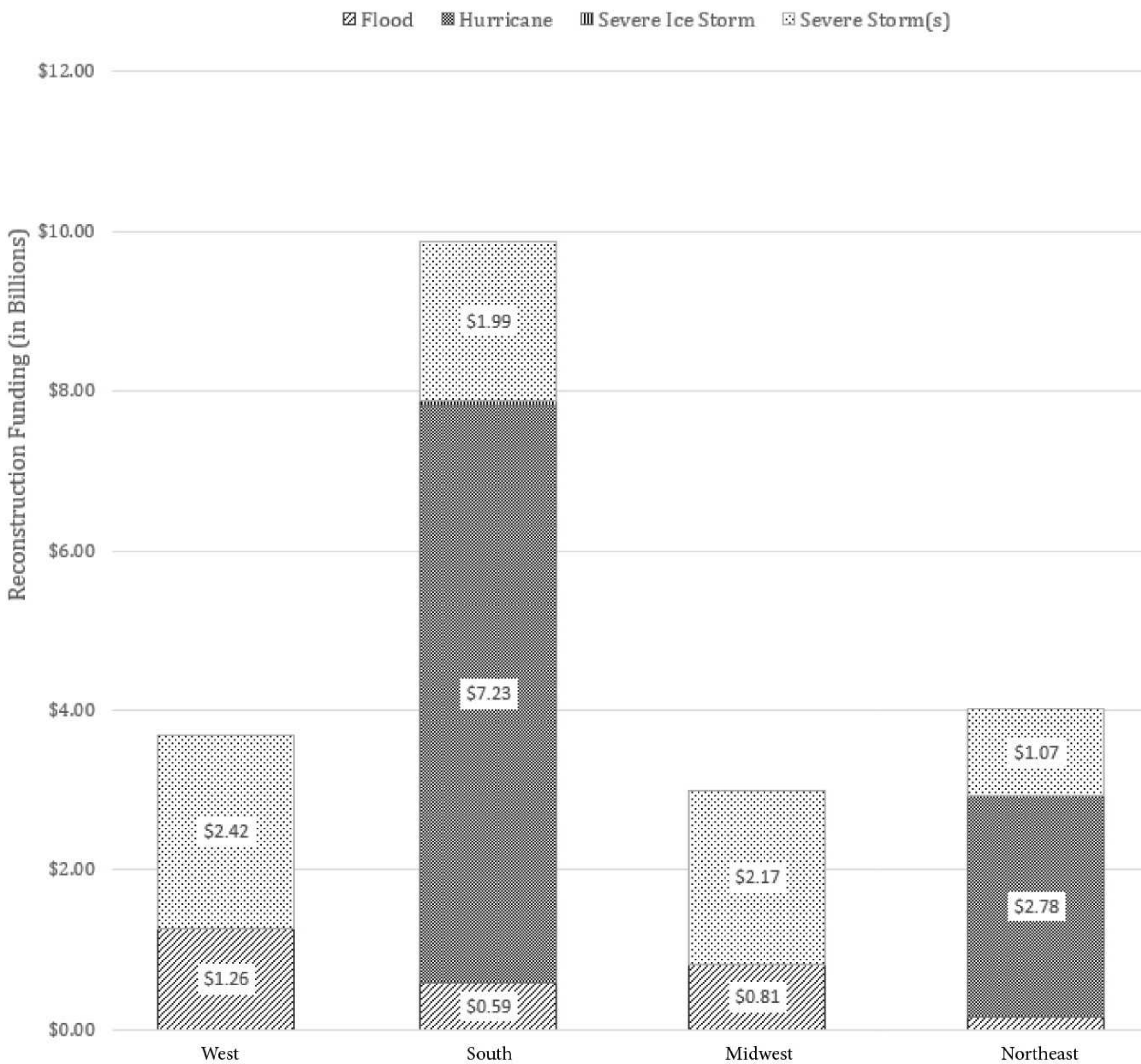


*Figure 16: Total federal funding (FEMA and FHWA) in each region for damages due to weather-related disaster events from year 2002-2016*

4.2 State-Level Labor (NAICS 237310) Wage Trends After Disasters

The first phase of the study included a trend analysis of U.S. state-level labor wages (NAICS 237310) before and after a disaster. The trend of weekly wages in disaster hit states was compared against that of disaster unaffected states and national average taking a note of any sudden change in weekly wages after a disaster event. It showed that for most of the study duration before and after a disaster event, the annual percent change in weekly wages for national average ranged around 3.0 ± 0.2% as represented by dashed gray trendline in Figure 17. The percent change in weekly wages in disaster hit states and disaster unaffected states followed alongside, with the former (in red) above national average and later (in green) below national average.

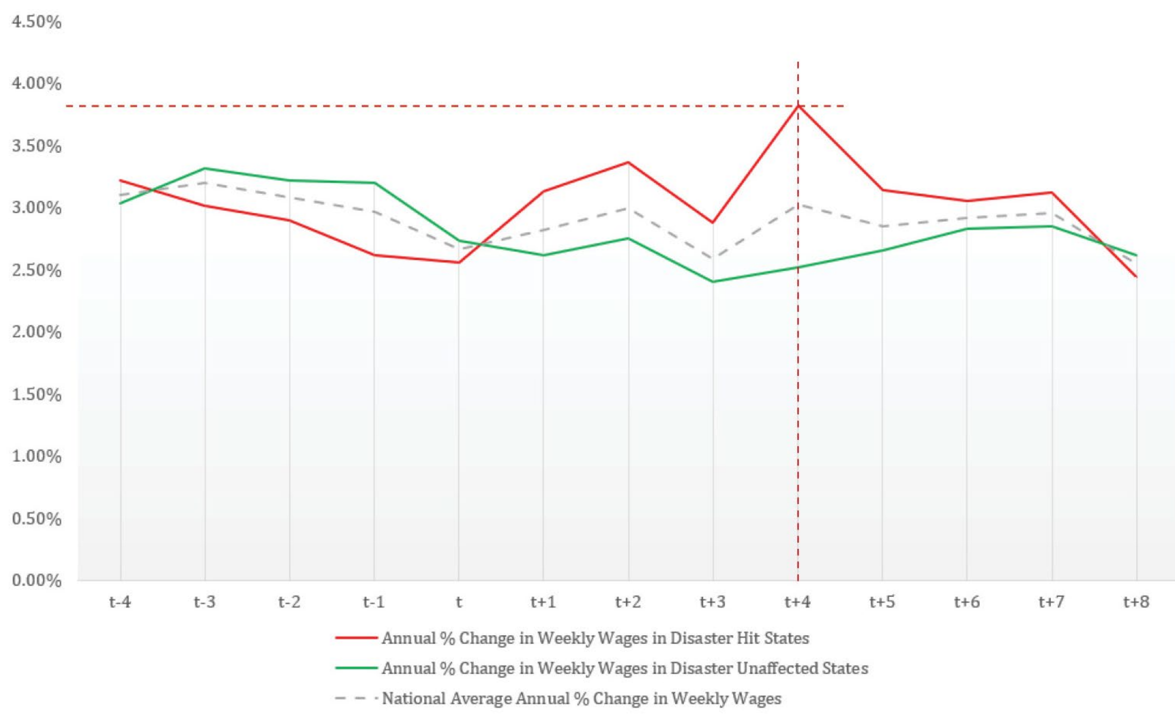


*Figure 17: Annual percent change in weekly wages*

*(calculated as percent increase from the same quarter of previous year)*

Similarly, the weekly wages in disaster hit states saw a higher growth after a year since the disaster event at 3.87%, compared to disaster unaffected states which stayed below national average of 3.0%. This difference is represented in t+4 quarters time (i.e. a year since the disaster event) in Figure 17.

### 4.3 Regional Analysis on the Percent Change in Weekly Wages (U.S. Census Region)

The findings of the previous section indicate a higher percent change in weekly wages one year after the disaster event. This part of the analysis focuses on the regional study of percent change in weekly wages, more specifically in 4 U.S. Census regions. It helps to see if the labor market in one region is more susceptible to weather related disaster than the other.

The results indicate that the percent change in weekly wages after a year for disaster hit states in each region varies broadly from the average of 3.8% obtained previously. Table 4 below compares the disaster numbers, funding, and the percent change in weekly wages in disaster hit states in all four U.S. census regions.

*Table 4: Disaster numbers, federal funding, and percent change in weekly wages by region from year 2002 to 2016 (15 years)*

| Region | Number of floods, hurricane, severe snow/storm events | Annual frequency of disasters | Total FEMA and FHWA funding | Percent change in weekly wages after a year since the disaster |
|---|---|---|---|---|
| West | 86 | 6 | $3,685,453,870.40 | 5.08% |
| South | 199 | 13 | $9,869,856,960.16 | 3.70% |
| Midwest | 154 | 10 | $2,988,417,585.79 | 3.27% |
| Northeast | 96 | 6 | $4,011,487,358.23 | 4.03% |

The West region had the highest growth in weekly wages after a year since disaster at 5.08%. The Northeast and South region with 4.03% and 3.70% change in weekly wages respectively were closer to the average of 3.8% change in weekly wages in disaster hit states. Lastly, the Midwest region showed some stable growth in weekly wages at 3.27% which is near to the annual percent change in national average weekly wages of 3%.

It is interesting to note that the initial study showed no relation between the federal funding and the percent change in weekly wages after the disaster event at the regional level as shown in Table 5. The South region with the highest amount of federal funding had below average growth in weekly wages for disaster hit states at 3.70%. But the West and Northeast regions with less than half the funding than South region and the least number of disasters were the ones with the higher than average percent change in weekly wages. Although it is in regional level, this result foreshadows on the relation between percent change in weekly wages and disaster funding that is to be explored in the next section.

However, looking at the disaster numbers in each regions, the regions with more frequent disasters had below average growth in weekly wages as shown in Figure 18. It was the South and the Northeast regions, with almost half the frequency of weather related disasters than the other two, which caused the average percent change in weekly wages in disaster hit states to be higher. During literature review, there was a study by S. K. Smith & McCarty (2006) which proposed the effect of expected frequency of disasters with out-migration of labor force. If the frequency

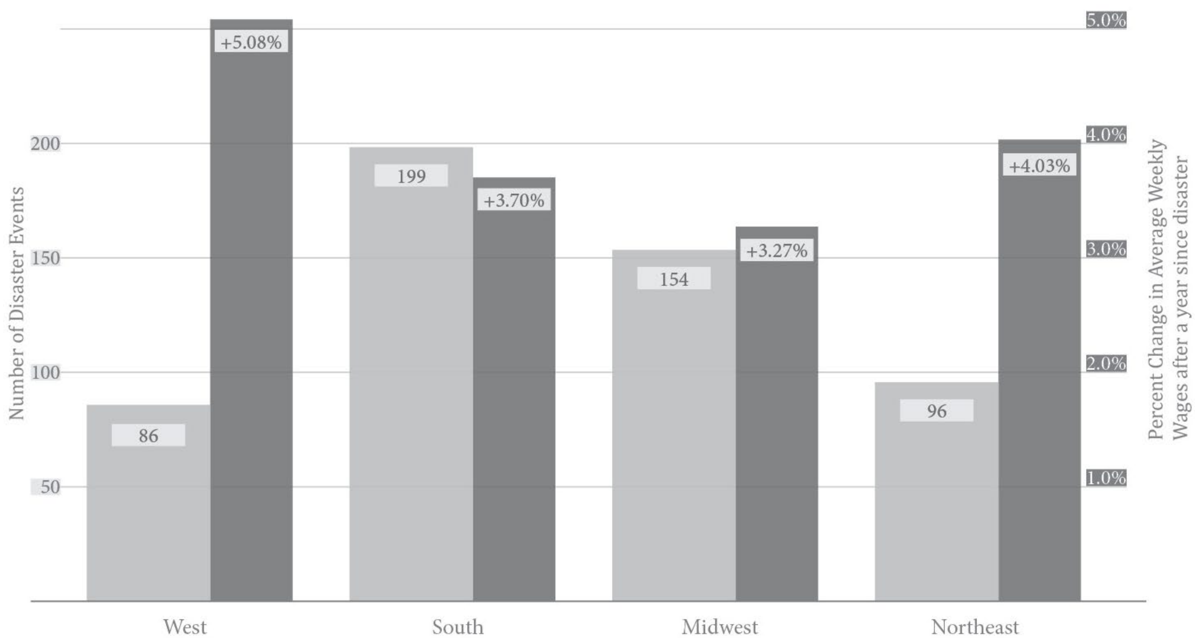


*Figure 18: Annual percent change in weekly wages by U.S. census regions*

of disaster is within the expected frequency, it will not affect labor migration while a greater frequency of disasters will lead to the out-migration of labor. Similarly, this is another example of how frequency of disasters affects the regional labor market. The labor market in states experiencing more frequent disasters have become flexible and adapted to the effects of those disasters. The labor market in these states can effectively respond to the immediate labor demand shock keeping the labor wages stable. On the other hand, the labor market in the states with less frequent disaster do not seem to be responding effectively to the demand shock due to disasters.

## 4.4 Comparison of State-Level Labor (NAICS 237310) Wages

The next phase of the study of trends of labor wages is establishing the statistical validity of difference seen in previous result between the percent change in weekly wages after a year in disaster hit states and annual percent change in weekly wages in disaster unaffected states, which is done through t-test of data between those two groups. An independent-samples t-test was conducted to compare the percent change in weekly wages between disaster unaffected states and disaster hit states after a year since disaster as shown in Table 5. There was a significant

*Table 5: Result for the t-test of annual percent change in weekly wages*

| | | | | *T-test* | | |
|---|---|---|---|---|---|---|
| | Mean | Variance | Size | df | P(T<=t) | t Critical |
| *Percent change in weekly wages in disaster hit state after a year since the disaster* | 3.87% | 0.004236 | 535 | 1317 | 0.002 | 1.96 |
| *Annual percent change in weekly wages in disaster unaffected states* | 2.79% | 0.003331 | 784 | | | |

statistical difference between the percent change in disaster hit states (M=3.87%, SD=0.0042) and disaster unaffected states (M=2.79%, SD=0.0033); t (1317) =1.96, p = 0.002. This result suggests that a disaster event affects the weekly wages after a year since its occurrence. Weather-related disaster events caused a higher percent change in wages after a year.

## 4.5 Socioeconomic Conditions Correlated with State-Level Labor (NAICS 237310) Wages

The third phase of this study examined state-level socioeconomic conditions for correlation with changes in state-level labor (NAICS 237310) wages after disaster events. The literature review revealed that reconstruction funding, unemployment rate, number of unemployed, population, and mileage of roads as state-level socioeconomic conditions which might correlate with the change in wages after a disaster. To test the strength of association with the percent change in weekly wages after a year since the disaster, the Pearson product-moment correlation coefficients were computed. The result of the correlation tests is presented in Table 6 on the following page.

As mentioned by Hallegatte et al. (2008) and Bartik (2015), the unemployment rate of a given U.S. state showed a significant negative correlation with the percent change in weekly wages in the same state. There was a significant negative correlation between the two variables, $r = -0.130$, $N = 535$, $p = 0.003$. Higher state-level unemployment rates before a disaster were correlated with a lower percent change in weekly wages after a disaster. A lower pre-disaster unemployment rate in a given state meant a higher post-disaster percent change in weekly wages in that state. This is in accordance with the findings in previous research (Bartik, 2015; Hallegatte et al., 2008). The unemployed population in a state acts as the supply pool for the immediate demand shock caused due to the disaster. A state with a higher pre-disaster unemployment rate can respond to demand shock for cheaper than a state with lower unemployment rate since there is a surplus of available construction labor and therefore less competitive wages.

As shown in Table 6 Pearson product-moment correlation coefficients were computed between percent change in wages and reconstruction funding, employment numbers, population, and mileage of road. The results showed a weak correlation which were not statistically significant. The percent change in weekly wages after a year since the disaster was not correlated with either of above-mentioned state-level socioeconomic conditions.

*Table 6: Correlation results*

**Correlations**
**Pearson Correlations**

| | Actual weekly wages after a year of disaster | Percent change in weekly wages | Reconstruction funding | Unemployment rate | Employment numbers | Population | Mileage of roads | GDP |
|---|---|---|---|---|---|---|---|---|
| **Actual weekly wages after a year of disaster** | **1** | **0.219**** | 0.015 | **0.184**** | 0.026 | **0.205**** | **-0.118**** | **0.287**** |
| **Percent change in weekly wages** | **0.219**** | **1** | 0.072 | **-0.130**** | 0.012 | 0.018 | -0.040 | 0.034 |
| **Reconstruction funding** | 0.015 | 0.072 | **1** | 0.041 | **0.135**** | **0.138**** | 0.039 | **0.142**** |
| **Unemployment rate** | **0.184**** | **-0.130**** | 0.041 | **1** | 0.037 | **0.181**** | -0.006 | **0.158**** |
| **Employment numbers** | 0.026 | 0.012 | **0.135**** | 0.037 | **1** | **0.896**** | **0.743**** | **0.856**** |
| **Population** | **0.205**** | 0.018 | **0.138**** | **0.181**** | **0.896**** | **1** | **0.653**** | **0.984**** |
| **Mileage of roads** | **-0.118**** | -0.040 | 0.039 | -0.006 | **0.743**** | **0.653**** | **1** | **0.611**** |

**. Correlation is significant at the 0.01 level (2-tailed)

However, the same set of correlation tests revealed some significant relationship between the actual average wages after a year since the disaster and some state-level economic conditions as shown in Table 6 above.

There was a weak but significant positive correlation between unemployment rate and the average weekly wage after a year since disaster, $r = 0.18$, $N = 535$; $p = .0001$. Contrary to the negative correlation with percent change in average weekly wages after a year, correlation of unemployment rate with the average weekly wages was positive. This suggests that the states with higher wages are the same states with high unemployment rate which is an interesting statement. One could argue that the general economics of demand and supply failed in this scenario, but this might be because of some third variable such as actual number of population and unemployment, GDP of each state, etc.

Similar to the percent change in average weekly wage, the actual wage after a year since the disaster and reconstruction funding in highway, street, and bridges showed no significant correlation. There was a very weak, positive correlation, $r = .015$, $N = 535$; however, the relationship was not significant ($p = .731$) inconclusive to dictate anything. Likewise, the employment number also showed no significant correlation with the actual wages after a year since the disaster. There was a very weak, positive correlation which was not statistically significant, $r = 0.026$, $N = 535$; $p = .549$. It showed that the actual wage does not correlate with reconstruction funding and the employment number.

During a disaster, milage of road and population in a certain state represent the possible demand shock level. Mileage of road is the total physical infrastructure for this research which has a possibility of getting damaged and seeking repairs, and the population represents the total possible size of community which can be affected by the damage to infrastructures during a disaster. However, in the correlation tests, the weekly wages after a year since the disaster event had positive correlation with population, r = 0.205, N = 535; p = .0001 but negative correlation with mileage of roads, r = -0.118, N = 535; p = .006.

## 4.6 Predicting State-Level Labor (NAICS 237310) Wage Changes After Disasters

The final phase of this research developed a linear regression model to predict the percent change in weekly wages one year after a disaster event. This model focuses on predicting labor wage shock four quarters (e.g., one year) after a given disaster since that is when post-disaster state-level wage shock is the highest, as detailed in Section 4.2 above. Additionally, the results of the correlation test (see Section 4.5 above) showed that only some of the socioeconomic factors included in this research were correlated with the post-disaster percent change in weekly wages. (e.g., demand shock). Although the literature review conducted as part of this research identified numerous socioeconomic conditions that have been correlated with demand shock in other industries and business sectors, results of this research found only a few of these conditions were strongly correlated with post-disaster demand shock for the highway, street and bridge construction sector (NAICS 237310).

Based on the results of the correlation tests performed as part of this research, this study identified four state-level socioeconomic conditions that could serve as pre-disaster predictors (e.g., independent variables) of post-disaster demand shock (e.g., the dependent variable) in the linear regression model. The independent and dependent variables included in the model are detailed below, and the linear regression formula is shown in Equation 1.

i. **Demand Shock:** Percent change in average weekly labor wages for workers in the highway, street, and bridge construction sector (NAICS 237310) within a state four quarters after the disaster occurs (%).

ii. **Wages:** Average weekly labor wages for workers in the highway, street and bridge construction sector (NAICS 237310) within a state during the Quarter the disaster occurs ($USD).

iii. **Unemployment:** Rate of unemployment across all industries within a state during the Quarter the disaster occurs (%).

iv. **Mileage:** Total miles of roads within a state during the Year the disaster occurs (# Miles).

v. **Population:** Average number of people living within a state during the Year the disaster occurs (# People).

**Equation 1.** Linear Regression Formula

$$\text{Demand Shock} = \beta_0 + \beta_1\text{Wages} + \beta_2\text{Unemployment} + \beta_3\text{Mileage} + \beta_4\text{ Population} + \text{e}$$

The results of the linear regression show that the post-disaster percent change in average weekly wages (e.g., demand shock) within a given U.S. state can be predicted with some accuracy. All four pre-disaster predictor variables – wages, unemployment, mileage, and population – were statistically significant model variables as shown in Table 7.

*Table 7: Linear Regression Model Parameters*

| Parameter | Estimate | Standard error | t-value | p-value |
|---|---|---|---|---|
| **Intercept** | 54.599 | 17.761 | 3.074 | **0.002** |
| **Wages** | 1.026 | 0.013 | 80.123 | **<0.001** |
| **Unemployment** | -548.661 | 178.325 | -3.077 | **0.002** |
| **Mileage** | -2.052 $e^{-4}$ | 8.730 $e^{-5}$ | -2.351 | **0.019** |
| **Population** | 1.777 $e^{-6}$ | 7.300 $e^{-7}$ | 2.445 | **0.015** |

*Note: R-squared = 0.936*
*p-value < 0.05 indicates statistical significance (95%)*

**Equation 2.** Linear Regression Equation

$$\text{Demand Shock} = 54.599 + 1.026(\text{Wages}) - 548.661(\text{Unemployment})$$
$$-2.052e^{-4}(\text{Mileage}) + 1.777e^{-6}(\text{Population})$$

### 4.6.1 Wages

The average weekly labor wages (NAICS 237310) within a state during the quarter the disaster occurs ($USD) – the 'Wages' model variable – shows a strong, statistically significant, and positive relationship with post-disaster demand shock ($p$-value = <0.0001; $\beta_1$ = 1.026). This means demand shock increases 1.026% ($USD) for every one-unit increase in wages ($USD) in the quarter a disaster occurs. In other words, for every $1.00 in average weekly labor wages paid during the quarter a disaster occurs, the same labor force will require $1.03 in wages to be paid four quarters after a disaster, all other variables kept constant. Essentially, there is a three-cent disaster surcharge on every dollar spent four quarters after the disaster event. For context, the average weekly labor wages for the highway, street and bridge construction sector averaged $1,480 across all U.S. states in 2020 (U.S. BLS, 2019). An average weekly wage of $1,480 within a state in the quarter a disaster hits is predicted to be $1,519 just four quarters later. This increase represents more than just annual inflation related wage increases, which are have typically remained under 2% in the highway, street, and bridge construction sector (U.S. BLS, 2019).

### 4.6.2 Unemployment

The unemployment rate across all industries (%) in a state during the quarter the disaster occurs – the 'Unemployment' model variable – shows a strong, statistically significant, and negative relationship with post-disaster demand shock ($p$-value = 0.002; $\beta_2$ = -548.661). These results indicate that for every one-unit increase in the state-level unemployment rate, the average weekly wages ($USD) in the highway, street, and bridge construction sector (NAICS 237310) decrease $548.67, all other variables kept constant. To put simply, for every 1% increase in the state-level unemployment rate (meaning more people within the state do not have jobs across all industries), the average weekly wages of the highway, street and bridge construction sector are predicted to decrease by $548.67. In other words, when there are fewer total jobs within a state, the competition for those jobs increases and workers have less bargaining power in regard to labor wages.

Economic downturns, such as the 2008 Great Recession, have previously led to rapid increases in unemployment rates across most U.S. states. During the timeframe of this study from 2002 to 2016, state unemployment rates ranged from a minimum of 2.60% to a maximum of 12.27% (U.S. BLS, 2020). Results of this study indicate that if a flood-related disaster hits a U.S. state, any highway, street, and bridge reconstruction work should be less expensive during an economic downturn and more expensive when the economy is strong.

4.6.3 Mileage

The total miles of highways and streets within any state during the year a disaster occurs (# miles) – the 'Mileage' model variable – shows a moderate, statistically significant, and negative relationship with post-disaster demand shock ($p$-value = 0.019; $\beta_2 = -2.052e^{-4}$). Mileage refers to the total length of roadways that are eligible to receive funding from federal government in case of damages due to a disaster. Results indicate that for every additional mile of roads within a state, the average weekly wages ($USD) in the highway, street, and bridge construction sector (NAICS 237310) decrease only a small amount. Put another way, for every additional 10,000 miles of total length of road within a state, the average weekly wages four quarters after a disaster event are expected to increase $2.05, all other variables kept constant. This is a very minor effect because the FHWA data shows that it took 10 years on average for the length of roadways in U.S. states to increase by around 3,000 miles (FHWA, 2020). In summary, states with more miles of roadway damages due to flood-related disasters will likely see slightly higher average weekly wages for workers in the highway, street and bridge sector in comparison to states with less damaged roadways.

### 4.6.4 Population

The average number of people living within a state during the year a disaster occurs (# of people) – the 'Population' model variable – shows a moderate, statistically significant, and positive relationship with post-disaster demand shock ($p$-value = 0.015; $\beta_2 = 1.777\ e^{-6}$). Results show that for every one-unit increase in the state-level population, the average weekly wages ($USD) in the highway, street, and bridge construction sector (NAICS 237310) increase a nominal amount. In other words, for every additional one million people added to the population of a state, the average weekly wages of the highway, street and bridge construction sector are predicted to increase by $1.78, all other variables kept constant. U.S. states with higher population bases will have to pay just a small amount extra in wages for post-disaster reconstruction work four quarters after a disaster event.

# 5 CONCLUSION

The background investigation on the exploration of labor wages behavior after a disaster revealed that there is a big gap in its study related to transportation infrastructure sector. With the increasing number of disasters and the increasing magnitude of physical damage due to these disasters, this established the need for research focused on highway, street, and bridge reconstruction sector.

Review of wage data from BLS QCEW for highway, street, and bridge (NAICS 237310) found that the there is a substantial increase in average weekly wages in disaster affected states after four quarters (i.e., one year). In fact, the disaster affected states in the U.S. see an average growth of 3.87% in weekly wages after a year of disaster compared to annual growth in disaster unaffected states of below 3.0% on average. This difference in behavior of labor wages was proved to be statistically significant with the help of t-tests.

Additionally, within the disaster affected states, there was a variation in percent change in four different regions (Northeast, Midwest, South and West). South and Midwest regions, with highest number of weather-related disasters, had below average growth in labor wages at 3.7% and 3.27% respectively. However, the West and Northeast regions showed a higher-than-average growth at 5.08% and 4.03% respectively. Both of these regions had almost half the disaster numbers than the former two. This showed how some regional labor markets have adapted to the increasing frequency of disaster and become resilient than others.

The review of previous works in related field helped in identifying unemployment, disaster funding, state infrastructure as some state-level socioeconomic factors that could impact labor wages after a disaster. During the correlation test, it was found that except for the state unemployment rate, none of the other variables had a significant degree of association with the percent change in labor wages in NAICS 237310 sector. Unemployment rate had significant negative correlation with the percent change in wages after a year since the disaster. The reconstruction funding which was expected to have some relation based on the literature review showed very weak correlation. However, further tests found some significant correlation of actual wages after four quarters (i.e., one year) with some state-level socioeconomic conditions. Labor wages after one year of disaster was correlated with unemployment rate, GDP, population, mileage of roads.

Finally, a linear regression model was computed for prediction of post-disaster percent change in weekly wages using four pre-disaster predictor variables – wages, unemployment, mileage, and population. The said linear regression model was able to explain 93.6% of variation in percent change in weekly wages after a disaster during the study timeframe of this research.

## 5.1 Theoretical Contributions

The various studies mentioned in the literature review helped shape this research. Several researchers had discussed the demand shock after the disasters and identified different variables that might impact the labor market conditions. Although the previously mentioned studies show the trend of overall construction labor market or sometimes a specific sector other than transportation, this research provided an outlook on labor market specifically in highway, street, and bridges sector and added to the body of knowledge regarding the construction industry labor market of transportation sector after disasters.

Besides this, the previous works referenced in this research had studied the labor wages in annual basis. This was because the data for wages was obtained from Current Population Survey (CPS) statistics which are published annually. In contrast, this research used the quarterly wage data from Bureau of Labor Statistics (BLS) Quarterly Census of Employment and Wages

(QCEW). This enabled the study of short-term demand shock in labor market due to weather related disasters. This research also takes into consideration the recommendation by Belasen & Polachek (2009) to include variables such as disaster relief fund, unemployment, etc. to study the phenomenon of labor wage change in highway, street, and bridges after a disaster.

## 5.2 Practical Contributions

The results from this research will help local and state governments to plan and account for construction labor wage spikes during post-disaster reconstruction of highway, street, and bridge systems. This research could also help contractors bidding on roads and bridge reconstruction projects to include more realistic cost for labor wages. The study of labor demand helps in assessing the current status of labor market and its capacity in supporting the post disaster reconstruction.

## 5.3 Limitations and Future Work

This research was supposed to provide a broader picture on the effect of weather-related disasters on labor market of highway, street, and bridges sector. Analysis of data obtained from public resources helped to study the trend of labor wages and thus to derive a model to predict it. But it does not consider labor migration pattern in county level and across neighboring states. Short term and long-term migration of labor have a vital role to play in response during post disaster reconstruction. It not only affects the states and counties with disasters but also neighboring regions and their labor market. Several research have been conducted to study the impact of disasters in neighboring states but they are very limited to a small specific region at county level or to individual disaster events. Further work on exploring this phenomenon at broader level would be a very important addition to the body of knowledge on labor market analysis.

# 6 REFERENCES


AGC, & Autodesk. (2019). *2019 Worker Shortage Survey Analysis* (2019 Worker Shortage Survey Analysis, p. 5). Associated General Contractors.

Arkell, B. P., & Darch, G. J. C. (2006). Impact of climate change on London's transport network. *Municipal Engineer*, *159*(ME4), 231–237.

Arneson, E., Javernick-Will, A., Hallowell, M., & Corotis, R. (2020). Predicting Postdisaster Residential Housing Reconstruction Based on Market Resources. *Natural Hazards Review*, *21*(1), 04019010. https://doi.org/10.1061/(ASCE)NH.1527-6996.0000339

Baird, M. E. (2010). *The Recovery Phase of Emergency Management*. Intermodal Freight Transportation Institute (IFTI), University of Memphis. https://www.memphis.edu/ifti/pdfs/cait_recovery_phase.pdf

Bartik, T. J. (2015). How Effects of Local Labor Demand Shocks Vary with the Initial Local Unemployment Rate. *Growth and Change*, *46*(4), 529–557. https://doi.org/10.1111/grow.12101

Belasen, A. R., & Polachek, S. W. (2009). How Disasters Affect Local Labor Markets: The Effects of Hurricanes in Florida. *Journal of Human Resources*, *44*(1), 251–276. https://doi.org/10.1353/jhr.2009.0014

Boustan, L. P., Kahn, M., Rhode, P., & Yanguas, M. L. (2017). *The Effect of Natural Disasters on Economic Activity in US Counties: A Century of Data* (No. w23410; p. w23410). National Bureau of Economic Research. http://www.nber.org/papers/w23410.pdf

Boyd, A., Hokanson, J. B., Johnson, L. A., Schwab, J. C., & Topping, K. C. (2014). *Planning for Post-Disaster Recovery: Next Generation* (No. 576; Planning Advisory Service, p. 204).

American Planning Association. https://floodready.vermont.gov/sites/floodready/files/documents/PAS_576.pdf

Buckle, P., Marsh, G., & Smale, S. (2001). *Assessment of Personal & Community Resilience & Vulnerability* (Emergency Management Australia Report).

Chang-Richards, A. Y., Wilkinson, S., Seville, E., & Brunsdon, D. (2015). Resourcing Issues Following Earthquake Disaster. In M. Beer, I. A. Kougioumtzoglou, E. Patelli, & S.-K. Au (Eds.), *Encyclopedia of Earthquake Engineering* (pp. 2218–2225). Springer. https://doi.org/10.1007/978-3-642-35344-4_352

Cheng, G., & Wilmot, C. G. (2009). Louisiana Highway Construction Cost Trend after Hurricanes Katrina and Rita. *Journal of Construction Engineering and Management*, *135*(7), 594–600. https://doi.org/10.1061/(ASCE)CO.1943-7862.0000015

Cooper, R. (2018). *Hurricane Florence: Preliminary Damage and Need Assessment* (Building Communities Stronger and Smarter) [Hurricane Florence Recovery Recommendations]. Office of the Governer. https://files.nc.gov/ncosbm/documents/files/Florence_Report_Full_rev20181016v10.pdf

Doyle, H. (2017, September 22). *Labor shortage deepens after hurricanes*. Reuters Events | Downstream. https://www.reutersevents.com/downstream/workforce-development/labor-shortage-deepens-after-hurricanes

Federal Reserve Board of Governors, & Roth Tran, B. (2020). The Local Economic Impact of Natural Disasters. *Federal Reserve Bank of San Francisco, Working Paper Series*, 1.000-61. https://doi.org/10.24148/wp2020-34

FEMA. (2011). *National Disaster Recovery Framework* (Strengthening Disaster Recovery for the Nation). FEMA. https://www.fema.gov/pdf/recoveryframework/ndrf.pdf

FEMA. (2017). Disaster Sequence of Events. In *Overview of Local, State, and Federal Response to a Disaster*. Emergency Management Institute. https://training.fema.gov/emiweb/downloads/is208sdmunit3.pdf

FEMA. (2021, April 21). *OpenFEMA Dataset: Public Assistance Funded Projects Details - v1 | FEMA.gov*. FEMA. https://www.fema.gov/openfema-data-page/public-assistance-funded-projects-details-v1

FHWA. (2014, September 7). *A Guide to Reporting Highway Statistics*. Office of Highway Policy Information | Policy and Governmental Affairs. https://www.fhwa.dot.gov/policyinformation/hss/guide/index.cfm

FHWA. (2020). *Highway Statistics Series—Policy | Federal Highway Administration*. Highway Statistics Series. https://www.fhwa.dot.gov/policyinformation/statistics.cfm

Gall, M., Emrich, C. T., & Cutter, S. L. (2015). *Who needs loss data?* https://doi.org/10.13140/2.1.4751.6969

Groen, J. A., Kutzbach, M. J., & Polivka, A. E. (2017). Storms and Jobs: The Effect of Hurricanes on Individuals' Employment and Earnings over the Long Term. *BLS Working Papers*, *499*, 76.

Hallegatte, S., Boissonnade, A., Schlumberger, M.-E., & Muir-Wood, R. (2008). Demand Surge and Worker Migrations in Disaster Aftermaths: Application to Florida in 2004 and 2005. *Journal of Regional Science*, 25.

Hopkinson, T. (2019a). Reconstruction cost increases show signs of flattening. *Verisk*. https://www.verisk.com/insurance/visualize/reconstruction-cost-increases-show-signs-of-flattening/

Hopkinson, T. (2019b, July 15). *Reconstruction cost growth continues at a steady rate*. Verisk. https://www.verisk.com/insurance/visualize/reconstruction-cost-growth-continues-at-a-steady-rate/

Hopkinson, T. (2020, October 19). *Reconstruction cost increases reach historic high*. Verisk. https://www.verisk.com/insurance/visualize/reconstruction-cost-increases-reach-historic-high/

Larry Wesemann, Tijana Hamilton, Steve Tabaie, & Gerald Bare. (1995). Cost-of-Delay Studies for Freeway Closures Caused by Northridge Earthquake. *Transportation Research Record*, *1559*(1), 67–75. https://doi.org/10.1177/0361198196155900109

Lavrakas, P. J. (Ed.). (2008). T-Test. In *Encyclopedia of Survey Research Methods* (Vol. 2, pp. 911–912). SAGE Publications; Gale eBooks. https://link.gale.com/apps/doc/CX3073300608/GVRL?u=coloradosu&sid=GVRL&xid=965f8e61

McCarty, C., & Smith, S. K. (2006). *Florida's 2004 Hurricane Season: Demographic Response and Recovery*. 40.

NAICS-OMB. (2017). *Nortn American Industry Classification System*. https://www.census.gov/naics/reference_files_tools/2017_NAICS_Manual.pdf

NCEI, N. N. C. for E. I. (2019, October 8). *U.S. Billion-Dollar Weather and Climate Disasters*. https://www.ncdc.noaa.gov/billions/

NOAA. (2021, April 20). *Hurricane Costs*. Office for Coastal Management NOAA. https://coast.noaa.gov/states/fast-facts/hurricane-costs.html

Olsen, A. H., & Porter, K. A. (2010). *What We Know about Demand Surge*. 38.

Olsen, A. H., & Porter, K. A. (2011). On the Contribution of Reconstruction Labor Wages and Material Prices to Demand Surge. *Structural Engineering & Structural Mechanics Report Series*, 81.

Olsen, A. H., & Porter, K. A. (2013). Storm Surge to Demand Surge: Exploratory Study of Hurricanes, Labor Wages, and Material Prices. *Natural Hazards Review*, *14*(4), 247–257. https://doi.org/10.1061/(ASCE)NH.1527-6996.0000111

Padgett, J., DesRoches, R., Nielson, B., Yashinsky, M., Kwon, O.-S., Burdette, N., & Tavera, E. (2008). Bridge Damage and Repair Costs from Hurricane Katrina. *Journal of Bridge Engineering*, *13*(1), 6–14. https://doi.org/10.1061/(ASCE)1084-0702(2008)13:1(6)

Pelling, M., Özerdem, A., & Barakat, S. (2002). The macro-economic impact of disasters. *Progress in Development Studies*, *2*(4), 283–305. https://doi.org/10.1191/1464993402ps042ra

Rodrigue, J.-P. (2020). Transportation, Disruptions and Resilience. In *The Geography of transport Systems* (5th edition, p. 345). Routeledge.

Saks, R. E. (2008). Job creation and housing construction: Constraints on metropolitan area employment growth. *Journal of Urban Economics*, *64*(1), 178–195. https://doi.org/10.1016/j.jue.2007.12.003

Sarmiento, C., & Miller, T. R. (2006). *Costs and Consequences of Flooding and the Impact of the National Flood Insurance Program* (Reports in the Evaluation of the National Flood Insurance Program). Pacific Institute for Research and Evaluation. https://www.fema.gov/sites/default/files/2020-07/fema_nfip_eval-costs-and-consequences.pdf

Simpson, A. (2014). *Understanding risk in an evolving world* (Understanding Risk in an Evolving World, pp. 44–73). The World Bank.

Smith, A. B., & Katz, R. W. (2013). US billion-dollar weather and climate disasters: Data sources, trends, accuracy and biases. *Natural Hazards*, *67*(2), 387–410. https://doi.org/10.1007/s11069-013-0566-5

Smith, S. K., & McCarty, C. (2004). *Florida's 2004 Hurricane Season: Demographic Response and Recovery*. 40.

Trevino, S. (2021, January 7). *QCEW Overview: U.S. Bureau of Labor Statistics*. U.S. Bureau of Labor Statistics. https://www.bls.gov/cew/overview.htm

United Nations Development Programme. (2016). *National Post-Disaster Recovery Planning and Coordination*. United Nations Development Programme. https://reliefweb.int/sites/reliefweb.int/files/resources/UNDP_Guidance_Note_Disaster%20Recovery_final.pdf

U.S. BLS. (2018). *Local Area Unemployment Statistics* (Handbook of Methods, p. 20). U.S. Bureau of Labor Statistics.

U.S. BLS. (2019). *QCEW Searchable Databases: U.S. Bureau of Labor Statistics*. Quarterly Census of Employment and Wages. https://www.bls.gov/cew/data.htm

U.S. BLS. (2020, March 20). *Local Area Unemployment Statistics Overview*. U.S. Bureau of Labor Statistics. https://www.bls.gov/lau/lauov.htm

U.S. EPA. (2016). *Climate Impacts on Transportation* [Overviews and Factsheets]. United States Environmantal Protection Agency. /climate-impacts/climate-impacts-transportation

US FEMA, & Galloway, G. E. (1994). *Sharing the challenge: Floodplain management into the 21st century*. The Committee : for sale by U.S.G.P.O. https://fas.org/irp/agency/dhs/fema/sharing.pdf

Vermeiren, J. C. (1989). *Natural Disasters: Linking Economics and the Environment with a Vengeance*. Conference on Economics and the Environment.

Zabel, J. E. (2012). Migration, housing market, and labor market responses to employment shocks. *Journal of Urban Economics*, *72*(2–3), 267–284. https://doi.org/10.1016/j.jue.2012.05.006

Zhang, W., Wang, N., & Nicholson, C. (2017). Resilience-based post-disaster recovery strategies for road-bridge networks. *Structure and Infrastructure Engineering*, 11. https://doi.org/10.1080/15732479.2016.1271813