ICCEPM 2022
The 9th International Conference on Construction Engineering and Project Management
Jun. 20-23, 2022, Las Vegas, NV, USA

Analysis of Federal Expenses to Restore, Repair, Reconstruct, or Replace Disaster Damaged Roads and Bridges in the U.S.

Arkaprabha Bhattacharyya[1]*, Makarand Hastak[2]

[1] *Lyles School of Civil Engineering, Purdue University, West Lafayette, IN, 47906, USA,* E-mail address: bhatta23@purdue.edu
[2] *Division of Construction Engineering and Management, Purdue University, West Lafayette, IN, 47906, USA,* E-mail address: hastak@purdue.edu

Abstract: In the U.S., the state, local, tribe, and territorial governments seek funding from the federal government through the Public Assistance program to carry out these recovery works. In this paper historic public assistance data between 1998 and 2021 have been analyzed to derive several insights such as: types of disasters causing the most damage, states requiring more support, net present value of the federal expense etc. This paper has found that the states requiring more support from the federal government are not always the states suffering the maximum losses from the disasters. It has also found that the net present value of the federal expense between 1998 and 2020 to restore, repair, reconstruct, or replace disaster damaged roads and bridges across the U.S. is $15 billion in 2021 values. Moreover, this paper has tested the correlation between the states' public assistance funds requirements and the existing condition and performance of roads and bridges as revealed by the American Society of Civil Engineer's infrastructure grade card. It has found a weak correlation between these two. The outcomes of this paper can be used by the decision makers to analyze the viability of any possible alternative to the exiting public assistance program. The insights can also help in better decision making in pre-disaster preparation and post-disaster funds allocation.

Key words: disaster risk reduction, public assistance, infrastructure grade

1. INTRODUCTION

Infrastructure facilities are essential for long-term economic prosperity of a nation. Besides, they also fortify a nation against natural disasters. Choi et al. [1] have classified infrastructures into seven categories to improve community resilience against natural disasters. They are civil, civic, social, financial, environmental, educational, and cyber. Out of these seven layers, civil infrastructures such as roads and bridges, dams, levees, etc., protect communities from the physical risk [1]. In the U.S., infrastructures suffer from chronic underinvestment. A recent report published by the American Society of Civil Engineers [2] has predicted the cost of underinvestment in American infrastructure systems. The report estimated the cost to be $3,300 annually to every American household between 2019 and 2039. During this period, the underperforming infrastructures will cumulatively cost American GDP an estimated $10.3 trillion [2].

Natural disasters cause direct physical damage to infrastructures. As an outcome of this damage the serviceability of infrastructures get reduced. When the serviceability is reduced, the economic impact is not limited to the infrastructure itself, but it cascades through the economy [3,4]. Bhattacharyya et al., [4] have found the cost of 1% reduction in production of utility sector to be $11.6 billion dollars of GDP in 2019 values. Likewise, Cartes et al. [5] have assessed the cost of disruption to the road system by natural disasters.

In the U.S. the state, local, tribe, and territorial (SLTT) governments seek funding from the federal government to repair, restore, reconstruct, or replace disaster damaged infrastructures such as roads and bridges, dams, levees, utilities, public buildings etc. This program is named as Public Assistance (PA) program [6,7]. Under this program the federal government pays for at least 75% of the eligible cost. The remaining less than 25% of the cost is borne by the SLTT governments. Due to the increasing frequency of natural disasters and simultaneous aging of infrastructures, the cost of the PA programs might increase in future. Therefore, there is a need to analyze the possibility of alternatives to the existing PA program. But before that, it is equally important to analyze the trends, actual costs, and derive insights from the historical PA data.

This paper has analyzed historical PA funded projects data to derive insights such as types of natural disasters causing the most damage, states with the highest requirements for PA program, net present value of the federal expense etc. Out of the all the projects, this paper has focused on the roads and bridges only. At the end, the paper has also tested the correlation between a state's PA funds requirements and the performance and condition of roads and bridges within that state. For doing that this paper has utilized ASCE's infrastructure grade card data [8]. The insights derived from this paper can be utilized by the decision makers to analyze the viability of alternatives to the PA program. The outcomes can be used in long term policy making regarding the purchase of disaster insurance for infrastructures. Since the paper has utilized historical data, it has conducted an evidence-based analysis thus paving the way for data driven decision making in infrastructure resilience.

2. PUBLIC ASSISTANCE PROGRAM

The public assistance (PA) program is managed by the Federal Emergency Management Agency (FEMA). Through this program the state, local, tribal, and territorial (SLTT) governments can seek funding to conduct both emergency and permanent works to recover from a major disaster. These emergency works can also be executed before the disaster takes place. The Stafford Disaster Relief and Emergency Assistance Act requires FEMA to reimburse not less than 75% of the eligible costs of disaster response and recovery works to the applicants.

There are seven categories of works that are eligible for reimbursement through PA program [6,7]. They are Category A – Debris removal cost after the disaster, Category B – Emergency protective measures costs such as search and rescue, emergency transportation, and distribution of food and first aid, Category C – Repair, restore, reconstruct, or replace disaster damaged roads and bridges except federal aid roads, Category D – Repair, restore, reconstruct, or replace disaster damaged water control facilities including dams and levees, Category E – Repair, restore, reconstruct, or replace disaster damaged buildings and equipment including eligible building contents, Category F – Repair, restore, reconstruct, or replace disaster damaged utilities including gas, power, water, communication, and sewage facilities, and Category G – Repair, restore, reconstruct, or replace disaster damaged parks, recreational, and others including railways, beaches, piers, ports, and harbors.

Category A and B are considered emergency works whereas the others are considered permanent works. Once the PA support is requested by the SLTT governments, FEMA conducts a preliminary damage estimation in collaboration with the applicants. The estimated cost of PA-eligible works should exceed $1 million across a state or territory and $250,000 across a tribe. Additionally, for states and territories, the cost must be more than or equal to the adjusted per capita threshold across the county and the state or territory requesting the support. For the financial year 2021, this threshold for requesting PA was $1.55 and $3.89 across state or territory and county, respectively [7].

3. PUBLIC ASSISTANCE DATA ANALYSIS

This paper presents the analysis of the FEMA's "Public Assistance Funded Projects Details" dataset. The dataset was downloaded from FEMA's website [9]. It provides records of the PA program funded projects since 1998. It had approximately 750 thousand records of the funded projects and provides a number of details for each project such as: disaster number, declaration date, incident type (flood, fire etc.), county, state, damage category (roads and bridges, utility etc.), project cost, federal obligated amount etc. This paper has only analyzed a subset of the PA funded projects where the damages were sustained by roads and bridges (Damage category – C).

Figure 1 display the total federal obligated amount for PA program where the damages were sustained by roads and bridges between 1998 and 2021. As it can be seen that the cost of PA program has been increasing since 1998. Three distinct spikes can be observed on the plot. Those spikes occurred in 2005, 2012, and 2017 – the years of hurricane Katrina, Superstorm Sandy, and Hurricane Harvey, respectively.

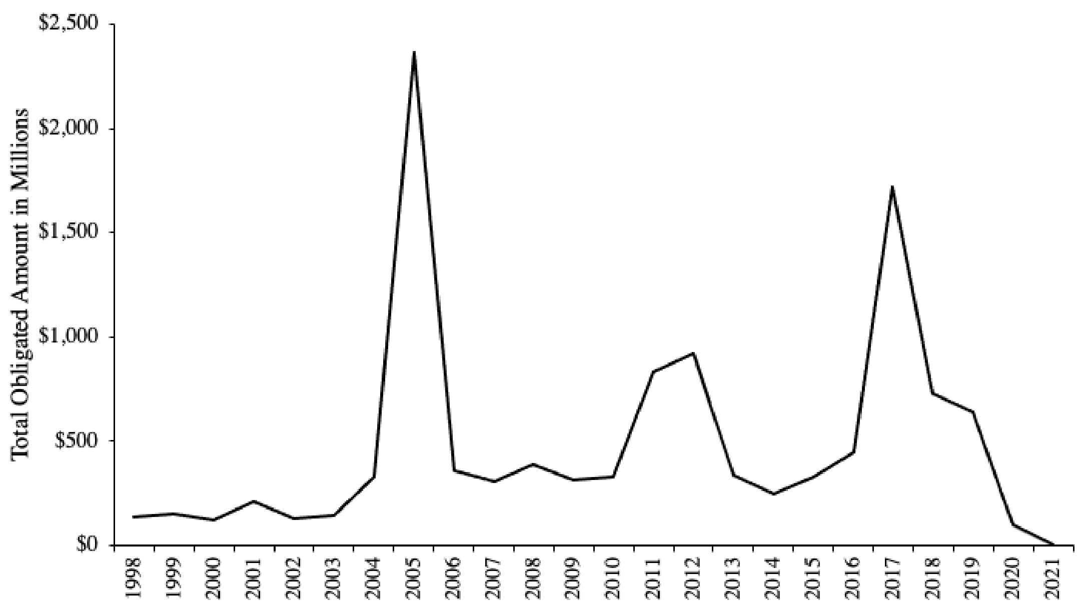

Figure 1. Historic PA Spending in Roads and Bridges

Among the types of natural disasters, it has been found that hurricanes have caused the highest damages to the U.S. roads and bridges. Figure 2 displays the total obligated amount between 1998 and 2021 for various types of the natural disasters. It can be seen that between 1998 and 2021, three types of natural disasters have required more than billion dollar of PA support to restore, repair, and reconstruct the disaster damaged roads and bridges. They are hurricanes, severe storms, and floods. Among these three, hurricanes have caused the most damage.

Table 1 shows the states that have received the highest amount of funding through PA program between 1998 and 2021 to repair, restore, reconstruct, or replace their hurricane, severe storm, and flood damaged roads and bridges. The information displayed in Table 1 is quite interesting. Although hurricane Harvey which is considered the second costliest tropical storm in the U.S.

history [10] devastated Texas, it has not appeared on Table 1. Again, the billion-dollar event database managed by the National Oceanic and Atmospheric Administration [11] show that between 1998 and 2021, the cost of severe storm in Alabama is much more than that of Kentucky. Still, Kentucky has received more public assistance support from the federal government during the said period. The same issue can be noticed for flood related PA programs as well. The NOAA database also records the cost of flood events. That database shows that the cost of floods between 1998 and 2021 has been much higher in Iowa than North Dakota. Still, North Dakota has received the highest amount of PA funding to repair, restore, reconstruct, or replace flood damaged roads and bridges.

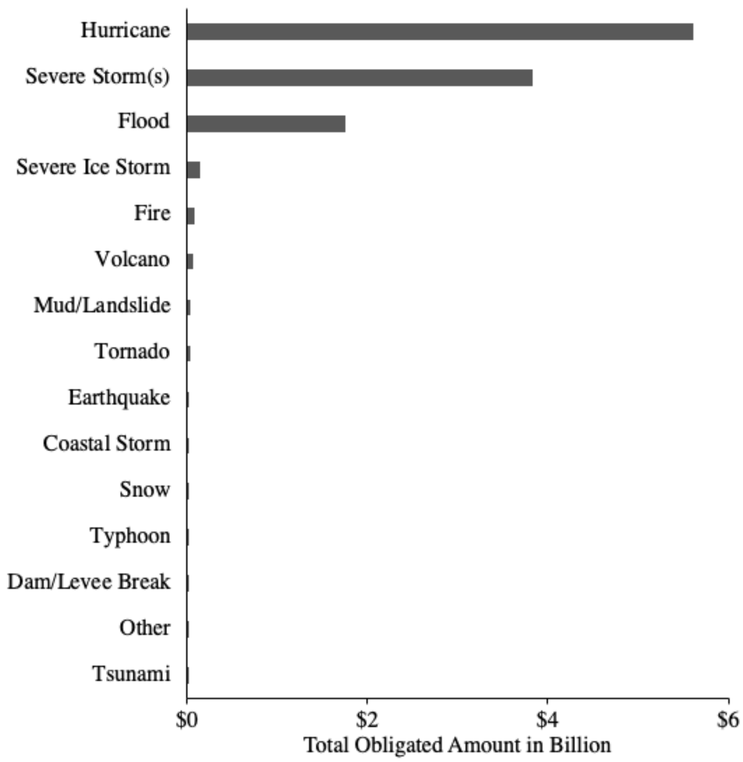

Figure 2. Total Obligated Amount for Different Types of Disasters (Damage Category – C)

Table 1. States Receiving the Most PA Support (Damage Category – C)

	Highest	2nd Highest	3rd Highest
Hurricane	Louisiana	New York	Florida
Severe Storm(s)	New York	California	Kentucky
Flood	North Dakota	Nebraska	California

This difference raises the question on what determines the need for PA program? It has been explained that PA fund requirement by states is not always determined by the cost of natural disasters in that state. That is the reason why Iowa – suffering much more flood losses than North Dakota – has required less PA support from the federal government. Based on this observation this paper has tested the hypothesis that the existing physical condition and performance of the roads and bridges in a state determines the PA funding requirements after a natural disaster. To do that, this paper has tested the correlation between the PA funding support and the condition and performance of roads and bridges reflected through the grade card developed by the American Society of Civil Engineers [8].

Before testing the main hypothesis, this paper has calculated the Net Present Value (NPV) of total PA support between 1998 and 2020 in 2021-dollar value. This calculation will give an insight on the total burden of the PA program to the federal government. The NPV is calculated for each state which will help in identifying the states where roads and bridges were more vulnerable to the natural disasters than others. This identification will further help in planning natural disaster resilience for the identified states.

For deriving the NPV, the annual discount rates were retrieved from the Federal Reserve Bank database [12]. These discount rates were provided by the International Monetary Fund on monthly basis. To calculate the annual discount rates the monthly discount rates of a given year were averaged out. The total obligated amount for each state for all types of natural disasters for all the years between 1998 and 2020 were calculated using the dataset explained previously. Finally, the NPV of the total obligated amount in 2021-dollar value was calculated for each state based on equation 1.

$$NPV = PA_t(1 + i_t)^{2021-t} \tag{1}$$

Where PA_t = PA obligated amount of a year t and t $\in$ [1998, 2020], i_t is the discount rate for the year t. Figure 3 displays the outcome of the NPV calculation. The NPV of the total federal obligation from the PA program for all 50 states and the District of Columbia is approximately $15 billion in 2021 values. Out of that $15 billion, $4 billion has been spent in Louisiana; approximately $2 billion has been spent in New York; $0.9 billion in Florida; $0.7 billion in California; $0.5 billion in Texas. Whereas, Utah, Rhode Island, Delaware, Wyoming, Washington D.C. had the lowest PA funding requirements between 1998 and 2020.

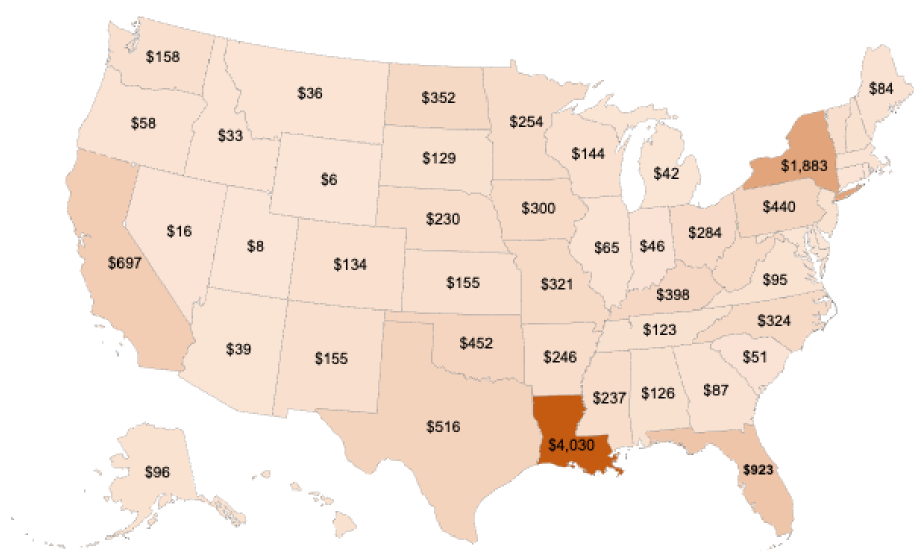

Figure 3. NPV of PA Obligation for the U.S. States between 1998 and 2020 (in Million)

In this paper, multiple datasets have been used. All these datasets are publicly available. First, the "Public Assistance Funded Projects Details" was used to derive the state wise and year wise PA statistics which have been shown and explained in the previous sections. As explained previously, it has been found that the PA support is not always determined by the overall damage of a natural disaster in a state. Based on this evidence, this paper has tested the hypothesis which claims that the amount of PA support has a direct correlation with the existing performance and condition of roads and bridges in a state.

The performance and condition of roads and bridges in a state has been represented in ASCE's infrastructure grades report. ASCE provides a snapshot of the performance and condition of roads and bridges for all the states. This paper has utilized the number of structurally deficient bridges and miles of road in poor condition as the two variables representative of the existing performance and condition of roads and bridges in a state. ASCE provides these statistics for the year 2019. Moreover, ASCE only provides the percentage of roads in poor condition. Therefore, to derive the miles of roads in poor condition, the total lane-miles of roads for all the states in 2019 were collected from the Federal Highway Administration's (FHWA) website [13]. Finally, the total lane-miles for a state were multiplied by the percentage of roads in poor condition to derive the miles of roads in poor condition. For bridges, ASCE provides the percentage as well as the total number of bridges.

Since the condition and performance of roads and bridges were available for the year 2019, this paper has tested its correlation with a state's PA support for 2019 and beyond only. For doing that, first the cumulative PA support for all the states from 2019 onwards were calculated. Next, the states were categorized into two groups. Group 1 contained the states that have suffered from more disaster losses since 2019 and Group 2 are the states that have suffered less from the disasters since 2019. To do that, first the natural disasters were grouped by states. This grouping is done through the unique number FEMA sequentially assigns to designate an event or incident declared as disaster. Then, the PA support corresponding to each FEMA designated disaster was derived from "FEMA Web Disaster Summaries – v1" dataset [14]. These two steps resulted in the total PA support for all the states from 2019 onwards. Then the total PA support for all the states were normalized and the weight for each state was calculated based on equation 2:

$$Weight\ for\ State\ i = \frac{Total\ PA\ Support\ for\ State\ i}{Total\ PA\ Support\ for\ all\ States} \quad (2)$$

Once the weights have been calculated, it was found that there were 11 states (Arizona, Colorado, Indiana, Maine, Massachusetts, Nevada, New Mexico, Pennsylvania, Rhode Island, Virginia, and Wyoming) and District of Columbia that had not received any PA support since 2019. Therefore, the grouping was done on the remaining 39 states. The median was selected as the point separating the two groups. Table 2 shows the two groups. Group 1 had 20 states while Group 2 had 19 states.

Table 2. Two Groups of States

Group	States
1	Louisiana, California, Nebraska, Oregon, Iowa, Kentucky, North Carolina, Mississippi, Missouri, Alabama, Alaska, Minnesota, South Dakota, Oklahoma, Tennessee, Ohio, South Carolina, Texas, Arkansas, Illinois
2	North Dakota, Kansas, New York, Wisconsin, Florida, Vermont, Washington, Michigan, West Virginia, Connecticut, New Jersey, Georgia, Idaho, New Hampshire, Delaware, Maryland, Montana, Utah, Hawaii

After the grouping was done, the correlations were tested for each group. Correlations of the total PA support for a state since 2019 were tested with the number of structurally deficient bridges and lane-miles of roads in poor condition. The outcome of the correlation analysis is shown in Table 3. It can be seen that contrary to the claim of the research hypothesis, the correlation between the total PA funded amount and the condition of roads and bridges were quite weak. In group 1, the correlation between the PA support and the lane-miles of poor roads in negative (-0.07). It indicates that the states that maintained more miles of roads in good condition received more PA support from the federal government. For Group 2, the correlation of PA support with the number of structurally deficient bridges is moderate (0.38) but the overall correlation for Group 2 is stronger than that of Group 1. Based on this evidence, this paper rejects the hypothesis that the amount of PA support is determined by the condition and performance of roads and bridges in a state as reflected through the ASCE's infrastructure facts. Next the paper also tested the correlation of PA support with the percentage of bridges structurally deficient and roads in poor condition. Since the states are of different size, percentage might be a better indicator of the existing condition of roads and bridges. However, like the previous case the correlations were found weak. Table 3 also shows the outcomes of the correlation analysis with the percentage measures. In this case, the correlations with the percentage roads in poor condition were negative for both groups.

Table 3. Outcome of Correlation Analysis

Group	Structurally Deficient Bridges		Roads in Poor Condition	
	Number	Percentage	Lane-Miles	Percentage
1	0.13	0.12	-0.10	-0.24
2	0.38	0.15	0.14	-0.36

This paper has found a weak correlation of the PA support for the states with the condition and performance of roads and bridges as revealed through ASCE's infrastructure grades. The states that have received the highest amount of PA support since 2019 are Nebraska, Kentucky, Ohio, South Dakota, Missouri etc. But these states did not have the worst conditioned roads and bridges. Out of the 5 states listed only Missouri had the 5th and 3rd highest number of structurally deficient bridges and lane-miles of roads in poor condition, respectively. Out of the 5 states listed, 4 are from the midwestern region. Only Kentucky does not belong to the Midwest of the U.S. However, the states that have the highest number of structurally deficient bridges were Iowa, Pennsylvania, Illinois, Oklahoma, and Missouri. Again, in this case the states are predominantly from the Midwest. However, the states that have the highest lane-miles of poor roads are not from the Midwest except for Missouri.

4. CONCLUSION

This paper presents the outcomes of an ongoing research initiative on making cities resilient to natural disasters at Purdue University. Natural disasters cause physical damage to the infrastructures. In the U.S. the state, local, territorial, and tribal (SLTT) governments use the federal public assistance program to seek funding to repair, restore, reconstruct, and replace disaster damaged roads and bridges. This paper has used FEMA provided public assistance funded projects dataset to derive several key insights. First, it was found that the highest amount of funding was allocated to compensate for the damages caused by hurricane. It was followed by severe storms, and floods. Next, it was found that the states that have received the maximum amount of funding are not always the states that have sustained the most losses from natural disasters. The net presnt value of the federal expense to the roads and briges related PA program between 1998 and 2020 is $15 billion in 2021 values. Next, the paper has tested the correlation between the amount of PA support and the condition and performance of roads and bridges as revealed by the ASCE's infrastructure grades. This paper has found a weak correlation between these two.

In future, other factors that can determine the PA support will be explored. Moreover, some other indicators of the condition and performance of roads and bridges will also be used to investigate the correlation. In future, the authors plan to collect historic information from the ASCE on the infrastructure grades to test for the time dependent correlation between PA amount, and the condition of roads and bridges.

REFERENCES

[1] Choi, J., Deshmukh, A., & Hastak, M. (2019). Seven-layer classification of infrastructure to improve community resilience to disasters. Journal of infrastructure systems, 25(2), 04019012. https://doi.org/10.1061/(ASCE)IS 712.1943-555X.0000486.

[2] ASCE (2021). 2021 REPORT: ECONOMIC IMPACTS OF STATUS QUO INVESTMENT ACROSS INFRASTRUCTURE SYSTEMS

[3] Bhattacharyya, A., Yoon, S., & Hastak, M. (2021). Optimal Strategy Selection Framework for Minimizing the Economic Impacts of Severe Weather Induced Power Outages. International Journal of Disaster Risk Reduction, 102265. https://doi.org/10.1016/j.ijdrr.2021.102265

[4] Bhattacharyya, A., Yoon, S., Hastak, M. (2021) "Economic Impact Assessment of Severe Weather Induced Power Outages in the U.S." Journal of Infrastructure System 10.1061/(ASCE)IS.1943-555X.0000648

[5] Cartes, P., Navarro, T. E., Giné, A. C., & Binet, E. A. (2021). A cost-benefit approach to recover the performance of roads affected by natural disasters. International Journal of Disaster Risk Reduction, 53, 102014.

[6] FEMA, Public Assistance Program and Policy Guide (PAPPG), FP 104-009-2, Effective June 1, 2020.

[7] Congressional Research Service (2021) A Brief Overview of FEMA's Public Assistance Program

[8] ASCE (2021) "2021 Report Card for America's Infrastructure" (https://infrastructurereportcard.org/) accessed July 21,

[9] 2021FEMA (2021) "OpenFEMA Dataset: Public Assistance Funded Projects Details - v1" (https://www.fema.gov/openfema-data-page/public-assistance-funded-projects-details-v1) accessed July 7, 2021

[10] NOAA (2021a) "Costliest U.S. Tropical Cyclones" (https://www.ncdc.noaa.gov/billions/dcmi.pdf) accessed July 20, 2021

[11] NOAA National Centers for Environmental Information (NCEI) U.S. Billion-Dollar Weather and Climate Disasters (2021b). https://www.ncdc.noaa.gov/billions/, DOI: 10.25921/stkw-7w73

[12] International Monetary Fund, Interest Rates, Discount Rate for United States [INTDSRUSM193N], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/INTDSRUSM193N, July 20, 2021.

[13] FHWA (2020) "Highway Statistics Series" (https://www.fhwa.dot.gov/policyinformation/statistics/2019/hm60.cfm) accessed July 22, 2021

[14] FEMA (2021) "OpenFEMA Dataset: FEMA Web Disaster Summaries - v1" (https://www.fema.gov/openfema-data-page/fema-web-disaster-summaries-v1) accessed July 7, 2021