A Resiliency Performance Analysis of Georgia’s Freight System

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Introduction to the Georgia Freight System

With one of the busiest airports in the world, Hartsfield-Jackson Atlanta International Airport, one of the largest ports on the East coast, the Port of Savannah, key railways, and a highway system infamous for its congestion, the resilience of Georgia's freight infrastructure system is not only necessary for the resilience of the state's economy but a key node in the supply chain for many industries at the national and global market scales as well. The statewide freight system is currently planned for and maintained primarily by the Georgia Department of Transportation. According to their Task Force on Freight and Logistics Final Report, the logistics industry, which the freight infrastructure supports, makes up 18% of the state’s gross state product. Furthermore, the report states that 5,000 companies employ over 110,000 Georgians across the sector and generate over $50 billion in sales each year. However, the report argues that the reach extends past logistics as over 30,000 companies employing 700,000 people in the state rely on the freight system to move goods and services through supply chains. Clearly, the infrastructure system must be resilient against all types of issues in order to maintain Georgia's strong economic standing.

Georgia’s trucking freight routes are primarily through the state’s interstate system. GDOT explains this is because the system's north-to-south running network provides efficient connectivity and provides a faster, more accessible option for truckers "relative to other types of roads" (GDOT Multimodal Report, pg. 2-5). This connectivity is illustrated in Figure 1's map. The road network is broken down into further detail in Figure 2. Unsurprising to any Atlanta travelers, the highest truck volumes in the state are found on I-75 just north and south of I-285 and to the west of I-285, which connects I-75 on both sides of Atlanta (GDOT, pg. 2-6). This means that the Atlanta region has the highest concentration of tonnage generated, though Savannah follows and generates more than other areas in the state (GDOT Multi-Modal Report, pg. 2-4).

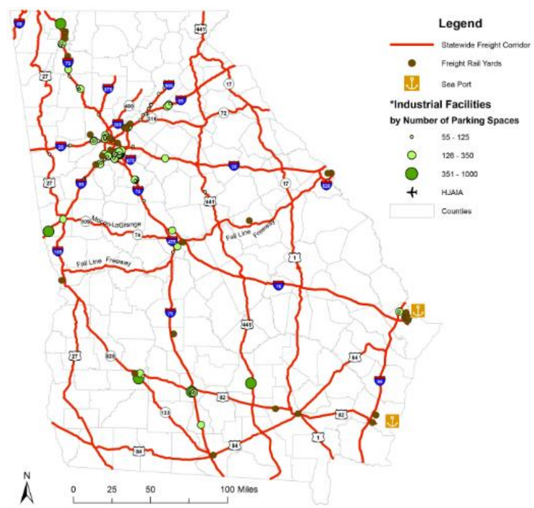

Figure 1

NATIONAL HIGHWAY FREIGHT NETWORK - GEORGIA				
PRIMARY HIGHWAY FREIGHT SYSTEM (PHFS) ROUTES				
State	**Route No**	**Start Point**	**End Point**	**Length (Miles)**
GA	I16	I75	2.28 Miles East of I516	165.44
GA	I185	I85	Columbus, GA	48.39
GA	I20	AL/GA Line	GA/SC Line	201.69
GA	I24	TN/GA Line	GA/TN Line	3.95
GA	I285	I85	I85	61.35
GA	I475	I75	I75	15.58
GA	I516	GA26R	GA25P	2.03
GA	I75	FL/GA Line	I475	156.89
GA	I75	I16	GA/TN Line	190.08
GA	I85	AL/GA Line	I285	70.39
GA	I85	I285	GA/SC Line	83.81
GA	I95	FL/GA Line	GA/SC Line	111.93
GA	S166	GA5R	I75	0.82
GA	S21	GA24P	I95	4.69
GA	S6	I20	U278	2.64
GA	U19	GA60R	GA28L	1.96
GA	U278	S6	6.62 Miles North of S6	6.62
Subtotal				**1128.29**

Figure 2

Considering all the delivered tons of freight trips that pass by and through the state of Georgia, domestic trips within the state are the primary trade type, with 90% of tons among all the freight movement in Georgia, followed by import movement with 5.8% of tons. The export movement is the least with only 4.2% tons. Though the percentages for different travel modes are slightly different for each trip type, the rank remains the same when grouped by tons, value, and ton-miles. As for the type of shipments, logs are the commodity with the highest percentage when grouped by tons and ton-miles. Nevertheless, when considering the value of shipments, machinery has the highest value percentage (FHWA, 2020).

Three different scenarios of projected potential growth are taken into consideration for this analysis. The first is based on American Trucking Association (ATA), the second is based on the data from Economy.com and the last one is based on the TRANSEARCH truck flow data. The ATA forecast shows that the increase in truck tonnage will be about 4.2% by 2021 since the model was built in 2018, and the truck industry will expect a market share increment compared to other freight modes. The growth rate used in the model corresponds to the forecast provided by GDOT statewide truck-related studies. The second projection model is developed from the Economy.com data set, which GDOT requires for the Georgia Statewide Freight and Logistics Plan. Figure 3 below shows the projected growth of the truck industry compared to the rail industry till 2027. The model estimated a compound annual growth rate of 2.3% for Georgia's economy, like the estimation by ATA, which is a 2.2% compound annual growth rate for truck tonnage.

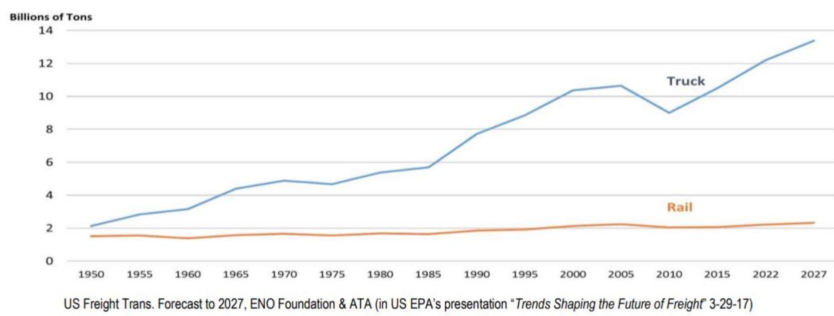

Figure 3: Project Tonnage

The last projection model is based on the data set from TRANSEARCH. TRANSEARCH is a tool for transportation planners to predict future freight or transportation trends. The truck flows were estimated by commodity for the years 2013 and 2050; there will be a growth of about four hundred tons in truck flow, and the estimated compound annual growth rate is 1.5%, which is less than the projection outcomes by ATA and Economy.com. Nonmetallic minerals, second traffic, and clay/concrete/glass/stone are the top three commodity types regarding transport tonnage. From the statistics above, it is evident that the estimation of TRANSEARCH is more conservative about potential growth.

Figure 4 below demonstrates the fuel efficiency by average MPG for each state/province in the North American area. Only class 7 (single unit 4 or more-axle trucks) and class 8 (single trailer 3- or 4-axle trucks) trucks are considered. The average MPG for Georgia is 6.11, which is about the average emission rate among the east coast states.

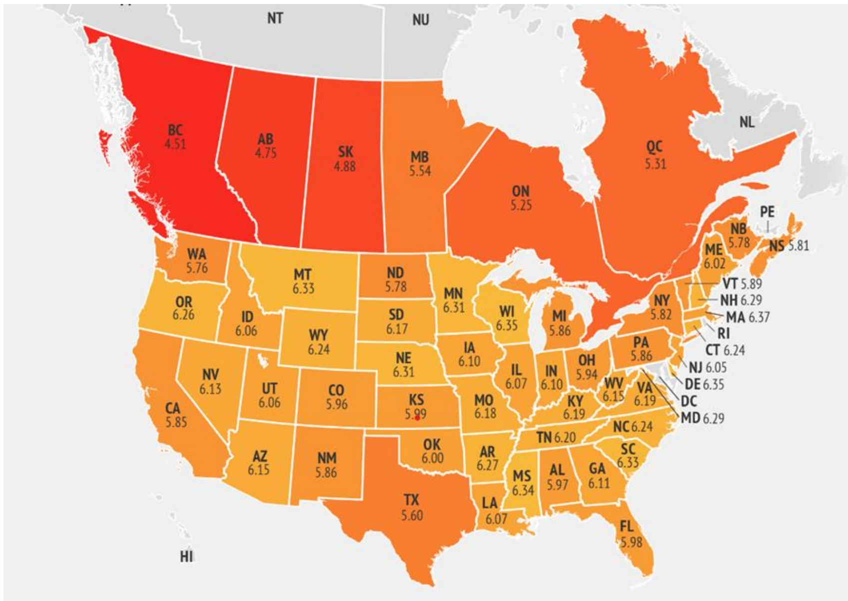

Figure 4: Fuel Efficiency

The result is obtained by having trucks equipped with Geotab GO telematics devices for one year. The travel data was then used to calculate the fuel economy by dividing the total fuel used by the distance traveled (Geotab, 2016).

Georgia Climate Hazards

The primary natural disaster in Georgia is the thunderstorm and the flooding that it causes, according to the Georgia Disaster History proposed by Georgia Emergency Management and Homeland Security Agency (GEMA/HS). The secondary climate hazards to be considered are tropical storms and hurricanes. Due to the area's proximity to the North Atlantic Ocean and the Gulf of Mexico, tropical storms and hurricanes are common natural disasters in late summer and early autumn. According to the data from historical hurricane tracks by the National Ocean and Atmospheric Administration (NOAA), the number of hurricanes that passed through Georgia has been slowly increasing in the past twenty years. Both the hazards mentioned above could lead to inland flooding or coastal flooding. In the United States, about a hundred thousand people are at risk of coastal flooding. In addition, more than 570,000 people live in areas that have a high likelihood of inland flooding. Coastal flooding will affect approximately 38,000 additional Georgia residents due to more powerful Atlantic hurricanes being forecasted in the future, and sea level rise is also a threat to coastal cities such as Savannah in the future.

Our report in Georgia will include extreme heat as the third climate hazard. There has been a significant increase in stagnant summer days per year since the 1970s. In 2015, there were about 20 dangerous heat days a year. However, it has been projected that by the year 2050, there will be more than 90 dangerous heat days a year. Direct danger to humans is not the only threat caused by rising temperatures; the mosquito growing season in Atlanta has become longer than it used to be (States at risk, 2015).

America's Preparedness Report Card 2015 (States at Risk, 2015) has given the score based on how Georgia faces five climate hazards. Figure 5 below shows the overall score and detailed scores for each element. Extreme heat and inland flooding got C- since no further detailed plans to improve the resilience were proposed when the report was published. Moreover, though Georgia has Hazard and

Resilience Plan for the coastal area, specific sectors and recommendations in the plan had yet to be implemented when the report was published. Therefore, the score for coastal flooding is D+.

Georgia's freight infrastructure system is critically important to the state's economy, a position it holds due to its demonstrated effectiveness at moving goods. However, the serious climatic pressures combined with the identified weakness in preparedness threaten the system and the state. This paper sets out to determine the extent of the vulnerabilities of the Georgia Freight System and how its resiliency and sustainability might be improved through infrastructure asset management practices to enhance its long-term performance. This paper defines vulnerability per the Department of Transportation's VAST model, defining Vulnerability as Exposure + Sensitivity – Adaptive Capacity.

Figure 5: Georgia's Grades on the American Preparedness Report Card

Resiliency and Sustainability Analysis

Given that vulnerability is assessed as a function of exposure and sensitivity weighed against adaptive capacity, this analysis will use a multidimensional resilience framework for our analytical approach. The roadmap in Figure 6 demonstrates two primary dimensions of our approach: the socio-technical analysis and a climate vulnerability analysis. These are highlighted in red. Our socio-technical analysis primarily uses a sustainability lens (Green) to assess needs (orange). This further breaks down into a social equity-specific analysis where we assess the spatial overlap of the system and its negative externalities with minority and low-income communities (maroon) and find further needs (orange). Our climate vulnerability assessment takes on three lenses: exposure, sensitivity, and adaptive capacity (green), which come from the DOT VAST approach. There are multiple ways we measure these (orange). The roadmap demonstrates the extent that the exposure analysis overlaps with the sustainability lens. This framework attempts to incorporate just how interconnected these issues are. Through systematically analyzing our way through the framework, our output is our recommendations for GDOT regarding its freight infrastructure asset management protocols, both policy-wise and through emerging technologies.

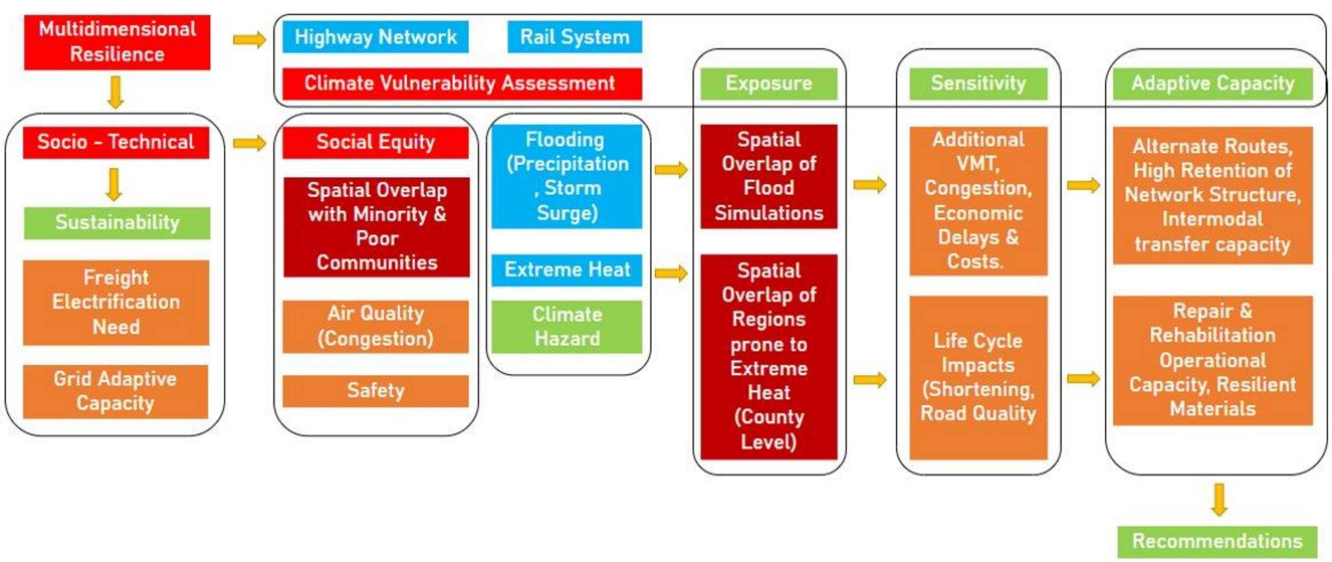

Figure 6: Resiliency Roadmap and Framework for Analysis

This analysis specifically will analyze two hazards: heat waves and flooding. We have broken down flooding by both coast and riverine flooding. These have been identified as critical hazards through our review of the existing literature mentioned above. We used census tracts as our spatial unit to bring the social demographic data and population information into the analysis and understand the people impact of the system and the hazards. Throughout the analysis, sensitivity and adaptive capacity will be defined as asset condition and choice of alternatives, respectively. These metrics will enable the multidimensionality we are seeking for our analysis to maximize both the sustainability lens and the climate vulnerability lens. This will allow us to assess how to maximize the performance of Georgia's freight infrastructure system in this multifaceted way.

Analysis Results and Findings

Vulnerability Assessment – Heat Waves

Extreme heat is one of the critical issues faced by Georgia today and has high implications for asset conditions and management. In terms of a Condition-Based Assessment, extreme heat can cause high levels of deterioration in asphalt surfaces and equipment failure. While the latter cannot be modeled due to elevated levels of point distribution, it is essential to understand the impact on rail networks and asphalt-based road networks. Exposure to the hazard will be calculated using predictive models of extreme heat and overlaying its geographic and time-based extent with the rail and road network. The results are demonstrated in Figure 7.

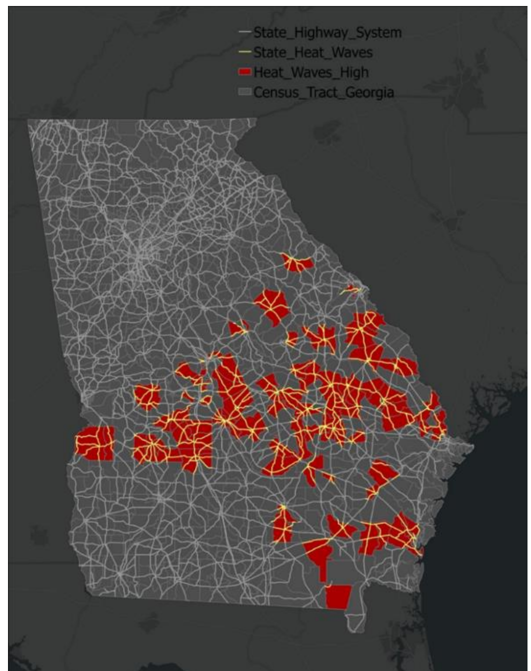

Figure 7

Qualitative condition-based materials research undertaken in the literature shows that asphalt tends to age faster in extreme heat. Additionally, concrete roads can exhibit buckling or blowups in response to limitations in expansion capacity. Similarly, steel rail tracts can expand in extreme heat, causing unintended curvatures in rail tracks which can cause potential derailments and accidents. The seriousness of extreme heat is shown in the fact that 92% of hazard damage in Europe in the 2080s is predicted to impact roads and railways due to heat.

Heat waves can impact the system by increasing deterioration rates for roadways, thereby increasing maintenance costs over extended periods. The heat waves can soften the asphalt, further leading to distress to rutting, raveling, cracking and potholes on the high-traffic route, which is detrimental to the asset's health. The map in Figure 8 showcases Georgia's geographical distribution of extreme heat. Many southern routes will be exposed to 30 more days with temperatures above, justifying the need for infrastructure management practices to adapt to create resiliency.

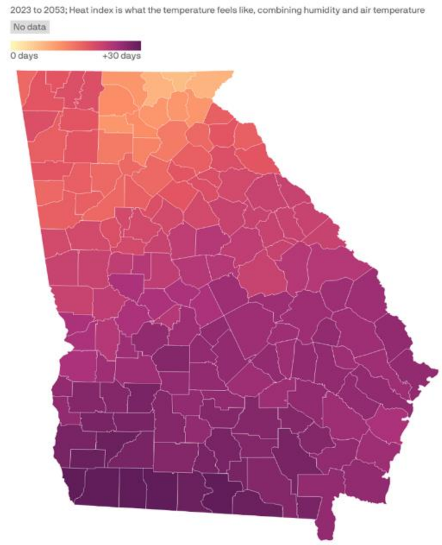

Figure 8: Increase in the annual number of days with a heat index above 100°F

Heat Wave Resiliency Recommendations

Given the extent of heat vulnerability in mid-Georgia, policy and technical solutions are needed to increase the resiliency of the freight system in the face of the threat. Several critical policy solutions would strengthen GDOT's work in this area:

1. Use developed Targeted Weather Data to Identify Priority Heat Corridors. Use Point Laser or Lidar-based Methodologies to analyze deterioration impact for immediate maintenance by vehicle-based assays.
2. Address GDOT Worker Safety Policies to reduce Health-related impacts of high heat exposure.
3. Study of State Roadway Resilience Plans with known High Heat Impact, such as Arizona, to understand transferable recommendations.

To augment the policy solutions above, several technical interventions that would reduce the threat of heat waves and increase the Georgia freight system’s ability to react and absorb extreme heat include the following:

1. Develop an Inventory of all Electrical Equipment, such as Traffic Control Boxes and Signals. Replace with Equipment that displays greater resilience through enhanced cooling.
2. Add Green Infrastructure along High Heat Priority Corridors utilizing Nature-Based Resiliency Methods. This will result in more equity-oriented outcomes in Noise and Air Quality.
3. Adopt Widespread Use of Hot-Mix Asphalt in Impacted Freight Routes that have more robust performance and are resistant to heat impact deterioration.
4. Develop a Real-Time Spatial Database of Road Temperatures by interfacing asphalt temperature prediction models with data from local weather stations.

Vulnerability Assessment – Flooding

Riverine and Storm Flooding

For the first flooding hazard case, riverine and storm flooding, we modeled the vulnerability of the hazards as a product of a scenario-based analysis. This is undertaken to assess the methodology and provide a better scope of analysis. The FEMA Risk Map considering high flood-risk census tracts is the basic data set used to map climate data. Georgia is particularly prone to flood risk since it has many riverine resources and is susceptible to storm surges and inland flooding associated with storms in the Gulf of Mexico and the Atlantic Coast. In this case, we consider the exposure as corresponding directly to road segments within the high-risk census tracts. It is important to note that each impacted segment will not be susceptible to flooding as it depends on local drainage topography and elevations. Since this analysis corresponds to a higher-level network scenario, we currently neglect to consider this data. Three metrics are considered to model exposure: the road length impacted, the number of junctions and nodes impacted, and the total number of freight vehicles impacted.

Through the geospatial analysis conducted in Figured 9 and 10, we found that the impacted road network in each case corresponds to 8,320 miles for riverine flooding and 2,794 miles for storm flooding. Furthermore, the number of impacted nodes in each case is 3,104 nodes due to riverine flooding and 728 nodes due to storm flooding. Finally, the cumulative impacted annual average daily traffic (AADT) associated with riverine flooding is 347,036,952 additional freight vehicles, while that associated with storm flooding is 39,325,987 additional freight vehicles. Neither of these estimates includes regular, non-freight traffic, which could significantly increase the count and impact.

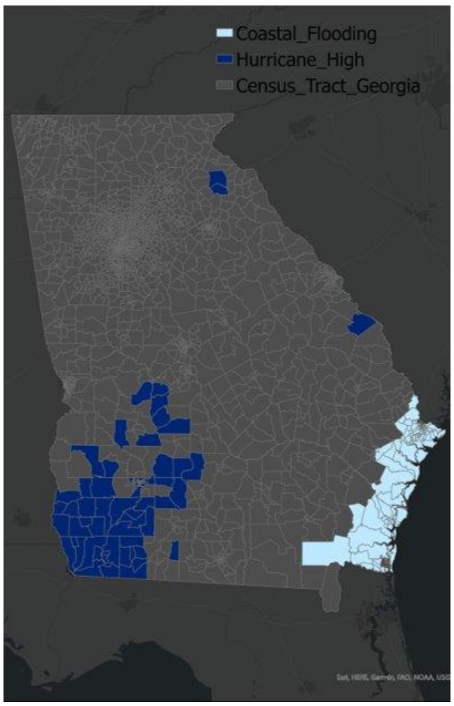

Figure 9

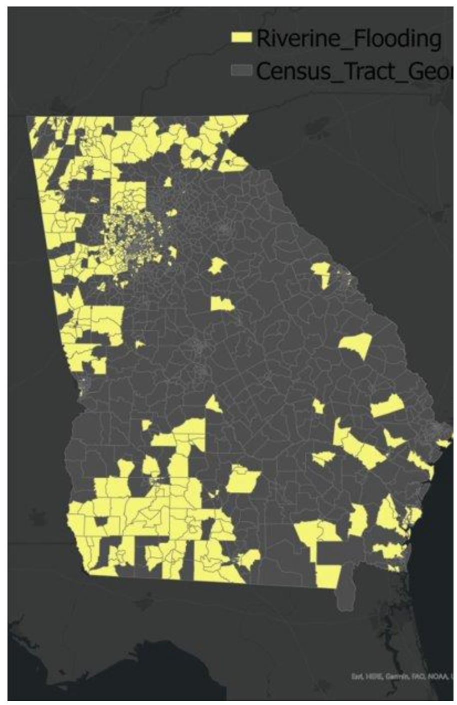

Figure 10

These results demonstrate that Flooding Events pass a high degree of threat in travel distance, distribution potential and travel volume due to many road segments, nodes and vehicles impacted. However, this exposure does not equate to how sensitive each segment is. The sensitivity of the infrastructure asset in terms of its actual inundation can only be identified with accurate data on local drainage and topography. This information requires a segment-by-segment analysis. This is a time consuming and elaborate process, and it may not respond to actual travel behavior at a systematic level.

Additionally, the length of a segment may be high but not correspond as being highly important in the economic flow of goods. Therefore, undertaking a multidimensional analysis framework, we define sensitivity as a product of its impact on the freight system as a network. In extension, sensitivity is defined as any disruption to the flow of goods from the origin to the destination. A detailed and more accurate analysis requires specific economic and vehicle data about origins and destinations. Foregoing this information, we will assume points of interest as being coincident with random nodes with a high degree centrality within freight volume clusters shown in the kernel density map. Routing will be undertaken using these Origin-Destination (OD) Maps. Two or three OD Pairs are considered to create a scenario to illustrate the method concerning the two flooding hazards. A summation of several such scenarios for high-priority OD Pairs can consequently be used to describe the sensitivity of a network.

The following metrics are considered to determine the sensitivity of the network :

Sensitivity = Change in Vehicle Miles Travelled [Scenario]+ Change in Congestion [Scenario]+ Economic Delay Costs Assuming Free Flow (in Hours) [For Every OD Pair Scenario]

Figure 11 considers several OD Pairs and derives the performance indicators for sensitivity. A Shortest Path Routing Algorithm is used to find the shortest distance between the OD-Pairs under two conditions: (1) without network disruption and (2) with network disruption due to the hazard. Associated performance indicators are derived for each scenario.

Figure 10

Four Different OD Pairs are considered, and alternate routes are developed upon network disruption. In this scenario, we find the following results:

1. There is a cumulative increase in travel segments from 95 to 107.
2. The number of intersections crossed increases from 409 – 531.
3. There is a 28.75% increase in vehicle volume if Cumulative AADT from the original route is transferred to this route.
4. The OD Pair Travel Distances increased from 607 Miles to 1254 Miles.
5. Assuming Traffic Free Flow at 40 mph results in 16 Hours of Additional Travel that can be interpreted as Economic Delay.
6. The above scenarios project a conservative estimate, whereas actual economic delay in hours will be much higher due to increased congestion because of rerouting and vehicular distribution from other routes.

The same geospatial analysis was explicitly conducted on riverine flooding, as seen in Figure 12.

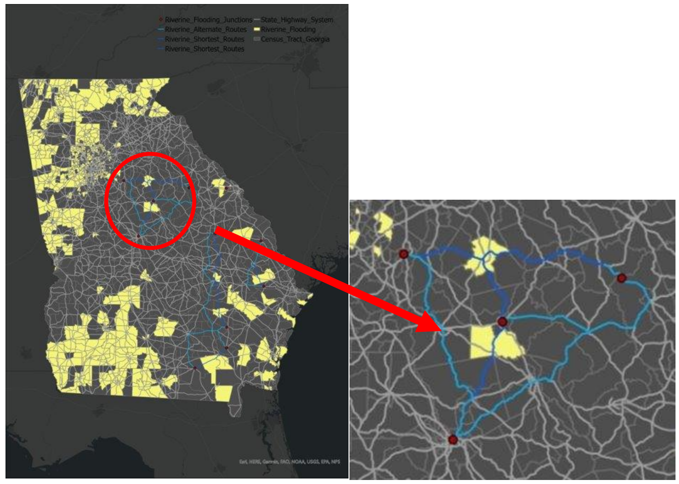

Figure 11

Six Different OD Pairs are considered, and alternate routes are developed upon Network disruption. In this scenario, the results demonstrate that:

1. There is a cumulative increase in travel segments from 54 to 75.
2. The number of intersections crossed increases from 650 - 696.
3. There is a 9.8% increase in vehicle volume if Cumulative AADT from the original route is transferred to this route.
4. The OD Pair Travel Distances increased from 508 Miles to 711 Miles.
5. Assuming Traffic Free Flow at 40 mph results in 5 Hours of Additional Travel that can be interpreted as an Economic Delay.

The above scenarios project a conservative estimate, whereas actual economic delay in hours will be much higher due to increased congestion because of rerouting and vehicular distribution from other routes and the addition of non-freight vehicles. In both scenarios, results show no direct correspondence between network disruption and OD pairs. Although riverine flooding has greater system exposure, in this case, a random selection of six OD Pairs has less sensitivity than four OD Pairs in the case of storm flooding. Therefore, to assess system-wide sensitivity, the most essential OD Pairs in economic productivity must be considered and assessed from a hazard scenario perspective.

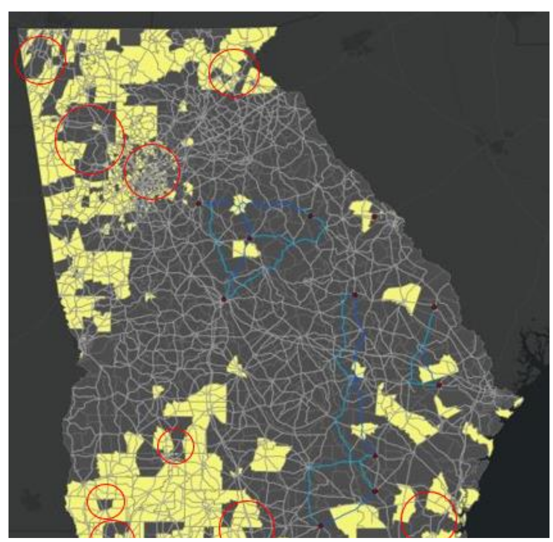

Figure 12: Areas lacking the adaptive capacity for rerouting potential

The next step of the analysis considers adaptive capacity, a combination of scenario-based analysis and the potential of the road system. Adaptive capacity is described in terms of the following description:

Adaptive Capacity = Alternative Routing Potential [Scenario] + Level of Loss in Integrity of Network Structure [Systemic] + Intermodal Transfer Capacity [Systemic]

This framework allowed exploration of the potential for rerouting impacted vehicles, which was already discussed in terms of its sensitivity. In the scenarios considered, the potential for rerouting exists. It is possible that the scenario for rerouting may not exist in theory for areas surrounded by high-risk census tracts, as shown below. Especially in the case of riverine flooding, North-West Georgia and the Metro Atlanta area lack adaptive capacity regarding rerouting potential, as demonstrated in Figure 13.

The next factor determining adaptive capacity is connected to distributive potential, which relates to how many directions or pathways a junction provides for movement. The spatial network measure associated with this concept is degree centrality. Degree centrality refers to how many road segments a junction is connected to. The higher the degree centrality, the greater the distributive capacity of the junction. Figure 14 illustrates an example. Consider the OD Pathway A-B in contrast with pathways C-E. If B is non-functional due to a climate hazard, the pathway ceases to exist because the intermediate node only connects to two segments. However, in C-E, if E is rendered defunct, the vehicle can be rerouted through C-D-F due to the intermediate node's high degree centrality. It is important to note that a high degree centrality may also increase the potential for vehicular congestion.

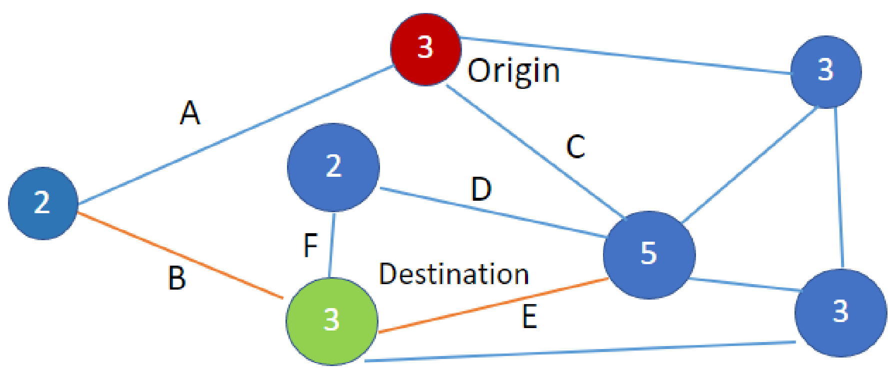

Figure 13

Most nodes with a high degree centrality are present in the Metro Atlanta Region. The nodes are marked with circle sizes proportional to their degree centrality value. They also coincide with areas of high AADT, as shown below in Figure 15, in the case of riverine flooding. We find that in both riverine and storm flooding cases, there is a proportional impact on nodes with a degree centrality of three, showing that distributive capacity is reduced. This issue can add to vehicle stress on remaining functional nodes while increasing rerouting distances and reducing access to many areas.

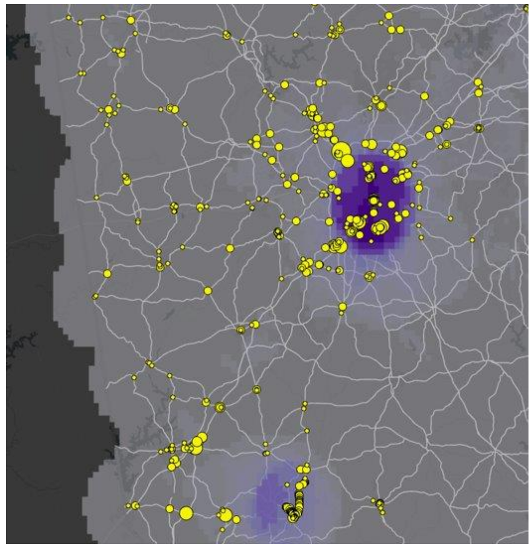

Figure 14

The capacity for intermodal transfer is not applicable in the state as it is found that each of the climate hazards results in a simultaneous disruption of rail service in proximity to the disrupted road networks. Therefore, the capacity for intermodal transfer is limited and subject to data that shows existing intermodal transfer points in the state.

From a higher-level analysis perspective, Georgia's Freight System is highly vulnerable to these specific climate issues. An analysis at the system-wide scale will need to be undertaken with greater granularity to understand the potential for redressals and specific impacts on priority areas. All the performance measures above provide contextual information about the DOT VAST Vulnerability Assessment Criteria. Based on priority, other performance measures can also be included. These performance measures only provide a way to measure the different vulnerability facets. A scoring matrix and criteria need to be developed to understand how to convert the performance metrics into a tangible numerical component for comparison. Below are recommendations on what a matrix could include.

	Measures 1	**Measures 2**	**Measures 3**
Exposure	Distance	Direction	Volume
Performance Indicator	Impacted Road Length (Miles)	Impacted Road Junctions (Count)	Impacted AADT (Count)
Sensitivity	Distance Change	Congestion Change	Economic Delay Cost
Performance Indicator	Added VMT	Added AADT Volume	Time Cost in Hours
Adaptive Capacity	Rerouting Capacity	Loss of Network Integrity	Intermodal Transfer Capacity
Performance Indicator	Categorical Alternate Routes	Degree Centrality Loss	Categorical Transfer Potential

The analysis leads us to make the following recommendations in order for GDOT to address the riverine flooding vulnerability within Georgia's Freight System:

1. Hyper-Connectivity: Develop Intelligent Freight Transportation Systems that provide accurate vehicle data points with IoT. High Value of Freight Efficiency will provide long-term benefits by providing real-time rerouting capacities and better traffic management.
2. Planning: Incorporate a Climate Resilience Section in the GDOT State Freight & Logistics Plan that identifies Risks and Vulnerabilities to the various specified Climate Hazard events.
3. Inter-Modality: In the event of Climate Hazards, Inter-Modal Freight Transfer Capacity is currently limited in Georgia since they are exposed to the same impacts. Intermodal Transfer Points need to be Revised. Future Network Expansion of Rail & Road Freight should consider Joint Capacity Development and enhance the potential for intermodal capabilities.
4. Consensus–Building: Actively **Interface with all Stakeholders** in Resiliency Building. [Freight Operators, Local Governments, GDOT] A Potential Outcome could be the Dissemination of Scenario Models that predict Road Closures and other outcomes of Hazards to Freight Operators to allow them to reduce system stress and restructure their logistics plan actively.
5. Planning & Action Plans: **Development of Performance Based Prioritization Methodology for Climate Action**. This includes Climate Specific Goals, Objectives, Performance Metrics and Outcome Indicators. **Develop Priority Zones** based on Metrics. High-level analysis shows that Atlanta, North of Columbus, Augusta, and Macon are essential connectors.

Coastal Flooding

Finally, we extended our analysis to the threat of coastal flooding. The Coastal Freight Network is Vital to the Economic Prosperity of Georgia. It consists of the Ports of Savannah and Brunswick and the Vital I-95 Corridor that connects the Coastal Region to Florida.

Unlike the previous two Hazards, the Coastal Freight Network's Resilience suffers the question of survival due to sea level rise and storm surges. With two nodal points and a connecting corridor, it is less a question of network alternatives and more a question of hazard mitigation and adaption of these three critical infrastructures. The system is illustrated in Figure 16.

Figure 15

We conducted a Cost Benefit Analysis of mitigation measures and economic loss due to lifecycle costs associated with hazard events to assess the network's sensitivity to coastal flooding. Suppose mitigation across the entire corridor proves unsuccessful or unfeasible due to a high need for robustness and financial commitment. In that case, the adaptive capacity can be ascertained by conducting an economic analysis of a new corridor facility bolstered by environmental suitability studies. This follows the principle of "Building Back Better." The analysis led to the following targeted resiliency recommendations:

1. Focusing on the High AADT Corridors of Savannah and Brunswick may prove more financially feasible.
2. Highly Granular Studies of Hazard Vulnerability with **Corridor-specific Analyses.**
3. Increase **Nature-based Resiliency Measures** such as Mangrove Planting in Vulnerable and Ecologically Sensitive Zones.
4. Interface with **Climate Prediction Models based on Sensor Detection** of Sea Level and Tide.

5. Develop Robust Mitigation Infrastructure, such as **Raised Berms**, where Necessary and Appropriate.

Intersection with Social Equity

The final part of the multidimensional analysis looks at the intersection of social equity with these hazards through sustainability principles and our recommendations. Using a sustainability lens to contextualize the environment created by Georgia freight, the lack of fuel efficiency in the system mentioned earlier means an increase in freight volume leads to a decrease in air quality. This inverse relationship is heightened in predominately minority census tracts, as evidenced by our geospatial Analysis in Figure 17 (left). Furthermore, increased freight volume increases crashes and road fatalities, which also disproportionately impact minority census tracts. If more freight vehicles were to move to electric power, this could decrease the negative impact of the freight network on these minority populations.

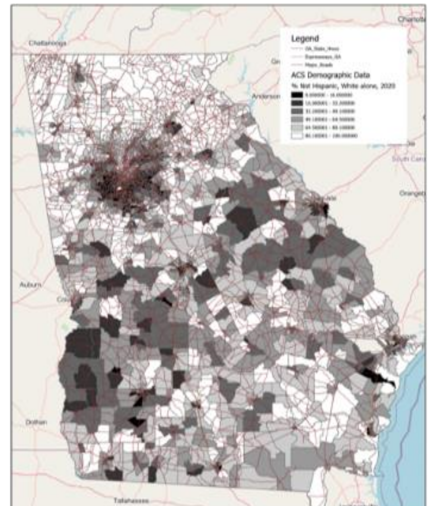

Figure 16: Overlap of Minority Majority Census Tracts and Road Network Clusters

In addition to this direct analysis, we came across an additional implication on social equity through the flood hazard analysis. In all alternate routes mapped as part of the flooding & storms scenario, a significant number of census tracts with a 48% – 100% African American population are impacted and have additional freight traffic because of these climate events (Figure 18). This shows that a social equity impact should also be considered when considering alternate routes. The addition of sustainability & social equity impacts concerning electrification and congestion add holistic value and depth to efforts at improving system resilience.

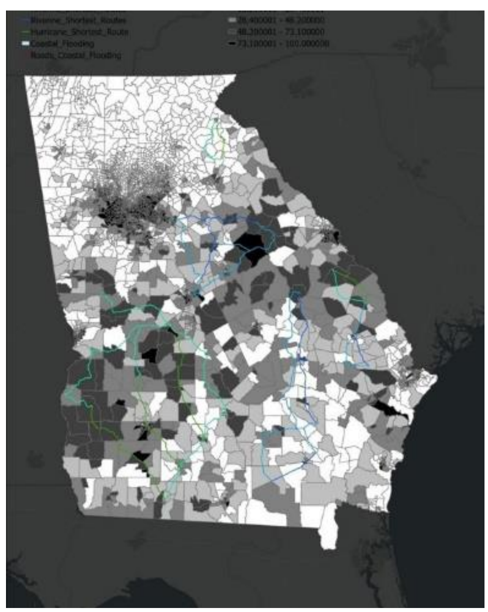

Figure 17

Learnings and Key Takeaways

Through our analysis, we learned that each hazard has different types of impact on the transportation system and that there is no “One-Size-Fits-All” solution. Our key takeaway is that our recommendations are possible. These recommendations are being implemented elsewhere. When comparing Georgia to other states known for being leaders in resiliency planning and freight transportation asset management, it was clear that an important element has strategic goals to provide the mandate for this work. A direct comparison between the strategic plan of the New York State Department of Transportation (NYSDOT), which has conducted a number of these types of analysis and recommendations, and the strategic plan of GDOT, which lacks these efforts, shows that it comes down to strategic goals that prioritize this work. These recommendations are within GDOT’s vast scope and ability, but they are missing the right vision.

Further detailed takeaways from our analysis can be summarized in our recommendations for incorporating resiliency considerations into GDOT’s asset management plan in the most dangerous areas we have identified:

1. For coastal flooding and hurricanes, asset management should focus on the Southeast Coast. This is the most critical area because it has the potential to disrupt the entire supply network.
2. For riverine flooding, asset management principles should focus on Northwest and Southwest Georgia.
3. For extreme heat, interventions and further analysis should focus on Central Georgia.

Limitations and Next Steps

A limitation of our approach is that it was a very high-level analysis of the state infrastructure system. The Federal Highway Administration’s Climate Resiliency Piot program demonstrates that many states are doing similar analyses to ours but on a much more granular and targeted scale (California, New York, Mississippi, and Texas are relevant examples). The next step would be for GDOT leadership to engage this program in Georgia at the targeted hotspots we have identified.

Another limitation is that the data available does not give us a granular picture of freight destinations and origins. We mostly know it is between Atlanta and Savannah. It would be helpful for GDOT to collect this data and, if they already do, make it publicly available.

A final limitation is the effectiveness of our recommendations given the political context GDOT must operate within. GDOT follows a top-down organizational structure and is hierarchical (like most agencies of its size and scope). However, the top of the agencies are political appointees (board members) or approved by politically appointed boards (commissioners). Given statewide political trends of Republican leadership, Republican policies of climate change denial, and promotion of small governance, these effects can be seen in the organization's strategic direction, which keeps it from pursuing policies and plans that address climate resilience and sustainability.

In conclusion, Georgia's freight infrastructure system is a valuable asset to the state that needs to be appropriately managed to ensure it provides the necessary mobility to the vast amount of goods that flow through it. By including resiliency and sustainability in its future strategic plans and implementing targeted intervention efforts in the face of extreme heat and flooding vulnerabilities, the state and GDOT can continue to rely on the success of this system for many years to come.

Appendix A: References

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