Understanding Current Resilience Practices and Their Application to the Treasure Valley

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Critical Terminology

This section identifies and defines critical terminology used in this report. Grose and Redd's (2017) presentation to COMPASS on Risk and Resilience as well as the Canyon (2021) and Ada (2017) County All Hazards Mitigation plans were used to create these definitions.

Adaptation- Actions taken to reduce Vulnerability or increase Resilience.

Adaptive Capacity- Ability to adjust to/moderate/cope with an ongoing threat. Resilience focuses on returning to an original state while adaptive capacity focuses on adapting to an ongoing threat.

Climate Change – Changes in climate patterns of temperature, precipitation, humidity, wind and seasons (Canyon County Sheriff's Office [CCSO], 2021, 15-1).

Criticality- The relative importance of an asset. Criticality is used to identify which projects require resources, especially when resources are limited. Redundancy, Risk, and Vulnerability are all variables that contribute to criticality.

Mitigation: A preventive action that can be taken in advance of an event that will reduce or eliminate the risk to life or property (CCSO, 2021, Glossary-6)

Redundancy- The existence of alternate routes/means of transport to maintain the system in the case of disturbance.

Resilience- The ability of a system to respond and recover from adversity and return to its original state.

Risk- The potential of gaining or losing something of value.

- Probability of Threat Occurrence x Probability of Failure x Cost of Failure
- Exposure x Sensitivity x Cost of Failure
- Likelihood x Consequence
- Effect of Uncertainty on objectives

Stressor- something that causes strain or tension.

Transportation Infrastructure- Highway/roadway, mass transit, railway, aviation, maritime and pipeline (CCSO, 2021, 4-9)

Uncertainty- The degree to which a value is unknown. Uncertainty can result from lack of information or from disagreement about what is known or even knowable.

Vulnerability- The degree to which a system is susceptible to, or unable to cope with, adverse effects. It is a function of Exposure, Sensitivity, and Adaptive Capacity.

Summary

This report is for the Community Planning Association of Southwest Idaho (COMPASS), which serves as the federally designated metropolitan planning organization (MPO) for Ada and Canyon Counties. In December 2015, the passage of the Fixing America's Surface Transportation (FAST) Act required MPOs to "improve the resiliency and reliability of the transportation system" (23 C.F.R. §450.306.9). Appendix A includes a full list of federal code requirements for reliance. In accordance with federal requirements, this report provides research to update the resilience chapter in the new edition of the long-range plan, *Communities in Motion 2050* (CIM 2050).

The first half of this report is a state of progress report on resilience practices at transportation planning organizations across the nation. The second half uses a simplified version of the Federal Highway Administration's (FHWA) *Vulnerability Assessment and Adaptation Framework (VAF), 3rd Edition* to create a resilience strategy for the COMPASS planning region. The framework helped identify four relevant factors with potential transportation impacts: (1) warmer temperatures, (2) changing precipitation patterns, (3) wildfire, and (4) population growth. Stakeholder input and the use of indicators to monitor system vulnerabilities were recognized as strategies that COMPASS can use to integrate resilience into their planning processes. These proposed strategies are based on findings in the state of progress report, conversations with staff, and use of the VAF framework.

Introduction

Natural disasters are becoming more frequent and expensive.

Much of today's critical transportation infrastructure is aging and designed for conditions of the past. As weather conditions change and cities grow, infrastructure is increasingly vulnerable. Major disasters in the US averaged about thirteen per year in the 1950s but increased to nearly sixty per year from 2010 to 2018 (Vroman, 2019).

Idaho mirrors this national trend and has declared natural disasters more frequently since 2005 (Figure 1). In the US, overall losses from natural disasters were $95 billion in 2020 and $51 billion in 2019 (Munich RE, 2019). Insured losses were $67 billion in 2020 and $26 billion in 2019 (Munich RE, 2019). Thus, disaster is costly and becoming more frequent.

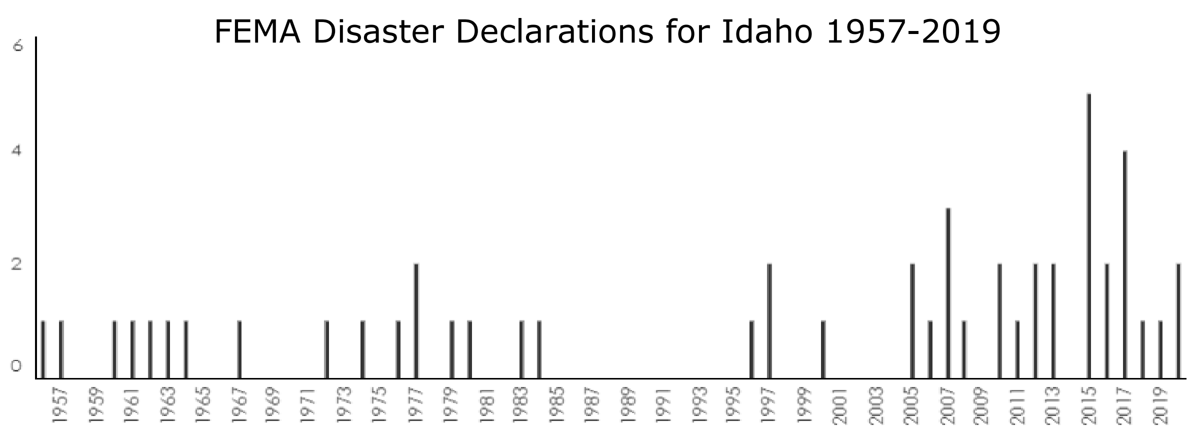

Figure 1: FEMA Disaster Declarations in Idaho 1957-2019

Resilience-planning saves money.

Porter et al. (2019) at the National Institute of Building Sciences estimates that:

- Adopting Model Codes saves $11 per $1 Spent
- Federal Mitigation Grants save $6 per $1 spent
- Private-Sector Building Retrofit saves $4 per $1 spent
- Exceeding Codes saves $4 per $1 spent
- Mitigating Infrastructure saves $4 per $1 spent

For economic reasons, federal, state, and local governments have engaged in resilience planning. Resilience planning uses climate models to project future weather conditions, identify how vulnerable the infrastructure is to future weather conditions, and plan accordingly. Just as COMPASS uses projected demographic and traffic data to model future conditions, resilience planning uses climate projections for the mid-21st century to evaluate impacts on infrastructure.

Resilience planning is good asset-management.

Roads, bridges, rail, and pipelines are critical to a region's economy and society. Roads move an estimated $27.3 billion in cargo into, out of, and within the Treasure Valley (COMPASS, 2017). Three major supply lines connect the Treasure Valley to other urban centers: Salt Lake City, Portland, and Seattle (COMPASS, 2017). Even minor disruptions along these critical transportation routes can disrupt economic activity. Yet, the Treasure Valley faces an estimated annual $235 million funding shortfall in Ada and Canyon counties for transportation costs (COMPASS, 2019). The necessity of these transportation connections makes it all the more important that today's investments into transportation are resilient against future weather conditions.

The goal of resilience planning is to protect and secure today's transportation system for current and future Treasure Valley residents. Therefore, resilience must be considered in the context of existing transportation needs. The COMPASS Board of Directors state that federal funding allocated through CIM 2040 2.0 be "focused on maintaining the existing transportation system, while strategically addressing regional priorities" (COMPASS, 2014). Resilience planning can "strategically (addresses) regional priorities" by identifying areas of vulnerability so we can plan proactively to ensure the safety, security, and prosperity of the Treasure Valley.

Current Practices

States:

Departments of Transportation (DOTs) use Resilience Models to Prioritize Projects.

All states address weather concerns in their asset management plans. However, resilience planning is not just asset management but asset management in the context of climate change. Therefore, to address resilience, states must understand future climate conditions and their potential impacts on infrastructure. States differ in both their understanding of future climate impacts and their ability to affect decision-making. Generally, states that experienced natural disasters leverage data from those disasters to improve their resilience plans. For example, Colorado experienced major flooding in 2013. The data collected from that incident was leveraged to fund vulnerability assessments and create a resilience model and plan for Colorado's transportation system.

State planning usually includes mathematical models to rate existing and new infrastructure projects by risk, vulnerability, and criticality. Resilience models in Colorado and Utah show decision makers the cost savings of repairing or rebuilding critical infrastructure. Vermont uses a redundancy model that prioritizes a project based on its criticality to the transportation network. Oregon emphasizes a project's contribution to its critical transportation lifelines to strengthen them in the event of an earthquake. A nationwide study by Ahmed and Dey (2020) found that models focus on one or more of the following concepts:

- (i) redundancy (i.e., same functionality of multiple components)
- (ii) diversity (i.e., different functionality),
- (iii) efficiency (i.e., demand and supply optimization),
- (iv) components' dependency (i.e., ability to operate independently),
- (v) strength (i.e., ability to withstand an event),
- (vi) stakeholders' collaboration (i.e., information and resource sharing among multiple entities of the system),
- (vii) adaptability (i.e., flexibility in the system elements),
- (viii) mobility performance (reaching destinations within a reasonable time),
- (ix) safety performance (i.e., less fatal/injury crashes), and
- (x) the ability to recover quickly (i.e., rapid restoration with minimal intervention)

The following table is a partial list of resilience models used by other states.

Table 1: State Resilience Models

State	Plans/Reports/Tools	Type of Model
California GHG reduction, sea-level rise, earthquakes, wildfire, urban heat, traffic	2018 **Climate Change Vulnerability Assessments** - *Regional vulnerability assessments identify sections of the highway system at highest risk to extreme weather events. Regions then identify adaptation strategies using FHWA's Adaptation Decision-Making Assessment Process (ADAP).*	Scenario driven (FHWA's ADAP)

Vermont floods	**Network Criticality Index** - *Areas with multiple highly vulnerable routes (to flooding) are categorized as higher risk.*	Redundancy model
Oregon Earthquakes, tsunami, GHG reduction	2012 **Seismic Lifeline Evaluation, Vulnerability Synthesis, and Identification** **-** *Focused retrofitting efforts based on the lifeline transport system.* 2013 **The Oregon Resilience Plan-** *341 page vulnerability assessment detailing the state's ability to respond to the Cascadia Earthquake/tsunami. A status report* was done in *2018.* *Established a State Resilience Office in 2015	Redundancy Model
Utah general	UDOT Asset Risk Management Process - *Assets, threats, user cost, risk value, criticality, risk priority, and ROI determine priority projects.*	Financial model
Delaware Sea level rise, storm surges	DelDOT **NIST-DGeS** Tool - *A quantitative analysis tool to analyze cost of inaction, retrofitting, or rebuilding.*	Financial model
Wyoming Traffic patterns (freight), tourism	WYDOT Risk and Resiliency plan - *plan to protect transportation pathways to tourism assets.* *First state to collect traffic data through 'connected vehicle systems' to improve the freight system.*	Probability/consequence risk matrix
Colorado Wildfire, flood, landslides	Risk and Resilience Analysis Tool and Resilience Program - *Prompted by floods in 2013, CDOT created a tool to quantitatively analyze risk and potential financial impacts to highway assets.*	Financial model

Limited funding and perceived lack of need have hindered resilience planning in Idaho.

According to a 2015 University of Idaho survey on perceived impacts of climate change, stakeholders in Idaho rated concerns about recreation and transportation impacts due to climate change as the lowest importance (Abatzoglou, et al., 2015). The top four concerns were water resource availability (16%), extreme drought (14%), changes in plant productivity (14%), and wildland fire (10%) (Abatzoglou, et al., 2015).

Huge funding shortages in Idaho also hamper resilience planning at the state level. "Each year Idaho needs an additional $241.8 million in revenue for restoration and maintenance. This figure does not account for safety and capacity enhancement needs" (McGinnis-Brown et al., 2020). While the Idaho Transportation Department (ITD) does not explicitly address resilience, some aspects of their current practices could be considered as resilience planning. For example, the Statewide Transportation Improvement Plan (STIP) acknowledges weather related impacts on transportation assets. The ITD Transportation Asset Management Plan (2019) also states that ITD's goal is to "sustain the desired state of good repair over the life cycle of the assets at a minimum practicable cost" (1-2). Per this goal, the agency conducts research that could be vulnerability assessments. Research topics include:

- Landslide risk
- Rapid regional earthquake response
- Risk based inspection practices
- Construction practices to address freeze thaw specifications
- Salt brine solutions for roadway deicing
- Reduce cheatgrass on ITD rights of way

Metropolitan Planning Organizations (MPOs):

Many MPOs have yet to include resilience in their long-range plans.

In 2015, the Fixing America's Surface Transportation (FAST) Act asked MPOs to "reduce the vulnerability of the existing transportation infrastructure to natural disasters" and "improve the resiliency and reliability of the transportation system" (23 CFR §450.324.7; 23 CFR §450.206.9). A comprehensive list of federal code requirements regarding "resilience" are included in Appendix A.

Despite federal code requirements, many MPOs have not explicitly addressed resilience. Differing weather conditions, funding capacity, state legislation, and state DOT resilience plans contribute to the varied MPO response. Like states, MPOs with specific resilience-related concerns generally have more specific resilience plans. For example, Broward County MPO, located on the eastern coast of Florida, has a specific resilience plan to address rising sea-levels. The following table is a list of resilience plans from various MPOs around the nation. This is not a comprehensive list.

Table 2: MPO Resilience Plans

Cheyenne MPO, Wyoming	
Climate Impact	Facility maintenance and flooding
Plan	[Connect 2045]
Goal	Design transportation facilities and networks so they are secure and resilient to impacts from manmade or natural disasters.

Major strategies/
 	
next steps
	Project Prioritization Criteria
	
	• Urban/Rural
	• Safety & Security
	• Operational Efficiency
	• Preservation & Resiliency
	    ○ Known flooding issues impacting the classified road system
	    ○ Pavement condition data
	• Livability & Economic Growth
	• Multimodal Integration

Performance Measures	• Bridge Conditions • Pavement Conditions
Mid-America Regional Council (MARC), Kansas	
Climate Impact	Flooding, drought, heat stress
Plan	[2018 Regional Climate Resilience Strategy]
Goal	Create and implement a Regional Transportation Climate Resiliency Action Plan guided by a regional advisory body.
Major strategies/ next steps	1. Conduct vulnerability analysis of regional transportation infrastructure to potential flood, drought and heat risks.

	2. Evaluate transportation mobility options and public health threats from urban heat islands in disadvantaged communities. 3. Evaluate opportunities to enhance resiliency through green infrastructure, green/complete streets, alternative fuels and electric vehicles. 4. Evaluate resilience of all regional initiatives, including the Planning Sustainable Places program.
Performance Measures	n/a
Broward MPO, Florida	
Climate Variables	Hurricane, sea-level rise, storm surge, precipitation-induced flooding
Plan	Commitment 2045 Metropolitan Transportation Plan
Goal	Incorporate climate resilience into project prioritization.
Major strategies/ next steps	Project Prioritization Criteria • Establish transportation asset vulnerability • Evaluate if the proposed project would improve resiliency of the asset regardless of its vulnerability Broward also recommended members to prohibit future investment to vulnerable roadways identified in the "Extreme Weather and Climate Change Risk".
Performance Measures	• lane miles of evacuation routes & • number of miles of public roads and rail forecasted to be inundated by between 1 and 2 feet of sea-level rise
Skagit Council of Governments (SCOG) MPO, Washington	
Climate Impacts	GHG reduction, flood, sea level rise
Plan	Skagit 2040
Goal	Minimize adverse social, economic and environmental impacts and costs.
Major strategies/	Programmatic-level to determine whether the project:

next steps	1) Reduces GHG/VMT; 2) Pursues new revenue sources; 3) Expands and enhance other modes of transportation; 4) Provides incentives for vanpool/carpool programs; 5) Develops park and ride lots; 6) Addresses congestion issues; 7) Addresses ineffective intermodal connections; 8) Increases use of rail for passengers and freight; Findings are then reported to SCOG's Transportation Policy Board, interested parties, and others to determine project priority.
Performance Measures	n/a
Bend MPO, Oregon	
Climate Impact	GHG reduction, earthquake, water quality, wildlife habitat
Plan	Bend 2040 MTP
Goal	n/a
Major strategies/ next steps	No conclusive strategy yet; however, identifies the "most appropriate actions for MPOs" as: • Conducting vulnerability analyses • Analyzing transportation network for redundancies • Analyzing the transportation network for emergency route planning
Performance Metrics	n/a

COMPASS is the first MPO in Idaho to address resilience.

There are five MPOs in Idaho. To date, COMPASS is the first to address resilience. In 2018, COMPASS included a section in CIM 2040 2.0 titled Transportation Security and Resilience. The section identified federal code requirements, climate threats, and current resilience efforts in the Treasure Valley. In preparation for the new edition of COMPASS's long-range plan, the following

FHWA Vulnerability Assessment and Adaptation Framework is used to create a resilience strategy for COMPASS.

The FHWA Vulnerability Assessment and Adaptation Framework (VAF)

The FHWA Vulnerability Assessment and Adaptation Framework (VAF), 3rd edition, is a framework used by DOTs and MPOs to help collect and organize relevant data to promote and integrate resilience into their planning processes. The VAF provides a clear step-by-step process on how to gather information relevant to resilience planning. Subsequent resilience planning can easily build off information provided by the VAF. Thus, it is the framework of choice for this report.

1. Articulate Objectives

The objective of this report is to gather data and create a resilience strategy for the new edition of COMPASS's long-range plan titled *Communities in Motion 2050*. In the future, a clear definition of resilience should be adopted by member organizations. Examples of resilience definitions can be found in Appendix D.

2. Define Scope

The scope of this report is geographically limited to COMPASS's planning region. The planning region includes Ada and Canyon counties, collectively referred to as the Treasure Valley.

3. Identify Relevant Assets

For initial data collection and analysis, relevant assets are limited to roadways, railways, and pathways. Future research efforts may broaden the scope to include traffic operations centers, maintenance yards, transit stations, and maintenance facilities/buses.

4. Collect Asset Data

Asset data is data on the state of a facility. This report's broad objectives and scope require data collection on all roadways, railways, and pathways in the Treasure Valley. The following table is a list of data sources for assets in the Treasure Valley. Primary sources used to find asset data sources were ACHD's Strategic Plan- 2035, ITD's Road Data webpage, COMPASS's Data webpage. Databases for Canyon County were not readily available on their websites. Further coordination with Canyon County highway districts is necessary to collect asset datasets. Please note that this is not a comprehensive list of data sources.

Type	Characteristics	Data Source
Roadways/ Pathways	Location	• GIS (COMPASS, ITD)
	Condition	• StreetSaver (ACHD) • Pavement Management System (ITD) • Sidewalk Inventory (ACHD)
	Geotechnical data	• Boise Metro Area Liquefaction (Idaho Geological Survey) • Gridded Soil Survey Geographic Database (USDA) • 10-meter digital elevation model (Idaho Geological Survey) • Map the Canopy Urban Heat Map (TVCN)
	Function	• Functional Classification Map (COMPASS)
	Annual average daily traffic (AADT)	• Traffic Counts (COMPASS, ITD, ACHD) • Bicycle and pedestrian counts (COMPASS)
	Truck traffic volume	• Truck Travel Time Reliability (COMPASS) • Vehicle Classification (COMPASS)
Bridges	Location	• National Bridge Inventory (FHWA)
	Condition	• InspectTech (ACHD) • Bridge Conditions (ITD)
	Design thresholds and parameters	• Load Resistance Factor Design Bridge Manual (ITD)
Culverts and flood control structures	Location	• GIS (COMPASS)
	Condition/ Functionality	• Lucky Peak Dam Inundation & Reservoir failure inundation area (US Army Corps of Engineers)

		• Blacks Creek Dam failure inundation depth grid (Idaho Department of Water Resources) • American Falls Dam failure structure exposure analysis results (Idaho Office of Emergency Management) • Effective Flood Insurance Rate Map (FEMA) • Storm water facilities (ACHD)
Signals, switches, and track	Location	• Signal Database (ACHD)
	Condition/ Functionality	• n/a
Freight rail	Location	• GIS (COMPASS)
	Condition	• n/a
	Goods movement data	• Truck GPS data (ATRI) • Vehicle Classification (COMPASS)
Bus routes	Location	• GIS COMPASS
	Average daily ridership	• National Transit Database (NTD)
Evacuation routes	Location	• Treasure Valley Incident Management Operations Manual and Detour Route Plan (COMPASS)
	Detour length	• n/a
Traffic analysis zones	Location	• Congestion Management System
	Travel volumes	• Traffic Counts (COMPASS)
Floodplain	Extent of FEMA 100 and 500 year floodplains	• Flood Zones (COMPASS)

5. Identify Climate Variables

In 2015, the University of Idaho published the Boise Climate Adaptation Assessment, which quantified potential weather changes in the Boise region by 2050. Findings from the report were used to identify four relevant climatic factors with potential transportation impacts in the Treasure Valley: (1) Warmer Temperatures, (2) Changing Precipitation Patterns, (3) Wildfire, and (4) Population Growth. Additional source data used in this section comes from Ada (2017) and Canyon County's (2021) All Hazard Plans, U of I's Indicators of Idaho's Changing Climate Report (2015), and COMPASS's Safety and Security report (2018).

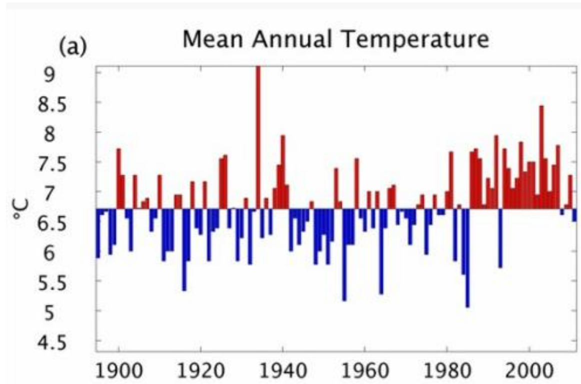

Figure 2: Mean annual temperature across Idaho (29 stations).

I. Warmer Temperatures

Warmer temperatures can damage roads and road foundations.

Estimates based on recent warming trends (Figure 2) project that the Treasure Valley will experience 8-9°F of warming during the summer months (Jul-Sep) by 2050 (Abatzoglou, 2016). The City of Boise has already warmed by 3.84 degrees Fahrenheit, making it the 13th fastest warming city in the nation (Climate Central, 2019). Warming will cause moderate risk days (heat index greater than 91 degrees F) to "increase from a historical baseline of around 16 days per summer to 66 days per summer by the mid-21st century" (City of Boise, 2016). High-risk days (heat index greater than 103 degrees F) "will become more common during the 21st century" (City of Boise, 2016).

Figure 4: Pavement Buckles in Vermillion, South Dakota (2019). Source: South Dakota Highway Patrol

Figure 3: Drought-Related Severe Pavement Crack in Travis County, TX (2005). Source: CAMPO

Warmer temperatures may affect transportation infrastructure by changing the soil structure underneath roads. Soil expansion and contraction due to drought has caused millions of dollars of damage to newly constructed pavement in Mississippi, Texas, Iowa, and other states. Idaho's various volcanic soil types are known to expand and contract. Therefore the Treasure Valley may be susceptible to this impact (Hardcastle, 2003). Thermal expansion, caused by extreme changes in heat, can cause the pavement to buckle (Minnesota Department of Transportation, n.d.). Also, road materials are stressed on moderate-high risk days and are likely to undergo road deformation (Alkaissi, 2020). Therefore, warming temperatures pose risks to transportation infrastructure through road foundation degradation, road deformation, and pavement buckles.

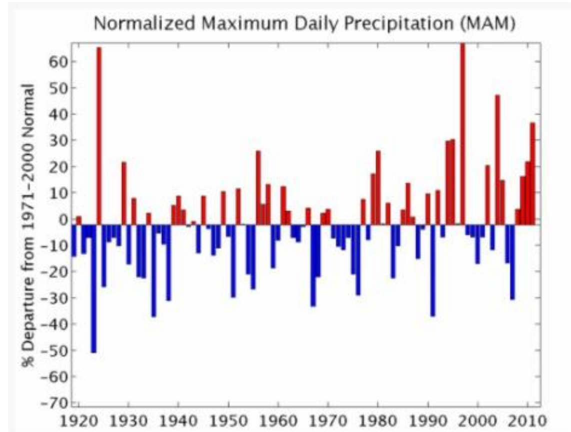

Figure 5: Precipitation indicator: intensity of the most extreme one- day precipitation event of the spring (MAM) in a given year relative to the mean from 1971–2000 (normal) for 28 stations in Idaho. Source: Abatzoglou, 2015

II. Changing Precipitation Patterns

More frequent heavy precipitation events in winter-spring months may cause road damage.

Idaho is projected to experience more heavy precipitation days, defined as days with total precipitation exceeding 0.7" (Abatzoglou, 2016). For projections for the state up to 2050, it's estimated that heavy precipitation days will double from 0.72 to 1.44 annually (Figure 5). Projections for the Treasure Valley also estimate a doubling of heavy precipitation days (City of Boise, 2016). Depending on the severity of the heavy precipitation event, road damage may occur.

Figure 6: Potholes on I-84 resulting from the 2017 winter storms, Source: ITD, COMPASS

In 2016, heavy snowfall forced ITD to advance maintenance activities a few years ahead of schedule to protect the longevity of the newly reconstructed Broadway Bridge in the City of Boise (COMPASS, 2018). Snowstorms in 2016-2017 also forced ITD to move up maintenance work on Interstate 84 to repair huge potholes (Figure 6). Current projections suggest more frequent precipitation events like those during 2016 may occur in the Treasure Valley.

Earlier snowmelt may max-out dam storage capacity resulting in minor flooding.

Idaho is experiencing earlier snowpack melt that increases the number of high streamflow events during the winter and spring months (Abatzoglou, 2015).

Earlier snowpack melt could max-out water storage capacity at Anderson Ranch Dam, Arrowrock Dam, Lucky Peak Dam, and within the 66 irrigation districts (AECM, 2017). According to the Ada County All-Hazards report – "the potential impacts of climate change on the operations of Lucky Peak Dam are real. The Boise River could see increased flows in response to a changing hydrograph that dictates dam operations" (Ada County Emergency Management [ACEM], 2017, 10-25). When dams reach their max storage capacity, they must release more water, potentially causing minor flooding downriver. Since 2004 there have been eight flood events in Ada County and two in Canyon County (AECM, 2017; CCSO, 2021). Causes include flash floods, capacity issues at Lucky Peak Dam, high flows on the Boise River, and canal breaches (AECM, 2017, 10-7).

In 2017, near-record snowfall, followed by earlier snowpack melt, caused minor flooding across the Treasure Valley (COMPASS, 2018). Water levels at Glenwood Bridge in Boise reached 9,000 CFS (flood stage is 7,000 CFS) causing damage to pathways and banks (Figure 7). The high flows also caused Five Mile creek to overflow into neighborhoods along Cole Road (Figure 8). Floods also forced residents of Caldwell Campground and RV Park to evacuate (Idaho Press-Tribune Staff, 2017). That year Idaho requested over $3.8 million in public assistance from FEMA to pay for approximately $10.3 million in flood damages that occurred from May-June in Ada, Bannock, Blaine, Camas, Canyon, Custer, Elmore, and Gooding counties (Idaho Office of Emergency Management, 2018, 3.2-40). The City of Boise used distributed FEMA funds to help repair pathways (City of Boise Planning and Development Department, n.d.).

Figure 7: 2017 flooding along the Boise River. Source: Idaho Foundation for Parks and Lands, COMPASS

Figure 8: 2017 Flooding Along Cole Road, Boise ID. Source: KTVB news

Sections of the roadway system in the Treasure Valley are vulnerable to flooding. There are 136 major bridges (20 feet or longer) within the 500-year floodplain, of which 32 cross the Boise River and are only built to accommodate 100-year flood events (Figure 9). Significant crossings in Canyon County include State Highway 45, State Highway 55, US 95, and US 20/26. The Interstate 84 Exit 27 interchange at Centennial Way in Caldwell is also vulnerable to flooding because, while the on/off ramps provide ample separation from the river, the interstate bridge itself does not.

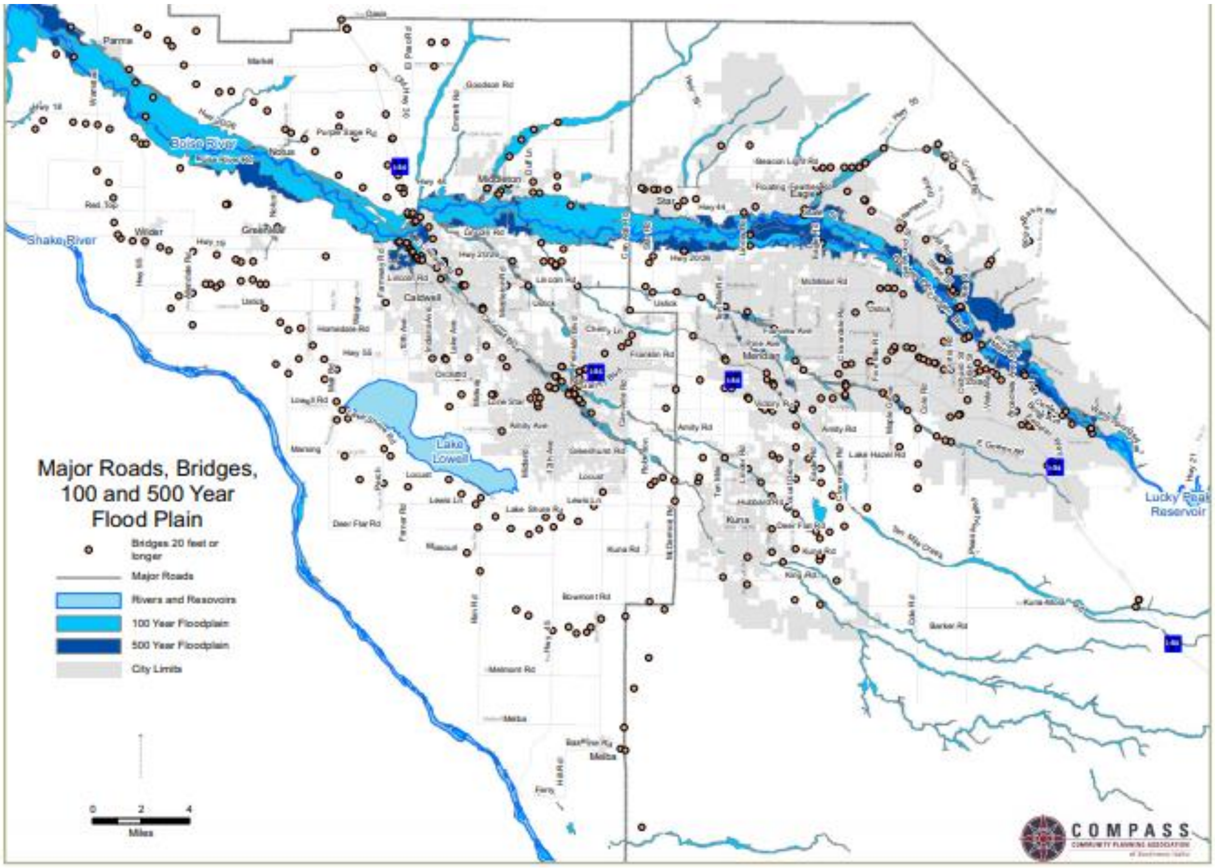

Figure 9: Major roads and bridges in the 100- and 500-year floodplain. Source: [COMPASS]

The value of properties in the floodplain has increased.

Across the Treasure Valley, the value of property exposed to 100-year flood events have increased significantly. From 2011 to 2017, values in Ada County increased by 5.6% or $1.5 billion (ACEM, 2017, 10-24). From 2013-2021, values in Canyon County increased by 44.3% or $498.9 million (CCSO, 2021, 10-18). In the event of a flood, more people, property, and transportation assets will be affected due to development in the floodplain.

The possibility of dam failure should be considered.

There are 26 dams that impound 1.319-acre feet of water in Ada County and by extension Canyon County (AECM, 2017, 7-6). In Ada and Canyon counties, a combined 472 critical transportation facilities are located within the Lucky Peak Dam Inundation Zone (AECM, 2017; CCSO, 2021). The failure of any dam would result in catastrophic human and infrastructure damages across the Treasure Valley. Even minor dam or canal failures are expensive. In 2010, an earthen dam associated with the Browns Pond Dam near McCall overflowed, resulting in $5.3 million dollars of damage to roads and bridges (Federal Emergency Management Agency, 2010).

III. Wildfire

Secondary impacts from wildfire like landslides and floods pose risks to roads, especially in the wildland-urban interface (WUI).

The 2050 projections estimate an increase from two large fires to 7.8 large fires per year in the Boise airshed (Abatzoglou, 2016). Estimations are based on warming temperatures and a growing abundance of fuel sources like cheatgrass, which burns four times more frequently than any native vegetation type (Balch, et al. 2012). From 2015-2020, the Boise Interagency Dispatch Center (BIDC) reported 536 fires in the Southwest region (CCSO, 2021, 13-5). Figure 10 shows the number of reported fires that occurred in Canyon and Ada counties.

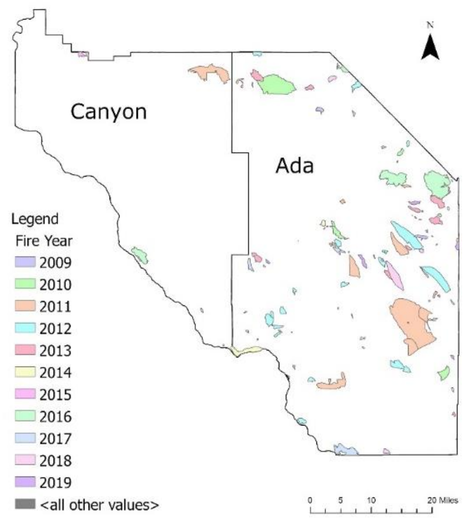

Figure 10: 2009-2019 Fires in Ada and Canyon Counties. Source: Idaho Fire Map

Since fire burns off vegetation, the soil after a wildfire is weakened and more susceptible to landslides and flash floods for several years after a wildfire. Large enough and hot enough wildfires can also bake soils, especially those high in clay content, increasing the imperviousness of the ground and further increasing the likelihood of a flash flood or landslide (CCSO, 2021, 13-4).

Figure 11: 2013 Table Rock Fire, Source: Idaho Statesman

Transportation assets in the wildland-urban interface (WUI) are at greater risk to wildfire and secondary impacts like flash flooding or landslide. In areas of 15-30% slope, there are three critical transportation facilities in Canyon County and eleven critical bridges in Ada County (CCSO, 2021, 11-9; ACEM, 2017, 11-8). Further research is required on whether those facilities or other transportation facilities coincide with the WUI.

IV. Population Growth

Population growth will increase frequency of road maintenance as well as result in new roads in the floodplain and wildland-urban interface.

Idaho's natural beauty and other economic and societal pull factors have contributed to population growth in the Treasure Valley. From 2010-2019, total population in the Treasure Valley has grown from 580,657 to 712,200, an annual growth rate of about 2.5 percent (COMPASS, 2018). By 2040, COMPASS estimates that the region will exceed 1 million people. Much of the growth is due to a rise in the over-65 population. By 2029 the over-65 population is projected to account for 33.4 percent of total population growth in the state (Idaho Department of Labor, 2020). This is more than four times the growth of the 15-64 age group (8.1%) (Idaho Department of Labor, 2020). Projected sea-level rise, minor flooding, and increased frequency of wildfires in Washington, Oregon, and California may also become significant push factors for coastal populations to move inland to states like Idaho. More people in the region means more cars on the road, therefore increasing the frequency of road maintenance.

The Ada and Canyon County All-Hazards reports show that over time, increasing populations have also resulted in more property and critical assets exposed to climactic hazards. Transportation infrastructure built in the floodplain and the wildland-urban interface are especially vulnerable to adverse impacts.

Long-anticipated earthquakes in California and Oregon would force millions inland, with significant impacts on Idaho's transportation system.

There is a 37% chance that the Cascadia earthquake, a megathrust earthquake of 7.1+ magnitude, will occur in the next 50 years (Oregon Office of Emergency Management, 2021). In California, a rupture along Southern San Andreas Fault could affect up to 3.5 million homes constituting $289 billion in reconstruction value (CoreLogic, 2016). Goldfinger and Gutierrez (2019) suggest that there would be "minimal time separation between the two ruptures"; in short one earthquake may trigger the other. If one or both of these earthquakes happen, Idaho's transportation infrastructure will be critical in transporting individuals to safety. It would also result in millions of people moving inland to states like Idaho.

6. Collect Climate Data

After identifying climate variables, the VAF asks planners to obtain climate data that includes projected future climate conditions the asset will be exposed to. The table below lists data sources for climate variables. Please note that this is not a comprehensive list.

Climate Variable	Data Source
Climate Change	• Downscaled Climate Models for Idaho: Multivariate Adaptive Constructed Analogs (MACA) datasets (U of I)
Wildfire	• Idaho Fire Map (Idaho Fish and Game) • Wildlife-Urban Interface (City of Boise) • Wind Resource Data (NREL)
Precipitation Patterns	• Advanced Hydrologic Prediction Service (NOAA)
Heat	• Heat Watch Study (TVCN)
Population	• Population Estimates (COMPASS)

7. Assess Vulnerability

Next, the VAF asks practitioners to assess the vulnerability of transportation infrastructure using the following four methods:

1. **Stakeholder input** – draw upon local knowledge and experiences from nearby communities and on-the-ground public agency staff to identify and rate potential vulnerabilities.
2. **Indicator-based** – use quantitative data on assets (e.g., elevation, geographic location, and existing flood protection) and projected climate stressors (e.g., sea level rise, temperature increases, and changes in streamflow) to serve as indicators to evaluate potential vulnerabilities.
3. **Engineering informed assessments** – use a detailed engineering assessment offers a way to evaluate risks to particular transportation assets in response to climate stressors.
4. **Considering risk –** assess the probability that an asset will experience a particular impact and determine the consequence (or severity) of that impact.

Stakeholder input and the indicator-based approach will be used to assess vulnerability in the Treasure Valley. The following table outlines current COMPASS actions to assess vulnerability using stakeholder input and indicators in their long-range plan.

<table>
<tr><th>Vulnerability Assessment Method</th><th>COMPASS Goals</th></tr>
<tr><td>Stakeholder Input</td><td>CIM 2050 Objective for Resilience: Support a resilient transportation system by anticipating societal, climatic, and other changes; maintaining plans for response and recovery; and adapting to changes as they arise.

Task 1: Assess vulnerability through stakeholder input.

COMPASS sought stakeholder input during the following meetings:
April 28, 2021- Resilience Intern’s presentation to RTAC</td></tr>
<tr><td>Indicators</td><td>Task 2: Use indicators to assess and monitor system vulnerability

The following performance measures were identified to track resilience in the Treasure Valley.
Bridge conditions (ITD)
% growth in public transit ridership
Potential new resilience performance measures are:
building permits (new units) in the floodplain
building permits (new units) in the wildland-urban interface
The following performance measures were discussed, but not included in CIM 2050. They may be included at a later date.
Lane miles on 15-30% slope area (buffer lane to capture roadway below steep slopes)
Acres of preserved open space in the floodplain and wildland-urban interface
# of unplanned maintenance projects (TIP amendment process) per year
# of unhealthy/hazardous AQ days (COMPASS)</td></tr>
</table>

8. Identify, Analyze, and Prioritize Adaptation Options

After assessing vulnerability, the VAF asks practitioners to identify, analyze, and prioritize adaptation options. To do this, the VAF suggests using either an Economic Analysis or Multi-Criteria Analysis.

An Economic Analysis asks practitioners to analyze costs and benefits of adaptation options. Robust climate projections and estimates of resulting infrastructure damages are necessary for this kind of analysis.

A Multi-Criteria Analysis assesses how the adaptation option would likely impact the following variables:

- Effectiveness in responding to climate stressors
- Capital and life-cycle costs
- Environmental impacts
- Technical feasibility
- Permitting constraints
- Public acceptance
- Environmental justice impacts
- Scale or impact of the response

The multi-criteria analysis takes into account environmental factors, agency constraints, and funding limitations. For these reasons, COMPASS will use the multi-criteria analysis to inform the following list of resilience strategies relevant to the Treasure Valley. The VAF refers to resilience strategies as adaptation options. The term was rephrased as 'resilience strategies' since COMPASS seeks to make recommendations rather than provide options.

Short-Term Resilience Strategies

- Review and adopt a list of critical transportation facilities starting with the list of infrastructure identified by the Hazards United States (HAZUS) model.
- Locate or relocate critical facilities outside of WUI and the floodplain.
- Collect spatial data on weather-induced unplanned maintenance events.
- Integrate critical infrastructure considerations into local continuity of operations plans.
- Integrate weather hazard scenarios into the Treasure Valley Incident Management Operations Manual and Detour Route Plan.
- Incorporate retrofitting or replacement of critical system elements in capital improvement plans.
- Develop and publish an emergency evacuation route map on the COMPASS website.

- Create a traffic mobile app that provides real-time data to residents on heavy traffic and weather-caused road closures in the Treasure Valley.

Long-Term Resilience Strategies

- Continue to collaborate with local agencies and organizations involved in resilience. A list of Idaho organizations and businesses that seek to address resilience are included in Appendix E.
- Promote open space in the WUI and the floodplain by implementing planned-unit developments, easements, setbacks, greenways, and sensitive-area tracks.
- Identify opportunities to increase system redundancy through alternate transit routes.
- Integrate floodplain management policies into other planning mechanisms within the Treasure Valley.
- Consider the residual risk associated with structural flood control in future land-use decisions.
- Implement stormwater management regulations and master planning; adopt a stormwater management master plan.
- Support research that investigates the link between harsh weather and transportation system impacts in the Treasure Valley.
- Encourage higher regulatory standards ordinances in hazard-vulnerable zones through zoning overlays, subdivision and development review, conservation easement, or a community rating system.

9. Integrate into Decision-Making

The final step of the VAF asks practitioners to incorporate assessment results into decision-making. As an MPO, COMPASS is committed to promoting decision-making that addresses risk and promotes resilience at the local level in the following two ways:

1. **Collect data to quantify resilience to help local decision-makers identify resilience-related concerns**
    a. Continued data collection by COMPASS
    b. Continued integration into COMPASS's long-range plan
2. **Reevaluate COMPASS's project prioritization process**
    a. Consider including resilience into COMPASS's project priority process

Conclusion

This report found that nationwide, the cost of disaster recovery drives resilience planning in the transportation sector. State departments of transportation and metropolitan planning organizations are building more detailed plans around resilience and integrating them into their long-range planning activities. Most transportation organizations in Idaho have not yet created specific resilience plans, partially due to Idaho's relatively infrequent large natural disasters. However, recent FEMA disaster declarations show that natural disasters are becoming more frequent in Idaho.

To address resilience in the Treasure Valley, section five of this report identified relevant projected climatic changes in the Treasure Valley. Based on that data, four factors with potential impacts to the transportation system were identified: (1) warmer temperatures, (2) changing precipitation patterns, (3) more frequent wildfires, and (4) greater regional population growth. To assess and identify the region's vulnerability to these potential impacts, two actions were chosen (1) engaging stakeholder input and (2) monitoring through indicators. These strategies were chosen because they included the greater Treasure Valley community while also focusing COMPASS's efforts on monitoring activities. A list of suggested resilience strategies were also included to guide future resilience efforts. As the Treasure Valley continues to grow, building resilience into the planning processes will be critical to creating a safe, prosperous, and resilient community. This report seeks to support and inform these efforts in the Treasure Valley.

Appendix A. Federal Code

23, CFR §450.206.9 (2021) **State:** Improve the resiliency and reliability of the transportation system and reduce or mitigate stormwater impacts of surface transportation.

23, CFR §450.306.9 (2021) **MPO**: Improve the resiliency and reliability of the transportation system and reduce or mitigate stormwater impacts of surface transportation.

23 CFR §450.300.a (2021) takes into consideration resiliency needs while minimizing transportation-related fuel consumption and air pollution.

23 CFR §450.316.b (2021) In developing metropolitan transportation plans and TIPs, the MPO should consult with agencies and officials responsible for other planning activities within the MPA that are affected by transportation. This should include state and local planned growth, economic development, tourism, natural disaster risk reduction, environmental protection, airport operations, or freight movements. MPOs should also coordinate planning (to the maximum extent practicable) with such planning activities.

23 CFR §450.324.7 (2021) Assessment of capital investment and other strategies to preserve the existing and projected future metropolitan transportation infrastructure, provide for multimodal capacity increases based on regional priorities and needs, and reduce the vulnerability of the existing transportation infrastructure to natural disasters. (…)

FHWA Order 5520: Informs state DOTs, MPOs, FLMAs, tribal governments, and others that existing funding eligibilities (must) support resiliency and adaptation in the delivery of title 23 programs.

Appendix B: Federal Grants

FEMA Building Resilient Infrastructure and Communities (BRIC) program: Provides funding for projects that demonstrate innovative, collaborative, research-supported, and proactive investment in community resilience.

FEMA Hazard Mitigation Grant Program (HMGP): Provides funds to 'build back better' after a presidentially declared disaster. Includes a specific *HMGP Post-Fire assistance program*.

Various Preparedness Grants from FEMA: Emergency management performance grant, Intercity Bus Security Grant, Regional Catastrophic Preparedness Grant, Transit security Grant, Dam Safety Grant, Earthquake State assistance Grant.

EPA Smart Growth Grants and Other Funding: To improve the quality of development and protect human health and the environment.

Appendix C. National Resources

Plan Integration for Resilience Scorecard: A tool to look at all community planning documents and spatially evaluate the level of plan integration in hazard regions.

Federal Highway Vulnerability Assessment and Adaptation Framework

Comprehensive Guide by MDOT: A comprehensive list of national resources for resilience-planning compiled by Montana DOT.

FHWA Climate Change Adaptation Guide for Transportation Systems Management, Operations, and Maintenance

Regional Climate Change Effects: Useful Information for Transportation Agencies

Appendix D. Definitions of Resilience

There are two different ways to define resilience. Inherent resilience views success as returning to a normal state of operations. Adaptive resilience views success as increased capacity of the system to withstand further shocks. The definition and subsequent objectives chosen by stakeholders should identify what a resilient transportation system produces for the residents of the planning area. The table below shows examples of currently adopted inherent and adaptive definitions of resilience.

State	Definition of Resilience
California *adaptive*	"Resilience is the capacity of any entity – an individual, a community, an organization, or a natural system – to **prepare** for disruptions, to **recover** from shocks and stresses, and to **adapt** and grow from a disruptive experience." (Planning and Investing for a Resilient California: 2017, p. 61)
Colorado *adaptive*	"The ability of communities to **rebound**, positively **adapt to**, or **thrive amidst changing conditions** or challenges, including natural disasters and climate change, and maintain quality of life, healthy growth, durable systems, and conservation of resources for present and future generations." (Colorado Resiliency Planning Fact Sheet, 2019, p. 1)
Madison Area, Wisconsin *adaptive*	"develop a transportation system that is **resilient in the face of climate change and rising fuel prices** in the future" and to "**reduce [the] vulnerability** of the public and the region's transportation infrastructure to crime and natural hazards" (Madison Area Transportation Planning Board, 2017, pp. 4-4, 4-6)
Minnesota *inherent*	"reducing vulnerability and ensuring redundancy and reliability to **meet essential travel needs**" (Minnesota DOT, 2017, p. 90);
Montana *adaptive*	The Rockefeller Foundation's 100 Resilient Cities Initiative definition: "*The capacity of individuals, communities, and systems to* ***survive, adapt, and grow amidst stressors and shocks***." – (Montana Ready Communities Initiative) "Rather than just bounce back from adversity, resilience communities recognize the need to **bounce forward** so that the next flood, wildfire, economic downturn or public health

	emergency has a **less traumatic impact.**" (Montana Ready Communities Initiative)
Oregon *adaptive*	"Oregon citizens will not only be protected from life-threatening physical harm, but because of risk reduction measures and pre-disaster planning, communities will **recover more quickly** and with **less continuing vulnerability** following a Cascadia subduction zone earthquake and tsunami." (Oregon Resilience Plan, 2013, p. xiv)
Tennessee *inherent*	"Ensuring the ability of the transportation system to **withstand and recover** from incidents" (Tennessee DOT, 2015, p. 4).
Wisconsin *inherent*	"ensuring the ability of the transportation system "to **quickly respond** to unexpected conditions and **return to its usual operational state**" (Wisconsin DOT, 2009, p. 9-2)

Appendix E. Idaho Programs for Resilience

Treasure Valley Canopy Network (TVCN)

A public–private partnership aimed to decrease urban heat by increasing the number of urban trees. TVCN also removes unhealthy urban trees and constructs green storm water infrastructure. TVCN also manages an urban heat ArcGIS web map.

University of Idaho's Idaho Climate-Economy Impacts Assessment

A research team at U of I is conducting a two-year project to evaluate the economic impact of climate change in Idaho. A report will be published in late fall/early winter, 2021. Content will be free, interactive, and available online. This report will build upon extensive climate change research also done at U of I.

Boise State's Hazard and Climate Resilience Institute

A research institute at BSU to promote climate resilience, including on the built environment.

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