U.S. Department of Transportation
Federal Highway Administration

Office of the Administrator

1200 New Jersey Ave., SE
Washington, DC 20590

The Honorable Thomas R. Carper
Chairman
Committee on Environment and Public Works
United States Senate
Washington, DC 20510

Dear Chairman Carper:

This letter transmits the enclosed report to Congress on the Disaster Relief Mobilization Study (DRMS) as required by Section 11505 of the Bipartisan Infrastructure Law (BIL) of 2021 (Public Law 117-58). The BIL required "a study to determine the utility of incorporating the use of bicycles into the disaster preparedness and disaster response plans of local communities."

This report to Congress summarizes the work and findings of the DRMS. The DRMS has the following three main components, and companion reports focusing on each are available separately: (1) An assessment of the most vulnerable links of active transportation systems that are at risk of disasters, including adapting and applying the Federal Vulnerability Assessment and Adaptation Framework methodology; (2) A feasibility evaluation of disaster preparedness and response planning procedures, which included a broad review of community response planning, to determine the critical role that bicycles can play; and (3) An assessment of existing training programs related to law enforcement, first responders, or other agencies that rely on bicycles for disaster response. Study findings suggest bicycles are a valuable but underleveraged resource in disaster response. The absence of planning for their use in disaster response is limiting opportunities for improved outcomes for those affected by disasters. Suggested next steps are relatively low investment and include planning, vulnerability assessments, and preparedness activities.

A similar letter has been sent to the Ranking Member of the Senate Committee on Environment and Public Works and the Chairman and Ranking Member of the House Committee on Transportation and Infrastructure.

Thank you,

Kristin R. White
Acting Administrator

Enclosure

U.S. Department of Transportation
Federal Highway Administration

Office of the Administrator

1200 New Jersey Ave., SE
Washington, DC 20590

The Honorable Shelley Moore Capito
Ranking Member
Committee on Environment and Public Works
United States Senate
Washington, DC 20510

Dear Ranking Member Capito:

This letter transmits the enclosed report to Congress on the Disaster Relief Mobilization Study (DRMS) as required by Section 11505 of the Bipartisan Infrastructure Law (BIL) of 2021 (Public Law 117-58). The BIL required "a study to determine the utility of incorporating the use of bicycles into the disaster preparedness and disaster response plans of local communities."

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A similar letter has been sent to the Chairman of the Senate Committee on Environment and Public Works and the Chairman and Ranking Member of the House Committee on Transportation and Infrastructure.

Thank you,

Kristin R. White
Acting Administrator

Enclosure

U.S. Department of Transportation
Federal Highway Administration

Office of the Administrator

1200 New Jersey Ave., SE
Washington, DC 20590

The Honorable Sam Graves
Chairman
Committee on Transportation and Infrastructure
U.S. House of Representatives
Washington, DC 20515

Dear Chairman Graves

This letter transmits the enclosed report to Congress on the Disaster Relief Mobilization Study (DRMS) as required by Section 11505 of the Bipartisan Infrastructure Law (BIL) of 2021 (Public Law 117-58). The BIL required "a study to determine the utility of incorporating the use of bicycles into the disaster preparedness and disaster response plans of local communities."

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Thank you,

Kristin R. White
Acting Administrator

Enclosure

U.S. Department of Transportation
Federal Highway Administration

Office of the Administrator

1200 New Jersey Ave., SE
Washington, DC 20590

The Honorable Rick Larsen
Ranking Member
Committee on Transportation and Infrastructure
U.S. House of Representatives
Washington, DC 20515

Dear Ranking Member Larsen:

This letter transmits the enclosed report to Congress on the Disaster Relief Mobilization Study (DRMS) as required by Section 11505 of the Bipartisan Infrastructure Law (BIL) of 2021 (Public Law 117-58). The BIL required "a study to determine the utility of incorporating the use of bicycles into the disaster preparedness and disaster response plans of local communities."

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Kristin R. White
Acting Administrator

Enclosure

Disaster Relief Mobilization Study

Content for Report to Congress

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None

16. Abstract

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
	NOTE: volumes greater than 1,000 L shall be shown in m^3			
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2,000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2,000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	2.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380. (Revised March 2003)

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS

ADA	Americans with Disabilities Act of 1990
APTA	American Public Transportation Association
ATRSI	Active Transportation Relief Support Index
ATV	all-terrain vehicle
BICP	Bike Instructor Certification Program
BIL	Bipartisan Infrastructure Law
CERT	Community Emergency Response Team
CFR	Code of Federal Regulations
DRMS	Disaster Relief Mobilization Study
DRT	Disaster Relief Trial
EMA	emergency management agency
EMS	emergency medical services
FEMA	Federal Emergency Management Agency
FHWA	Federal Highway Administration
FIOP	Federal Interagency Operational Plan
FY	fiscal year
IIJA	Infrastructure Investment and Jobs Act
IPMBA	International Police Mountain Bike Association
LEBA	Law Enforcement Bicycle Association
NRI	National Risk Index
PIARC	Permanent International Association of Road Congresses
PROTECT	Promoting Resilient Operations for Transformative, Efficient, and Cost-Saving Transportation
RDPO	Regional Disaster Preparedness Organization
RETR	Regional Emergency Transportation Route
DOT	U.S. Department of Transportation
VAAF	Vulnerability Assessment and Adaptation Framework
VAST	Vulnerability Assessment Scoring Tool

Executive Summary

Introduction

The frequency, severity, and costs of weather-related disasters are rising in the United States. Communities and organizations prepare for disasters through planning, training, and capacity building. Ingenuity, dynamic decisionmaking, and swift action are often necessary during and after a disaster. Communities should consider every tool and technology at their disposal, and including how bicycles may support disaster preparedness and response operations.

Section 11505 of the Bipartisan Infrastructure Law (BIL), also known as the Infrastructure Investment and Jobs Act (P.L. 117-58), authorized the Disaster Relief Mobilization Study (DRMS). The BIL required "a study to determine the utility of incorporating the use of bicycles into the disaster preparedness and disaster response plans of local communities." This DRMS has three main components:

1.) An assessment of the most vulnerable links of active transportation systems that are at risk of disasters, including adapting and applying the Federal Highway Administration (FHWA) Vulnerability Assessment and Adaptation Framework (VAAF) methodology and Vulnerability Assessment Scoring Tool (VAST).
2.) A feasibility evaluation of disaster preparedness and response planning procedures, which included a broad review of community response planning, to determine the critical role that bicycles can play.
3.) An assessment of existing training programs related to law enforcement, first responders, or other agencies that rely on bicycles for disaster response.

This report to Congress summarizes the work and findings of the DRMS.

Bicycle Use in Existing Disaster Preparedness and Response

Study findings suggest bicycles are a valuable but underleveraged resource in disaster response. The review revealed few cases where bicycles have been used during disaster relief efforts and even fewer cases where bicycles are explicitly mentioned in disaster planning or emergency response documentation.

Ad hoc examples of bicycle use in disaster response include supply distribution, reaching individuals in need, provision of first aid, search and rescue, local evacuation, information gathering and communications, security patrols, providing portable power for small devices, and as general transportation.

Bicycle use during disaster mobilization is rarely included in official emergency response plans. Uses were restricted to local evacuation, general transportation mode, or prioritizing bicycle routes for clearance post-disaster.

Similarly, there are limited examples of bicycle training programs either integrated into disaster planning and preparedness activities or focusing specifically on bicycle use in disasters and available to a wide audience. One notable example is the Disaster Relief Trials, community-led cargo bike competitions simulating a supply run 4 days post-disaster.

Assessing Vulnerability of Active Transportation Infrastructure

The active transportation network is an essential element to consider when exploring bicycle use in disaster response. The conditions, connectivity, and types of infrastructure influence how bicycles might travel to reach their destinations. This study used a method that relies on specific indicators or measurements to assess how vulnerable a community's active transportation network (like bike paths and walking trails) is to natural disasters (like floods or earthquakes) and technological issues (like power outages). The approach builds on existing frameworks from the FHWA utilizing VAAF and VAST, which are tools used to evaluate and improve the resilience of transportation systems.

The assessment methodology combines vulnerability (exposure, sensitivity, and adaptive capacity) with criticality (how important a segment is to get to an essential location). Results can be used to identify areas where bicycle, pedestrian, and other active transportation activity are suitable and most important for supporting disaster response efforts. This study demonstrates the active transportation vulnerability assessment using Tacoma, Washington, and Harris County, Texas as initial case study locations.

Feasibility of Planning for and Using Bicycles in Disaster Response

Despite ad hoc bicycle use cases and limited formal planning, there are many opportunities to incorporate bicycles into disaster response. Bicycles offer advantages over motor vehicles due to their efficiency, low cost, wide availability, maneuverability, and independence from gasoline and telecommunication networks.

How a community uses bicycles will depend on many factors. What type of hazard? What type of task? Which type of bicycle is best for the selected task? Who owns and will use the bicycle? What are the conditions of the community's geography, climate, development patterns, and transportation network? It is up to stakeholders within a specific community to determine the best use cases to meet their needs.

Bicycles are not an appropriate solution for all communities or disasters. Bicycle use may be less feasible in rural communities, areas with mountainous terrain, or locations with cold weather climates and frequent snow and ice. Bicycle use is not suitable for certain hazards, such as avalanches, extreme heat or cold temperatures, or chemical or radiological hazards.

For communities who determine that bicycles can play a viable role in disaster response, bicycle use should be integrated into the formal processes of disaster planning, training, and operations. This is especially true for community volunteer organizations, law enforcement, and first responder bicycle units. It may be more challenging to plan for and integrate informal, ad hoc, and individual bicycle use into disaster response plans. Volunteer bicyclists could be disruptive to operations when not properly trained and integrated into disaster preparedness and response. Should volunteer bicyclists be needed, it is suggested that they receive both disaster- and bicycle-related trainings including first aid, safe riding practices, rules of the road, use of communication tools, light search and rescue, and team organization.

Disaster Relief Mobilization Study Findings

Suggested next steps are relatively low investment and include planning, vulnerability assessments, and preparedness activities.

There are opportunities to advance local community preparedness by planning for scenarios in which to use bicycles. Communities should define their goals and answer the questions of why, how, when, where, by whom, and with what equipment.

Building partnerships can support robust and safe bicycle use during disaster response. This includes groups who are responsible for or adjacent to disaster response and who may benefit from bicycle use. It also includes bicycle retail shops, rental shops, rideshare programs, advocacy groups, and riding clubs, who have access to equipment, maintenance services, and local knowledge and connections.

Training is an essential component of bicycle disaster response, yet currently there are no training modules for bicycle use specifically for disaster relief. Organizations that offer bicycle patrol trainings may consider developing a program on disaster response planning and tactics. Communities may also adopt or expand programs such as the Disaster Relief Trials or Community Emergency Response Teams to train and prepare volunteers for bicycle use in disaster response.

This study illustrates an opportunity to pilot the active transportation vulnerability assessment with local communities. This would serve to extend the proof-of-concept, validate the suitability of publicly available data, and refine the methodology. At the policy level, this study shows a need to incorporate active transportation infrastructure into community vulnerability assessments, including further addressing equity.

There are opportunities to further explore how bicycle use during disaster response and active transportation vulnerability connect to existing Federal, State, and local policy, programs, and data sources. The integration of ongoing active transportation efforts and stakeholders into disaster response planning is imperative for safety and success.

Conclusion

The DRMS lays key foundations for a framework and guidance on bicycle inclusion in response plans and operations. However, it will be local community stakeholders' responsibility to customize to their situation, conditions, hazards, and available resources. Collaboration is essential to identify vulnerabilities, develop plans, access resources, and properly train bicyclists.

Communities engaging in such activities—and especially those that have recently dealt with disasters—should pursue open communication with other communities to facilitate transfer of knowledge and experience.

Chapter 1. Introduction and Background

Our Nation faces the challenge of increasing frequency, severity, and costs of weather-related disasters. The effects of climate change are likely to increase risks for weather-related natural hazards, such as longer seasons for wildfires and hurricanes.[1,2] At the same time, the U.S. must protect against cybersecurity threats, hazardous material emergencies, power outages, and other technological hazards. More frequent and more severe disasters could damage roads and utilities, disrupt supply chains, and tear apart communities.

These effects are already being borne out across the Nation. The number of weather disaster events with losses exceeding $1 billion each (Consumer Price Index adjusted) has increased over the last 4 decades.[3] The average annual number of billion-dollar disasters quadrupled from 3.1 events in the 1980s to 12.8 events in the 2010s. Four out of the top 5 years with the highest number of billion-dollar disasters have occurred since 2017.

Emergency management is the interdisciplinary field that works together to prevent, protect against, mitigate, respond to, and recover from disasters.[4] Because each disaster is unique, emergency management uses an all-hazards approach to build institutional capacity, identify resources, and develop partnerships to address any disaster situation regardless of location, size, or complexity. Emergency management creates a framework leveraging the whole community's capacity and expertise to reduce vulnerability to hazards and to cope with, respond to, and recover from disasters.

Successful emergency management requires proactive communication, collaboration, coordination, and creativity across organizational and jurisdictional boundaries. Players include all levels of government, private and nonprofit sectors, non-government and faith-based organizations, first responders, academia, and the public. Communities should consider every tool and technology at their disposal, including how bicycles may support disaster preparedness and response operations within a community.

Active Transportation and Disaster Relief Mobilization

The DRMS specifies the *active transportation* activities of bicycling, walking, and personal mobility devices. Other examples of active transportation include skateboards, in-line skates, small scooters, or single-wheel devices. The definition of active transportation does not extend to larger, heavier, or higher-speed forms of transportation sometimes included under the term "micromobility."

Per the Americans with Disabilities Act (ADA) and Title 28 Section 36.11 of the Code of Federal Regulations, *personal mobility devices* include wheelchairs, walkers, canes, crutches, braces, and some power-driven mobility devices.[5]

Active transportation offers multiple benefits to its users: increased physical activity and improved health; emissions reductions when switching from motor vehicle trips; and accessible options for federally defined disadvantaged communities or people who may be Asset Limited, Income Constrained, and Employed. Functioning active transportation is dependent upon a network of infrastructure to ensure people can move safely and efficiently: sidewalks, bicycle lanes, shared use paths, crosswalks, signs, and more.

A state of good repair is important for a reliable transportation system. When the transportation system is in disarray (for example, wind-blown debris on roadways, destroyed roadways or bridges, lack of electricity to power traffic control systems, or extreme flooding), people may not be able to rely on their vehicles or other motorized transportation modes to move between places. However, first responders, emergency workers, law enforcement, and goods still need to reach their destinations. Active transportation modes may offer alternative mobility options over short distances.

Bicycles offer several advantages over other modes when transportation, power, and communications systems have been disrupted. Bicycles are multipurpose, offer flexibility and adaptability, and are relatively accessible and affordable. Bicycles may be ridden on roads, sidewalks, trails, or other surfaces, and can navigate around debris or blockages. Cargo and electric bicycles may transport people or goods over longer distances than nonelectric bicycles. Therefore, it is important to explore the potential role of bicycles in disaster preparedness and response.

The Bipartisan Infrastructure Law Disaster Relief Mobilization Study Scope

Per Section 11505 of the BIL, this study explored three facets of possible bicycle use in disasters. First, the study adapted a vulnerability assessment methodology to identify critical and vulnerable active transportation links within a transportation network, using case study locations and disaster types for initial proofs of concepts. Second, the study evaluated the feasibility, appropriateness, and conditions under which bicycles may be used in disaster preparedness and response. This explored in depth whether and how bicycles have been considered in existing disaster plans or used in past response operations. Third, the study explored training programs and materials used to train law enforcement and first responder bicycle patrol teams, to better understand how these or new practices could promote the safe and effective use of bicycles during disasters.

National and International Frameworks

Relevant existing guidance, frameworks, and plans were reviewed throughout the DRMS. This included important and relevant policies and resources such as Executive Order (EO) 13653, FHWA Order 5520, and the U.S. Department of Transportation (DOT) Climate Adaptation and Resilience Plan.[6,7,8] In addition, the DRMS reviewed key Federal policies on emergency preparedness and continuity such as EO 12656, Presidential Policy Directive 40, and Federal Continuity Directives 1 and 2.[9,10,11] Many resources and guidance in this area are organized and available via the Federal Emergency Management Agency (FEMA) Office of National Continuity Programs.

None of these resources mention bicycles, and any mention of bicycles or active transportation in guidance or literature on disasters or resilience is the exception, not the norm.

However, we note that Congress enacted the Promoting Resilient Operations for Transformative, Efficient, and Cost-Saving Transportation (PROTECT) Program in BIL (23 United States Code Section 176), starting in Fiscal Year 2022. This program provides funding both through formula and competitive discretionary grants to plan and improve the resilience of surface transportation

infrastructure, including conducting vulnerability assessments.[12] The program includes projects involving eligible pedestrian and bicycle facilities.

Common resilience frameworks found in the U.S. are generally organized around four characteristics.[13,14] These are listed in table 1 with an example of its relevance to the DRMS.

Table 1. Resilience characteristics and relevance.

Characteristic	Description	Example Relevance to Bicycles in Disasters
Robustness	The ability of the elements of the system to withstand crisis without significant deprivation or loss of performance.	Vulnerability assessments and maintenance of active transportation infrastructure.
Redundancy	The extent to which the system elements are substitutable and thus adept at satisfying functional requirements when disturbances occur and significant deprivation or loss of function transpires.	National criticality evaluation of bicycle networks, followed by targeted improvements to improve priority access routes.
Resourcefulness	The ability to diagnose and prioritize challenges and implement solutions by identifying and mobilizing material, monetary, informational, technological, and human resources.	Equipment readiness and incorporating disaster planning and response into first responder bicycle training programs.
Rapidity	The ability to mitigate losses and timely restore functionality to prevent future disruptions.	Better prepared to mobilize law enforcement, first responders, and volunteers for response operations.

Federal Emergency Management Agency Guidance and Resources

The FEMA provides guidance for practitioners and organizes shared responsibility of preparedness around five National Planning Frameworks, one for each mission area: (1) Prevention, (2) Protection, (3) Mitigation, (4) Response, and (5) Recovery.[15] Each area contains 1 to 11 Core Capabilities of its own, and 7 other Core Capabilities crosscut 2 or all 5 mission areas.[16] The Response area is the focus of the DRMS, including planning and preparedness actions that support response operations. Several of the Response Core Capabilities are especially relevant, e.g., Critical Transportation, Mass Search and Rescue Operations, or Operational Communications. Each of the five areas has an associated Federal Interagency Operational Plan (FIOP).[17] The FEMA representatives were involved in the DRMS, and the DRMS research found that bicycles are not an explicit part of FIOPs nor generally in other FEMA guidance.

The FEMA *National Response Framework* identifies Emergency Support Functions that coordinate group resources and capabilities. Although there are no explicit mentions of bicycles within, there are opportunities to consider and prepare active transportation infrastructure, discussed later in this report. For example, when Hurricane Florence approached North

Carolina, the Cape Fear Public Transportation Authority, designated in the County Emergency Operations Plan for Emergency Support Function #1 (Transportation), supported evacuation with Wave Transit buses.[18] This effort successfully transported 138 vulnerable residents to shelters farther inland. Assessing and reducing vulnerability of active transportation networks near public transportation facilities is among the key opportunities addressed in this study to further use the lifesaving services of transit providers like Wave Transit.

Many other Federal and national resources are referenced throughout this report and the supplementary material developed during the DRMS.

Limited Use of Bicycles in Disasters

The DRMS looked within the U.S. and internationally for other guidance or examples of bicycle use in disasters. Domestic findings are documented further in the next chapter. Internationally, an example is the Permanent International Association of Road Congresses (PIARC) Disaster Management Manual, a comprehensive guidance resource with numerous examples and case studies.[19] The manual is organized around the cycle of Disaster, Response, Recovery, Preparedness, and Mitigation. Nonetheless, bicycles are not mentioned.

Although the DRMS surfaced very few instances of bicycles in disaster preparedness or plans, there are examples of bicycle use in practice. The ongoing Disaster Relief Trials (DRT) Program is a coordinated effort found to prepare for bicycles in disaster response.[20] The DRTs have occurred in multiple United States cities as well as in Japan. Notable examples of bicycle use in disaster response include the use of bicycles in response to Hurricane Maria September 2017 in Puerto Rico, experience of Fort Myers following Hurricane Ian in September 2022, and the Turkey-Syria earthquake in February 2023. When Knysna, South Africa was devastated by wildfires in June 2017, a nonprofit bicycle program provided 50 bicycles to first responders for better access to people in need of services.[21]

Source: Can Topalfakioglu/BisiDestek (left), Kelley Stangl/Disaster Relief Trials (right).

Figure 1. Photograph. Two examples of supply bicycles.

Study Purpose

The DOT has completed this study in fulfilment of requirements outlined in the BIL. Section 11505 of the BIL (P.L. 117-58) requires the Secretary of Transportation to "carry out a study to determine the utility of incorporating the use of bicycles into the disaster preparedness and disaster response plans of local communities."[(22)] This requirement includes a vulnerability assessment of community infrastructure supporting active transportation; evaluation of whether disaster preparedness and response plans should include bicycle use; and review of bicycle-related training programs for various disaster responders.

The purpose of this report to Congress is to summarize study results and suggestions for the Committee on Environment and Public Works of the Senate and the Committee on Transportation and Infrastructure of the House of Representatives. Specifically, suggestions consider how bicycles could be incorporated into disaster planning for local communities, as well as improvements and expansions to bicycle training programs.

Organization of Report

This DRMS report to Congress is organized into five chapters as follows:

- Chapter 1 is an introduction to the DRMS, with background, context, and definitions.
- Chapter 2 provides a summary of current presence of bicycles in disaster preparedness and response among local communities, including guidance, existence in planning, and training.
- Chapter 3 outlines an adapted approach to vulnerability assessment methodology applicable to active transportation facilities and networks, with proof-of-concept assessments for two communities.
- Chapter 4 returns to the question of feasibility of the use of bicycles in disaster planning and response.
- Chapter 5 provides concluding remarks and a summary of potential next steps.

The BIL Section 11505 text is included as an appendix for reference. Additional material for each of the three primary DRMS components specified are available from the FHWA Office of Operations.

Key Terms and Definitions

Table 2. Key definitions.

Term	Definition
Active Transportation	The DRMS specifies *active transportation* as bicycling, walking, and personal mobility devices. This does not extend to larger, heavier, or higher speed forms of transportation sometimes included under the micromobility term. Per the ADA, *personal mobility devices* include wheelchairs, walkers, canes, crutches, braces, and some power-driven personal assistance mobility devices such as e-scooters.
Active Transportation Network	For this study, includes all routes allowing active transportation. The research team relied on networks from Open Street Map given the requirement to use only free, public, and nationwide sources. Limited access roads were identified using the motorway, and motorway links identifiers available from Open Street Map.
Criticality	The degree to which a given asset is important to fulfilling the mission and goals of the agency/project sponsor. Widely used for prioritization support, criticality provides a basis for understanding the impacts of loss or damage of the assets, that if disrupted, would severely degrade, or curtail an agency's ability to perform core functions or its mission.
Disaster[I]	An event that disrupts the functioning of a community or society at any scale due to hazardous events interacting with conditions of exposure, vulnerability, and capacity, leading to human, material, economic, and/or environmental losses and impacts.
Disaster Planning[II]	The capability to conduct a systematic process engaging the whole community, as appropriate, in the development of executable strategic, operational, and community-based approaches to meet defined objectives. This includes having a flexible planning process that builds on existing plans, conducting training and exercises, and taking corrective actions.
Disaster Preparedness[II]	The range of deliberate, critical tasks and activities necessary to build, sustain, and improve the operational capability for an organization or community to prevent, protect against, mitigate, respond to, and recover from disasters.
Disaster Response[II]	The capabilities and actions needed to save lives, protect property and the environment, and meet basic human needs during and immediately after a disaster has occurred.

Table 2. Key definitions (continuation).

Term	Definition
Local Community[III]	A unit of local government, political subdivision of a State or local government, metropolitan planning organization (MPO), a rural planning organization, or a Tribal government.
Public Transportation[IV]	Regular, continuing shared-ride surface transportation services that are open to the public or open to a segment of the public defined by age, disability, or low income. This excludes intercity passenger rail, intercity bus service, charter bus service, school bus service, sightseeing service, courtesy shuttle service for patrons of one or more specific establishments, intraterminal or intrafacility shuttle services.
Vulnerability[V]	The degree to which a system is susceptible to, or unable to cope with adverse effects of climate change or extreme weather events. In the transportation context, climate change vulnerability is a function of a transportation system's exposure to climate effects, sensitivity to climate effects, and adaptive capacity.

[I] Adapted from the United Nations Office for Disaster Risk Reduction: https://www.undrr.org/terminology/disaster.

[II] Adapted from the FEMA Independent Study Course IS-230.e "Fundamentals of Emergency Management": https://training.fema.gov/is/courseoverview.aspx?code=IS-230.e&lang=en.

[III] As defined in Public Law 117-58 Section 11505(a): https://www.govinfo.gov/content/pkg/PLAW-117publ58/pdf/PLAW-117publ58.pdf.

[IV] As defined in United States Code Title 49 Section 5302(15): https://www.govinfo.gov/content/pkg/USCODE-2021-title49/pdf/USCODE-2021-title49-subtitleIII-chap53-sec5302.pdf.

[V] As defined in the Vulnerability Assessment and Adaptation Framework, 3rd Edition, FHWA Office of Planning, Environment, & Realty, FHWA-HEP-18-020, December 2017, https://www.fhwa.dot.gov/environment/sustainability/resilience/adaptation_framework/.

Chapter 2. Bicycles in Existing Disaster Preparedness and Response

How, when, and why bicycles may be used in disasters will vary based on many factors. For a community planning to integrate bicycles into disaster planning and response operations, it is useful to see what has already been done by peer communities. This study investigated the extent to which bicycles have been included in disaster preparedness and response strategies around the U.S. through a literature review and interviews. An extensive literature review was conducted of city- and community-level disaster preparedness and operations plans, news media coverage of disasters, and bicycle training programs. The study supplemented the literature review with targeted outreach and interviews with Federal, State, local, and organizational stakeholders.

The review revealed very few cases where bicycles have been used during disaster relief efforts and even fewer cases where bicycles are explicitly mentioned in disaster planning or emergency response documentation.

First, this chapter explores key questions to consider when defining bicycle use in disasters. Next, this chapter summarizes how bicycles have been incorporated into local plans or used in disaster response operations. Lastly, this chapter reviews available bicycle training programs and best practices relevant for communities looking to use bicycles in disasters.

Defining Bicycle Use in Disasters

There are many interrelated questions that must be answered to define how a community would use bicycles in a disaster. Some of these questions include:

- **What type of disaster?** The nature, magnitude, and extent of a disaster will influence the condition of the transportation system (and whether motorized vehicles also are present on roadways with bicycles), the overall needs during response, and who will be involved.
- **What task is the bicycle serving? What types of bicycles should be used?** These two questions go hand in hand. Bicycles may serve many functions during and after a disaster. The type of task will determine whether a conventional, electric, cargo, mountain, trailer-mounted, or other type of bicycle is most appropriate. Nationwide electric bicycle technology is an important consideration, as these may extend the range, terrain, and the number of personnel able to use bicycles with the assistance of onboard motors and speed management systems. The task also will determine the origin, destination, and routes used by bicycles.
- **Who is using the bicycle? Who owns the bicycle?** The type of user and organizational affiliation will affect equipment sources and type, skill levels and expertise riding a bicycle, and the type of task being executed. The intended audience of bicycle users may include first responders, law enforcement, emergency workers, community organization representatives, resident volunteers, or citizens. Bicycles may be owned by a private individual, private-sector company, nonprofit organization, or public agency.
- **What are the characteristics of the community?** The location, size, geography, topography, development patterns, road network, infrastructure conditions, and available

resources and funding of the community will affect the applicability and appropriateness of bicycles for a given task.

How bicycles may be used during and after disasters varies greatly. For example, community members may use bicycles to evacuate following an earthquake. First responders may navigate wind-strewn debris on blocked roads following a tornado. Citizens may pick up supplies on a cargo bike at a point of distribution after a hurricane. Law enforcement may patrol a community and enforce a mandatory curfew following a severe storm. Messengers may use bicycles to ferry communications between operation centers during a widespread power outage. Each community should consider the above questions in scoping when, how, and who will use bicycles.

In addition, bicycles will not be an appropriate solution for all communities or disasters. Bicycle use may not be feasible in rural communities, areas with mountainous terrain, or locations with cold weather climates and frequent snow and ice. In many regions, all-terrain vehicles (ATV), farm equipment, horses, or snowmobiles/snowmachines may be more likely. The feasibility of including bicycles in disaster response is discussed further in chapter 4.

Bicycle Use in Local Community Disaster Preparedness Plans and Response Operations

To understand how bicycles have been considered in disasters, this study performed a literature review of community-level plans related to emergency management, operations, preparedness, response, and recovery. County-level plans were reviewed in the absence of city-level emergency response plans for rural communities. Additional efforts were placed on obtaining information from Tribal communities, including seeking communities with recent Federal disaster declarations or included in the FHWA's Climate Change Adaptation Case Studies.(23) The review also included information that is available in English from communities in countries that have implemented bicycles in their emergency response plans. Community geographic and socioeconomic characteristics were identified through sources including the U.S. Census. From the initial findings, seven communities were selected for a further comprehensive review.

One key challenge was identifying communities that proactively planned for bicycle use or used bicycles in a disaster. There is no nationwide repository of local-level emergency management plans. Furthermore, local jurisdictions are not required (at the Federal or State level) to create and maintain disaster plans. There are Federal and State grant funding programs that may require the development of a disaster-related plan to be eligible for funding (for example, FEMA requires a State to have a hazard mitigation plan to apply for certain types of nonemergency disaster assistance). In general, however, local communities may choose to develop disaster plans at their own discretion and with varying levels of resources. Similarly, there is no central database of disaster response activities, and each disaster situation is unique.

Local Community Characteristics

For the purposes of this study, a local community may refer to a unit of local government, a political subdivision of a State or local government, MPO, rural planning organization, or a Tribal government.[1] Examples of communities include cities, counties, and Tribal nations. In

[1] As defined in Public Law 117-58 Section 11505(a): https://www.govinfo.gov/content/pkg/PLAW-117publ58/pdf/PLAW-117publ58.pdf.

total, emergency management plans and other documentation were reviewed for around 50 communities. The community inventory spans large urban, small urban, and rural communities across the Nation, representing a diversity of geographies, demographics, and economies.

Seven communities were selected for further review of emergency response efforts to represent the diversity of community characteristics, including DRT participation, existence of a Community Emergency Response Team (CERT), established Bicycle Emergency Transportation Routes, urban versus rural, presence of a bicycle culture, types of hazard exposure, and sociodemographic characteristics. These communities included Portland, Oregon; New York City, New York; Davis, California; Arlington, Virginia; Makah Tribe in Neah Bay, Washington; Tacoma, Washington; and Houston, Texas. In December 2022, the Makah Tribe was a featured case study in FHWA's series, Climate Change Adaptation Case Studies.(23)

Table 3. Communities with plans reviewed in depth.

Community	Population	Density (Persons/Square Mile)	Disability Status (%)	Minority Population (%)	No car Households
Portland, OR	652,603	4,888	11.9%	31.2%	14.0%
New York City, NY	8,804,190	29,303	10.9%	65.9%	54.8%
Davis, CA	66,850	6,703	7.9%	45.3%	8.9%
Arlington, VA	238,643	9,179	6.0%	39.1%	13.9%
Makah Tribe,[1] WA	935	398	12.1%	90.2%	9.2%
Tacoma, WA	219,346	4,412	14.3%	42.6%	8.9%
Houston, TX	2,304,580	3,598	9.8%	67.9%	8.5%

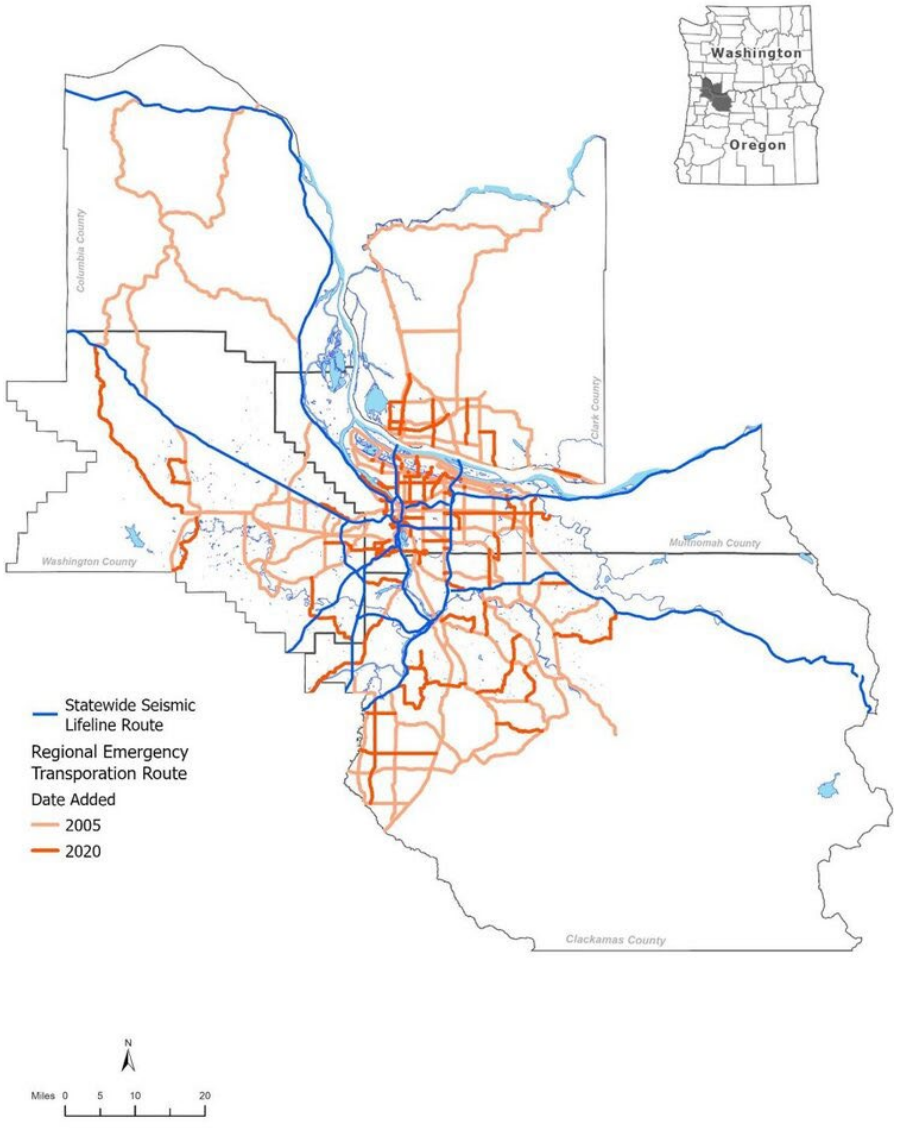
[1] Demographic data are for the Neah Bay and are not exclusive to the Makah Tribe members.

Inclusion of Bicycles in Emergency Management Plans

Bicycle use during disaster mobilization is rarely included in official emergency response plan documentation. Typically, these mentions are restricted to presenting bicycles as a potential mode for local evacuation or in general transportation during an emergency (e.g., Portland, Oregon, and Kirkland, Washington) or to mentioning that bicycle routes are to be repaired and restored in the aftermath of a disaster (e.g., Issaquah, Washington).(25,26,27) Notably, the review of the literature has revealed that only select communities on the West Coast have considered formally including bicycles in emergency response.

Portland, Oregon, has institutionalized the use of bicycles by documenting Regional Emergency Transportation Routes (RETR) in its emergency response planning.(28) These designated routes are prioritized to be cleared following a disaster in order to move people, resources, and supplies.

Police, fire, and emergency medical services (EMS) will follow the RETRs to make recovery efforts. These routes also are alternative paths for pedestrians and bicyclists who may not have access to motorized vehicles following a disaster. Originally designated in 2005 and updated in 2021 by the Regional Disaster Preparedness Organization (RDPO), figure 2 shows the designated RETRs throughout the Portland-Vancouver Metropolitan region in Oregon and Washington.[29] In general, the designation of bicycle-specific evacuation routes would support elevating priorities for those active transportation facilities regarding funding, maintenance, and debris removal.



Source: RDPO. RETR Update—Phase 1.

Figure 2. Map. Regional Emergency Transportation Routes.

Bicycle Use in Disaster Relief
Despite the lack of formal incorporation of bicycles in disaster relief, bicycles have been used in disaster relief for a variety of hazards and purposes. In general, bicycles have been used for:

- Supply distribution (e.g., food, water, medical supplies, and power sources) through interrupted road networks or congested areas
- Reaching individuals in need
- Search and rescue activities
- Local evacuation through interrupted road networks or congested areas
- Information gathering and delivery (e.g., reuniting families)
- Assistance with other disaster relief tasks
- Providing portable power for small devices (e.g., cell phone charging)
- Post-disaster transportation of first responders and residents without access to other travel modes
- Security patrolling and traffic control; see figure 3

Source: Policia de Puerto Rico (left) and Eleni Christofa (right).

Figure 3. Photograph. Law enforcement on bicycles and micromobility in Puerto Rico.

In addition to directly supporting disaster response operations, bicycles should be considered as a necessary self-resiliency tool post-disaster. Bicycles serve as an essential transportation mode to access places of employment, housing, healthy food, and health care following a disaster, in particular when other transportation modes (such as personal vehicles or public transportation)

may not be operational. For example, bicycle commuting in New York City increased threefold following Hurricane Sandy.[30]

Several overarching themes emerged from the identified case studies. Typically, emergency response (professional or volunteer) has ridden conventional bicycles. Trailers are valuable for supply distribution, leveraging the versatility to convert a conventional bicycle for added cargo when a trailer is added. Bicycle use in disasters has typically occurred in more densely developed and populated urban areas, such as New York City or Austin.

Bicycle ownership varies by the type of activity. When volunteer residents are directly involved in emergency response in an informal way, they tend to use their own bicycles. In other cases, publicly available-for-rent bicycles such as those belonging to bicycle rideshare systems can be used. Government-owned bicycles are provided for law enforcement, EMS, and other emergency response teams. Examples from recent disasters also revealed that bicycle manufacturers are donating bicycles for use in disaster relief (both for residents and police departments).

There are many benefits of bicycle use in disaster relief when compared to using motor vehicles. Bicycles may access areas difficult to reach or inaccessible via motorized vehicles. Bicycles also offer emissions reduction, noise reduction, and cost savings for users. Bicycle use for supply delivery also minimizes contact, as compared to centralized distribution locations (e.g., food banks).

A summary of case studies from the U.S. and internationally is provided in table 4 and table 5.

Table 4. Summary of bicycle use in disaster response case studies in the U.S.

Location	Disaster Type	Bicycle Type	Bicycle Ownership Plan	Bicycle User	Bicycle Use Purpose
New York City, NY	Hurricane	Cargo Bikes	Privately Owned	Volunteer Residents	Supply Distribution
Seattle, WA	Pandemic/ Food Shortage	Cargo Bikes & Bike Trailers	Bicycle Nonprofits	Volunteers	Supply Distribution
Austin, TX	Hurricane	Conventional Bikes	Bike Share	Residents	Provide Transport Post-Disaster
Coffey Park, Santa Rosa, CA	Fire	Bicycle Trailer	Privately Owned	Residents	Local Evacuation
Fort Myers, FL	Hurricane	Conventional Bikes	Abandoned Rental Bikes	Law Enforcement	Patrolling, Curfew Enforcement
Houston, TX	Hurricane	Conventional Bikes	Donated by bicycle manufacturer, Bike Share	Residents	Everyday transportation needs
Puerto Rico	Hurricane	Conventional Bikes	Donated by bicycle manufacturer	Law Enforcement	Patrolling, Transportation for police officers

Table 5. Summary of bicycle use in disaster response case studies internationally.

Location	Disaster Type	Bicycle Type	Bicycle Ownership Plan	Bicycle User	Bicycle Use Purpose
Philippines	Volcanic Activity	Cargo Bikes & Conventional Bikes	Bicycle Nonprofits	Volunteers	Supply Distribution
Philippines	Tropical Storm	Cargo Bikes & Conventional Bikes	Bicycle Nonprofits	Volunteers	Supply Distribution, Information Gathering and Delivery
Philippines	Illness/Pandemic	Cargo Bikes & Conventional Bikes	Bicycle Nonprofits (lent)	Frontline workers	Provide Transportation Post-Disaster
Mexico City, Mexico	Earthquake	Conventional Bikes	Privately Owned	Residents	Supply Distribution, Damage Assessment, Victim Location
Sumatra, Indonesia	Tsunami	Bicycles	Bicycle Nonprofits (gifted to residents)	Residents	Provide Transport Post-Disaster
Hanshin, Japan	Earthquake	Cargo Bicycles	Response Team Owned	Crisis Management Response Team	Cell phone Distribution
Jordan	Terrorism	Cargo Bikes	State Owned	Law Enforcement	Crowd Control
Turkey & Syria	Earthquake	Bicycle Trailer	Private or Non-Profit	Volunteers	Supply Distribution, Individual Aid

Relevant Training Programs

In addition to disaster plans and response operations, training and exercises are essential capacity building elements for disaster planning and preparedness. This study reviewed a wide range of

training and preparedness practices incorporating active transportation, specifically bicycles, in disaster planning. There are both disaster-specific best practices (such as the DRTs) and general bicycle best practices (including bicycle maintenance and safety, such as wearing helmets). Despite limited formal training for citizen bicycle use in disaster relief, communities may leverage a wealth of existing bicycle training knowledge relevant to but not specifically focused on disaster response.

Agency/Community Programs Reviewed

This study sought to collect examples from organizations and institutions about bicycles integrated into disaster planning and preparedness activities, as well as training programs or materials relevant to bicycle use in disaster response. The study performed a literature review and engagement with numerous organizations. This included resources provided by Federal organizations such as FEMA and DOT; national, global, and local bicycle training organizations and programs; community disaster response organizations; local and government institutions, including police departments; and general bicycle use nonprofit and advocacy organizations.

Best Practices and Identified Gaps in Training Programs

Similar to use of bicycles in disasters, **there are limited examples of bicycle training programs either 1) integrated into disaster planning and preparedness activities, or 2) focusing specifically on bicycle use in disasters and available to a wide audience.** Several specific training programs and groups are described in subsequent sections. In general, the lack of disaster relief-specific bicycle trainings is a major gap in disaster preparedness for bicycles.

Stakeholders identified opportunities to expand existing preparedness and partnerships regarding bicycle use in disaster relief. Communities may consider and plan for scenarios in which to include bicycles in response plans and emergency preparedness efforts (including how, when, where, by whom, and with what equipment). Examples of planning may range from developing relationships with bicycle shops for distribution and as maintenance hubs, to maintaining a fleet of bicycles, trailers, helmets, and maintenance equipment for use in disaster response.

Several stakeholders identified bicycle rental companies as potential partners during disaster relief, including both traditional rental stores and bicycle rideshare programs. Although rideshare programs typically rely on power availability to release bicycles to users, these systems could provide a strategic reserve of bicycles during a disaster.

In addition, organizations may develop bicycle disaster relief training modules for both law enforcement and for other community organizations (e.g., CERTs). Organizations with mature, general bicycle training programs may add a section on disaster response planning and tactics.

It is essential throughout all preparedness and training efforts to promote the safety and wellbeing of bicycle riders. This includes wearing appropriate personal protective and safety equipment such as bicycle helmets, high-visibility clothing, and lighting on the bicycle or bicyclist.[31] Despite a disaster situation, bicyclists should continue to observe all "rules of the road" related to traffic and merging, obeying traffic laws, and maintaining situational awareness. Bicyclists, too, should be aware of their own physical limitations. Training should strive to avoid introducing additional risk to bicyclists during disaster response such as from flooded

routes, traversing debris (both from above and on the ground), downed power lines, and limitations or hazards of electric bikes. Trainings also may consider possible emergencies such as electric bicycle lithium-ion battery fires.[32]

Disaster Relief Trials

The DRTs are the primary disaster relief bicycle training available to U.S. citizens.[20] The DRTs are community-hosted cargo bike competitions simulating a supply run 4 days after a disaster has happened. The DRT was founded in 2012 to improve community engagement and resilience through the use of cargo bikes. The intent of DRT is to prepare communities for disaster response and encourage a more formal inclusion of bicycles in community emergency response. The focus of these races is on post-disaster relief, rather than evacuation.

The DRT Program recommends incorporating bicycles into local disaster planning and response, leveraging both local or regional bicycling organizations and motivated volunteers. Further, emergency planners should consider training small community teams on bicycling use during disasters, and roles of points of distribution, logistics, and communications during disaster response.[33]

The first DRT took place in Portland, Oregon, in 2012. Since then, DRTs have been hosted in Portland, Oregon; Eugene, Oregon; Seattle, Washington; Arlington, Virginia; and San Francisco, California. Internationally, Japan has hosted a DRT and Victoria, British Columbia, has hosted a similar event called "Tour Disasters."

For a DRT event, participants ride their own fully loaded bicycles throughout the host city, visiting designated check points at which riders encounter obstacles or complete tasks to assist response teams. Certain requirements exist for these races, including carrying up to 110 pounds of supplies, lasting at least 3 hours, and carrying fragile items (for example, eggs, which represent fragile supplies such as medicines) that cost the rider points if not delivered intact. Figure 4 shows participants engaging in a DRT.

Source: Disaster Relief Trials Pedal Toward Community Resilience.[34]

Figure 4. Photograph. June 2016 Disaster Relief Trials.

The DRTs have evolved and integrated new technologies and needs over time. For example, participants using electric bikes must prove that they have an off-grid charging system, which

addresses resilience concerns around the need for charging when electricity may be unavailable following a disaster. In 2022, the Portland Bureau of Emergency Management presented a bicycle ambulance concept trailer for transporting people during disasters, as pictured in figure 5.

Source: Jonathan Maus/BikePortland.

Figure 5. Photograph. Bicycle ambulance concept.

The Portland DRT also has been successfully integrated with other local and State disaster relief programs. For example, participation in the DRT counts towards volunteer hours for the region's CERT. The CERT Program is described in more detail in the following section on additional training program opportunities. Within the Portland region, the DRT also prompted the 2019–2021 update of Regional Emergency Transportation Routes (discussed earlier in this report). The DRT competitors are provided with a map of the RETRs.

Bicycle Associations and Programs

The study reviewed national, global, and local bicycle associations and programs, including the International Police Mountain Bike Association (IPMBA), Law Enforcement Bicycle Association (LEBA), and Bike Instructor Certification Program (BICP). Each of these organizations offers bicycle-focused training programs and networking for law enforcement, EMS, and security professions. **These organizations have not specifically considered the use of bicycles in disaster planning or response.**

The IPMBA is an established nonprofit organization dedicated to promoting the use of bicycles for public safety by providing trainings, resources, and networking opportunities. The IPMBA provides a comprehensive selection of in-person courses focusing on police, EMS, security, instructors, bicycle maintenance, and electric bikes.[35] The IPMBA also hosts an annual conference with in-person trainings and certifications (such as shown in figure 6), networking,

and a bicycle patrol product exhibition.[36] However, these courses and conference are only available to security, law enforcement, or EMS organizations.

Source: IPMBA Conference Archives. 2019 IPMBA Conference.[37]

Figure 6. Photograph. 2019 International Police Mountain Bike Association conference in Fort Worth, Texas.

Another organization focused on law enforcement bicycle training is LEBA.[38] The LEBA provides both basic and advance courses focusing on the general use of bicycles with law enforcement. Topics include training rides, slow speed balance drills, mechanics, and off-road riding. The LEBA "Train the Trainer" course focuses on providing the skills needed to train other officers in police mountain biking.

At the global level, the BICP offers professional trainings and certifications for mountain bike skills to law enforcement.[39] The BICP trainings span topics from basic mountain biking skills, to leading rides, to "train the trainer" courses such as the BICP Patrol Cyclist Instructor Training course.[40,41] The curriculum covers topics related to the overall vulnerability of bicycles, including how to safety mount and dismount, how to handle terrain changes, and managing the weight of electric bicycles.

Local and regional organizations also offer training and education related to public safety and security bicycle patrols, including the Homeland Security Training Institute (located at the College of DuPage in Illinois), American Bike Patrol Service, Inc. (southern California), and Bicycle Patrol Outfitters (southern California).[42,43,44] Training topics typically include basic riding skills, patrol procedures, tactics, and equipment maintenance and for a variety of bicycle

types. None of these trainings have specifically considered the use of bicycles in disaster planning or response.

Additional Training Programs and Opportunities

This study identified several training programs or organizations with opportunities to expand current trainings to consider bicycles in disaster relief. This includes existing emergency management and disaster relief programs, police department bicycle patrol trainings, and general bicycle-oriented organizations. These opportunities are summarized below.

The FEMA Center for Domestic Preparedness offers a training for Bicycle Crowd Control Teams. This training covers basic concepts, formations, transitions, and logistical considerations related to the use of bicycles and crowd control teams.[45] With its range of all-hazards event courses, the FEMA Center for Domestic Preparedness offers a potential home for future courses on the integration of bicycles and disaster relief.

The FEMA's CERT Program is a local-level training program to educate volunteers about disaster preparedness and response to the hazards most likely in their areas.[46,47] The CERT volunteers enhance capabilities to prepare for, respond to, and recover from disasters while professional responders focus on more complex and dangerous tasks. The CERTs (and similar efforts, such as Neighbor Emergency Teams) are present in communities across the country. The CERT training educates volunteers in basic disaster response skills, including fire safety, light search and rescue, team organization, and disaster medical operations. At this time, CERT curriculum does not include any information related to bicycle use in disaster relief.[47,48] There is an opportunity to incorporate safe bicycle use in disaster relief into CERT curriculum. In addition, CERT could be an essential recruitment method to identify disaster relief volunteers with bicycle equipment and skills, as seen in the Portland, Oregon, CERT and DRT collaboration described above.

As noted in the review of bicycle associations and programs, many trainings exist for law enforcement, EMS, and security bicycle patrols. For example, the Chicago Police Department (figure 7), University of Illinois at Chicago Police Department (figure 8), and New York State University Police at Oswego (figure 9) have dedicated bicycle patrol programs that receive training internally or from larger law enforcement training organizations, such as IPMBA.[49,50,51] These bicycle training programs typically do not consider the use of bicycles in disaster planning or response, although some trainings do cover special events. These existing frameworks and resources could serve as the foundation for disaster-specific bicycle trainings.

Source: Chicago Tribune.

Figure 7. Photograph. Chicago Police Department—bike patrol certification class.

Source: University of Illinois Chicago.

Figure 8. Photograph. University of Illinois at Chicago Police Department—bicycle patrol.

Source: Oswego Suny. Bike Patrol.

Figure 9. Photograph. Oswego State University of New York University Police 2012 bike school.

While this study focuses on the intersection of bicycles with disaster planning, other general bicycle-oriented nonprofit organizations may provide valuable training programs and resources about bicycle safety, education, and advocacy. Organizations such as the League of American Bicyclists, the Street Trust, and the Active Transportation Alliance have not specifically considered the use of bicycles in disaster relief as a part of their training and advocacy.[52,53,54] However, communities seeking to include bicycles in disaster preparedness and response operations may leverage these existing resources and trainings. Programs address a wide range of bicycle skills, including rights and responsibilities, tips for commuting, maintenance, appropriate equipment and attire, e-bikes and e-scooters, group riding, bikeshares (such as shown in figure 10), and safely sharing the road. Communities also may partner with their local bicycle advocacy and nonprofit organizations for bicycle disaster preparedness.

Source: The Street Trust.

Figure 10. Photograph. The Street Trust clinics support inclusive bikeshare, May 2022.

Chapter 3. Assessing Vulnerability of Active Transportation Infrastructure

The active transportation network is an essential element to consider for a community exploring the use of bicycles in disaster relief. The conditions and types of infrastructure influence how bicycles and other active transportation modes can travel to reach their destinations. The use of these networks also is highly dependent on connectivity. The FHWA provides a planning guide for improving components of active transportation network connectivity, which also is a resource for practitioners paying special attention to this during vulnerability assessments.[55] Furthermore, a community cannot assume that a specific segment will be operational following a disaster. It is essential to understand which active transportation segments are the most critical (i.e., necessary to travel between two essential destinations) and the most vulnerable (i.e., susceptible to the impacts of a hazard). For example, flooding after an extreme precipitation event may cut off a key route between the hospital and the temporary shelter location within a community.

This study adapted an indicator-based methodology to evaluate the vulnerability of a community's active transportation network to natural and technological hazards. The vulnerability assessment builds upon and adapts the FHWA Vulnerability Assessment and Adaptation Framework (VAAF).[56] This VAAF is an important guidance for examining vulnerability of transportation infrastructure. The VAAF focuses on conventional motor vehicle infrastructure, therefore the DRMS extended and adapted the methodology for active transportation. The DRMS similarly leveraged and adapted the Vulnerability Assessment Scoring Tool (VAST).[57] Results can be used to identify areas where bicycle, pedestrian, and other active transportation activity are suitable and most important for supporting disaster response efforts.

The study demonstrates the vulnerability assessment methodology through case studies representing large urban, small urban, and rural communities which have low levels of vehicle ownership and lack sufficient active transportation infrastructure routes to public transportation.

Universe of Locations and Hazards

As discussed in chapter 2, there are many factors that influence how bicycles and active transportation may be used in disasters. Two of those factors are the characteristics of the community and the type of disaster. This section explores the universe of possible locations and hazards.

The location, size, geography, topography, development patterns, road network, infrastructure conditions, demographics, and available resources of the community will affect the objectives and outcomes of the vulnerability assessment. To demonstrate the methodology, this study selected case study communities representing a diversity of sizes, demographics and social vulnerability, disaster risks, and available infrastructure data. Information sources included the FEMA National Risk Index (NRI) to identify disaster risks and U.S. Census Bureau data to identify communities with a high proportion of zero-car households and a high proportion of a disabled population relative to national averages.[58] In addition, the study used both Census data and geographic/geological characteristics to identify communities representing coastal, inland,

and mountainous areas; large urban (population greater than 50,000), small urban (population between 2,500 and 50,000), and rural (not classified as an urban area by the Census) communities; and a rural Tribal location.[59]

The vulnerability assessment also is applicable for a wide range of natural and technological hazards, supporting the "all-hazard" approach to emergency management. Natural hazards are extreme and severe weather, environmental, and climate phenomena that have the potential to impact societies and the human environment. Natural hazards include but are not limited to coastal flooding, droughts, earthquakes, heat waves, hurricanes, landslides, riverine flooding, wind storms, tornados, tsunamis, and wildfires. Technological hazards are risks caused by malfunction of or human error in handling technology. Technological hazards include but are not limited to cybersecurity events, power outages, dam failures, chemical or hazardous material emergencies, and radiological events. For the purposes of this study, the vulnerability assessment evaluated hazards for each case study location that were rated as "relatively moderate" to "very high" in the NRI.

The case study communities, with aggregate National Risk Index, are shown in figure 11.

Source: FHWA.

Figure 11. Map. Vulnerability assessment locations.

Vulnerability Assessment Methodology

This section summarizes the vulnerability assessment methodology, including key concepts and assumptions, underlying data sources, and the methodology framework. Two foundational concepts for the methodology are **criticality** and **vulnerability**.

Criticality
Criticality is how important a segment is to get to an essential location. For example, the sole access road to a major hospital would be critical to a community during a disaster. For this analysis, the criticality of a segment is a function of 1) its proximity to Essential Disaster Relief Facilities (defined below) and 2) its ability to support active transportation during a disaster, quantified by the Active Transportation Relief Support Index (ATRSI). Criticality is measured for walking, bicycling, and electric bicycling, and then combined into a final score.

At the census tract level, the ATRSI is composed of three factors: demographic information, mobility potential, and critical location access. Demographic information combines density of people, employment, and historically underserved communities. Mobility potential examines how well a given area can enable bicycle or pedestrian use, including density of on-street bicycle infrastructure, shared use paths, and public transportation stops with access to active transportation facilities. Critical location access includes important locations in two subcategories:

- *Essential Disaster Relief Facilities:* Facilities that store or administer resources essential for disaster response and recovery, including hospitals, urgent care facilities, police and fire stations, large event stadiums, shelters, and Emergency Operations Centers.
- *Activity Centers:* Places where people gather locally, engage in, or administer nonessential activities during disaster response and recovery, such as churches, schools, libraries, recreation facilities, and higher education facilities. Activity centers may be expanded to include additional locations such as bicycle shops.

Vulnerability
Vulnerability is how susceptible a segment is to the impacts of a hazard. This methodology evaluates vulnerability as a function of exposure, sensitivity, and adaptive capacity.

Exposure is the relative risk of being affected by a hazard. For example, inundation levels can be a factor of exposure in coastal areas at risk of flooding.[60] The methodology uses multiple national and local modeling resources as indicators of exposure for stressors, including temperature changes, precipitation changes, sea level rise, storm surge, and wind.

Sensitivity is how well a given location can handle the stress from a hazard impact or how susceptible the transportation infrastructure is to failure under disaster conditions. An example of sensitivity is the build quality or state of repair of a bridge. The methodology includes many proxy indicators of transportation network segment sensitivity to temperature, heavy precipitation, sea level rise, storm surge, and wind.

Adaptive capacity, or redundancy, defines how well a transportation network mobilizes people and resources when a given location is taken out of service. An example of adaptive capacity is the prevalence of viable detours for traveling around a segment that is out of commission due to flooding.

Key Assumptions
There are several key assumptions underlying the vulnerability assessment. For the purposes of this study, the active transportation network is defined as roads, bicycle lanes, shared use paths, sidewalks, and other infrastructure where active transportation modes are permitted during normal operations. Limited access roadways are not included, although road access may change under disaster response conditions and practitioners may want to consider the utility of including all roads in active transportation vulnerability assessments.

This approach considers active transportation infrastructure routes to public transportation, which is critical to connect users to needed services such as employment, health care, and healthy food. Active transportation is often a first/last-mile solution for public transportation trips: according to the American Public Transportation Association (APTA), more than two-thirds of all public transportation riders walk to their stop or station.[61] The APTA also estimates at more than 3.8 million Americans commute to work on public transportation, including many workers in industries adjacent to disaster relief such as hospitals, grocery stores, and warehouse and distribution centers.[62] The analysis considers active transportation facilities within 0.5 miles of public transportation stops, which is typical representing a 10-minute walk at 3 miles per hour. Practitioners may choose to adjust this parameter, for example to 0.75 miles consistent with ADA paratransit requirements.[63]

The assessment calculates distances for critical locations that are near to, a medium distance from, and a far distance from a given segment (see table 6). Research suggests the average walking trip to public transportation is between ¼ and ½ miles, and in some counties, people are willing to walk up to one mile to reach their destinations.[64,65] Studies suggest that the average bicycling trip may be between 2.5 and 3.8 miles. Average e-bike trips are between 6 and 15 miles, with e-bikes replacing journeys up to 15 miles.[66,67]

Table 6. Active transportation distance assumptions.

Active transportation mode	Near distance (miles)	Medium distance (miles)	Far distance (miles)
Walking (pedestrians)	0–0.25	0.25–0.5	0.5–1
Bicycle	0–3	3–5	5–8
Electric bicycle	0–7	7–12	12–15

Data Sources
The vulnerability assessment methodology purposefully focused on publicly available national, regional, and other datasets, to provide practitioners with a starting point to identify and collect data for the assessment.

Partitioners may opt to combine national and local data for their vulnerability assessment. National data sources include the FEMA Geospatial Resource Center, FEMA NRI, Open Street Map, DOT Coupled Model Intercomparison Project Climate Data Processing tool, as well as multiple datasets provided by the U.S. Geological Survey and National Oceanic and Atmospheric Administration.

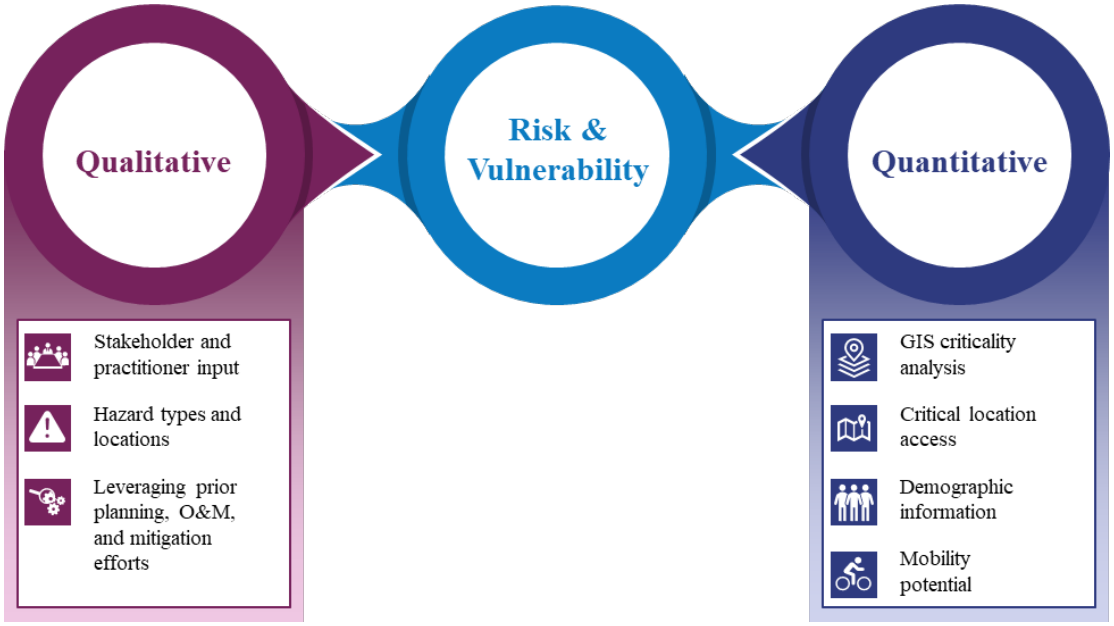
Regional and local datasets may be available to supplement gaps in nationally available information or be combined with other data for the assessment. For example, a community may derive a list of critical locations from nationally available data and bring in local information on the location of Emergency Operation Centers to better understand critical areas. Regional and local datasets may include active transportation or sidewalk inventories and State or local emergency management agency plans.

Assessment Framework

The vulnerability assessment methodology offers a process posing critical questions for communities to answer as they begin the vulnerability assessment. The process helps to identify the most relevant hazards that affect their community, define use cases for active transportation during disaster relief, and begin identifying critical areas and vulnerable infrastructure. Some questions were described previously in the report section defining bicycle use in disasters: which hazards are most relevant to the community and which outcomes are most likely from those hazards? How does the community plan to integrate and use bicycles? Who are the intended bicyclists?

Other questions focus more on the vulnerability assessment process itself: who specifically is performing this vulnerability assessment, and what resources and knowledge do those individuals and organizations have? What related plans, policies, and processes exist in that community or at the regional or State levels? The community should use existing plans and previous analyses to identify relevant hazards and vulnerability, such as State hazard mitigation plans, local risk assessments, or climate action plans.

The DRMS included a review of nationally and locally available public geographic information system data for use in the adapted vulnerability assessment methodology. The DRMS applied an indicator-based desktop review to identify vulnerabilities of active transportation facilities. Stakeholder engagement with specific communities was not part of the proof-of-concept work of the DRMS, which necessarily relied on the indicator-based approach. In vulnerability assessments – including this adapted methodology for active transportation – a best practice is a hybrid combination of both qualitative stakeholder input and quantitative data-driven indicator analyses.



Source: FHWA.

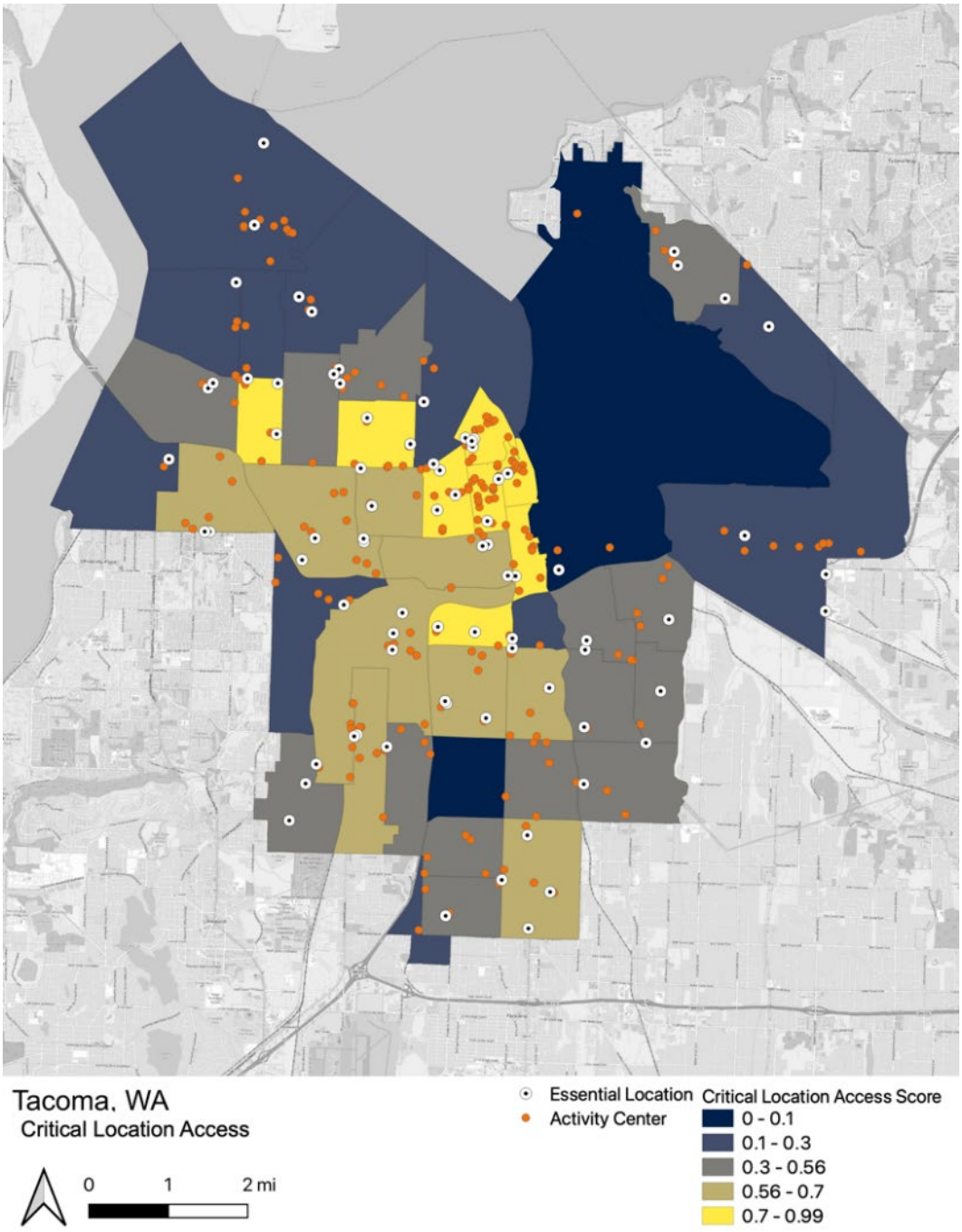
Figure 12. Diagram. Hybrid stakeholder-indicator approach.

The approach also applies the VAST, which builds on the VAAF with a spreadsheet tool that scores an infrastructure's vulnerability as a function of exposure, sensitivity, and adaptive capacity. These factors are combined to create a composite index score for each road segment that will provide a relative understanding of vulnerability given the local conditions and risks within the target area.

Vulnerability Assessment Findings

Tacoma, Washington, and Harris County, Texas, were selected as initial case study locations to demonstrate the active transportation vulnerability assessment. Tacoma is home to approximately 220,000 people, according to the 2021 Census data, and is highlighted in this report. A companion report from the DRMS focuses on vulnerability assessments and includes complete analysis and results for Harris County, which includes the city of Houston.

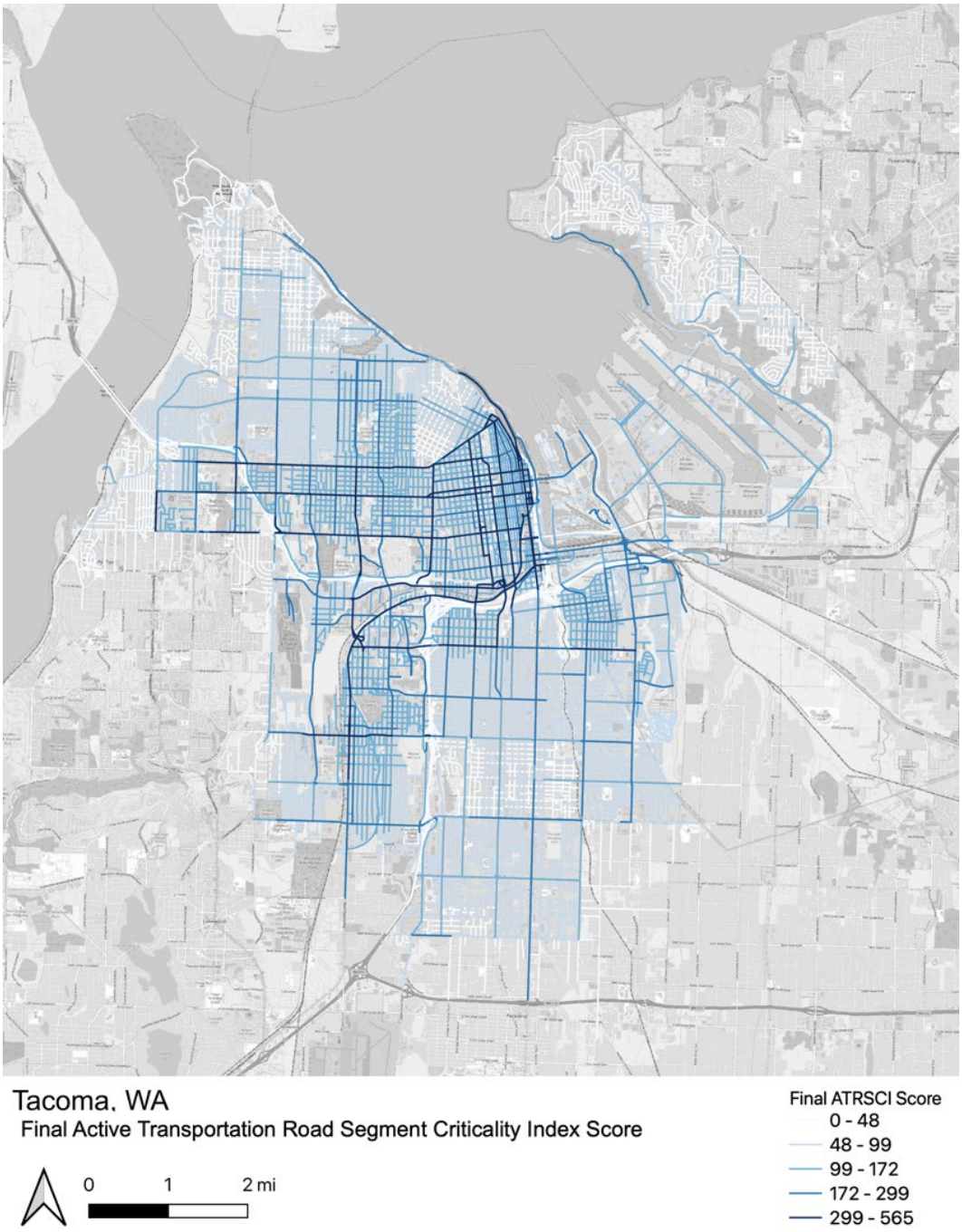
The Tacoma region is susceptible to earthquake and flooding hazards, along with potentially other human-caused and technological hazards. Figure 13 below is an example of a step within criticality determination. Critical Location Access is defined by the density of critical locations within each census tract, differentiated into essential locations (e.g., hospitals) and activity centers.



Source: FHWA.

Figure 13. Map. Tacoma, Washington, critical location access.

Combining Critical Location Access with active transportation network data will provide practitioners with segment level criticality scores, an example of which is shown below in figure 14.



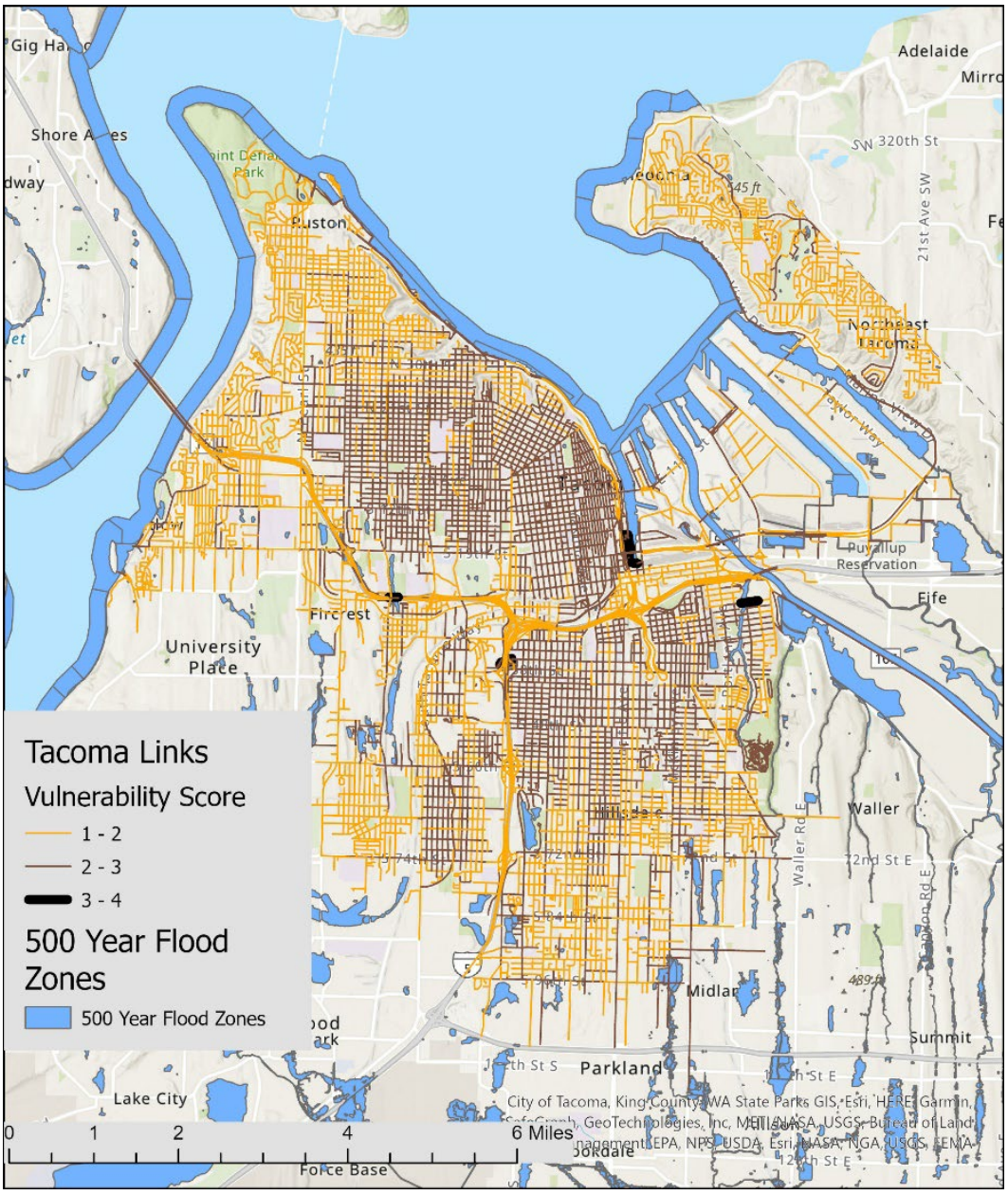
Source: FHWA.

Figure 14. Map. Tacoma, Washington, segment criticality results.

Results of the analysis at this point already have practical applications for emergency management planners. For example, identifying bicycle evacuation routes for consideration in Emergency Management Plans, identifying routes to support the development of bicycle and

pedestrian infrastructure to promote safety during disaster recovery, and developing resource distribution routes for disaster response teams, such as CERTs.

Leveraging VAST, the methodology follows the indicator-based process, evaluating the components of exposure, sensitivity, and adaptive capacity. Results of the assessment can then be summarized on maps such as the example in figure 15.



Source: FHWA.

Figure 15. Map. The vulnerability map of Tacoma, Washington.

Extensions to Use Cases and Locations

Various iterations of the derived vulnerability results can be refined by additional indicator-based and stakeholder approaches through locally available data and institutional knowledge. For example, these vulnerability scores can be linked with other metrics to understand how their networks may be disproportionately affected through demographic data, or by observing which points of interest may be isolated due to links in their proximity being vulnerable to potential disasters. For demographic data, disadvantaged census tracts from the Justice40 dataset can be mapped along with vulnerability on a county level.

This methodology is intentionally designed to be transferable to many other local communities. Using national, publicly available data is a starting point. To further support wide transferability, the DRMS effort has also initiated the concept of a national active transportation criticality resource hub. This resource could be a valuable stepping off point for many local communities evaluating the vulnerability of their active transportation networks and the viability of including bicycles in disaster planning and response.

Chapter 4. Feasibility Evaluation of Including Bicycles in Response Plans

Bicycles offer multiple advantages as both a disaster preparedness and response vehicle due to their efficiency, low cost, wide availability, and independence from gasoline and telecommunication networks.[68,69] Despite limited evidence of bicycle use in previous disaster planning or response, there is untapped potential for bicycle use in the future.

For communities who determine that bicycles can play a viable role in disaster response, bicycle use should be integrated into the formal processes of disaster planning, training, and operations. This is especially true for community volunteer organizations, law enforcement, and first responder bicycle units. It may be more challenging to plan for and integrate informal, ad hoc, and individual bicycle use into disaster response plans.

This chapter summarizes the conditions and tasks for which bicycles can be useful during emergency planning, preparedness, and response efforts. In addition, it discusses types of bicycles and ownership models that should be considered for various types of disasters, along with infrastructure considerations and barriers that may affect feasibility. Necessary resources, community efforts, and other considerations that would support bicycles being formally included in disaster preparedness and response plans also are discussed.

Feasibility Evaluation Methodology

To evaluate the feasibility of bicycle use in disaster relief, an extensive literature review was conducted of city and community-level disaster preparedness and operations plans, news media coverage of disasters, and bicycle training programs. This compiled inventory revealed insights in patterns and trends of bicycle characteristics, community characteristics, and disaster response scenarios.

Building upon the literature review findings, the evaluation explored the feasibility for various bicycle types, ownership options, users, and purposes. The analysis considered the broad range of community geographic and socioeconomic characteristics, including area population and density; percent of minority, senior, and vulnerable population groups; percent of zero-vehicle households; and geography and transportation features that could be important in an emergency response setting. This study also considered the feasibility of using bicycles in a wide range of response scenarios, including:

- Mandatory evacuations of local communities, such as notifying and evacuating residents and essential supplies.
- Search and rescue activities to find individuals in need.
- Transport of supplies or commodities for lifesaving or life-sustaining purposes, such as water, food, first-aid supplies, and power sources and electric supplies. Examples are depicted in figure 16 and figure 17.
- Communication and situational awareness.

Source: Can Topalfakioglu/BisiDestek.

Figure 16. Photograph. Volunteers in Hatay Province, Turkey, February 2023.

Source: Kelley Stangl/Disaster Relief Trials.

Figure 17. Photograph. Example of a cargo bike used in a Disaster Relief Trial.

Feasible Conditions for Bicycle Use

The feasibility of bicycle use for disaster preparedness and response is highly dependent on hazard types, geographic factors, and other conditions and disruptions that may be present during a disaster. The potential for bicycle use is highest when using motor vehicles is not feasible, for example due to disruptions in electricity, fuel, transportation networks (congested or obstructed), or access to the vehicles themselves (for example, if destroyed). In these scenarios, bicycles may offer critical maneuverability and/or independence from power sources. However, even under circumstances of major infrastructure disruptions, the level of feasibility will still be highly dependent on hazard type, climate, and land use.

Hazard Types
Flooding, blizzards, and wildfires, and to a lesser extent tornadoes, hurricanes, and severe storms, are scenarios during which bicycles cannot be significant contributors to disaster response due to the risks associated with bicycling during such weather conditions.[69] Bicycle use may be more productive after the immediate dangers of these hazards have passed.

Other types of disasters such as earthquakes, terrorist attacks (including cyberattacks), and civic unrest may be more conducive to bicycle use for emergency response. Notably, these types of events may have little warning time and can lead to disrupted transportation and communication infrastructure, making the use of bicycles much more critical.

Climate, Environmental, and Situational Factors
General climate, weather, and lighting conditions are major factors in assessing the feasibility of bicycles. Inadequate lighting and severe weather can be particularly limiting for bicycle use in rural areas. Inclement weather conditions may restrict or prohibit bicycle use, or else require specialized equipment (such as snow tires and warm, waterproof clothing).

Practitioners must consider potential conditions putting bicyclists' health and safety at risk when determining bicycle feasibility for disaster preparedness and response. For example, heat waves, downed yet active power lines, or active shooting events may preclude bicycle use due to unsafe environmental or situational conditions.

Geography and Built Environment
The geography, land use, overall built environment, and population density of a community are critical factors affecting bicycle feasibility for disaster preparedness and response. Large urban locations are most feasible due to the combination of a high-density urban environment with a potentially large volunteer force, in comparison with rural communities. Areas with relevant, established organizations and training efforts such as DRTs, CERTs, and bicycle advocacy groups may be more likely to use bicycles in disaster response. Bicycles also might be feasible in small urban and potentially rural locations in cases where large groups of volunteers are not necessary.

Despite the benefits of denser urban environments, the presence of urban sprawl and freeways may limit the use of bicycles, especially when carrying supplies. The types of roadways matter; bicyclists should avoid limited-access and high-speed roadways that do not offer protection from passing motor vehicles, such as Interstates and highways.

Mountainous or hilly terrain also can limit bicycle use, requiring electric bicycles or mountain bicycles, especially to carry supplies. In many cases, such terrain can prohibit the use of large cargo bicycles that are harder to maneuver.

The amount and types of bicycle-specific transportation infrastructure also will influence the feasibility of bicycle use in disaster relief. This includes both on-road amenities such as bicycle lanes and shoulders, and off-road amenities such as sidewalks, shared use paths, and trails that contribute to the diversity and redundancy of the transportation network.[70] In particular, off-road bicycle infrastructure provides distinct routes that can be used for supply distribution,

rescue operations, and evacuation that are separate from the motor vehicle transportation network. When roadways are congested or disrupted (for example, by landslides, downed power lines, or debris), separate bicycle routes may provide alternative paths (if they remain clear or are prioritized for debris clearance).

Feasible Response Tasks for Bicycles

When environmental, geographic, and situational conditions are appropriate, bicycles can be used for a variety of disaster preparedness and response tasks. Bicycles may support evacuations, supply distribution, communications, damage assessments, rescue operations and provision of first aid, debris management, and personal transportation. Despite the multitude of tasks that bicycles could accomplish, it is likely that these tasks will be ad hoc and piecemeal, rather than widespread use in disaster relief.

Pending an imminent disaster or in its immediate aftermath, people may use bicycles to evacuate or distribute supplies (such as food, water, or medicine) to shelters or residents sheltering in place.[71,69] Bicycles offer a resilient, equitable, and efficient method to evacuate residents or carry supplies over short distances. For residents in single- or zero-vehicle households, bicycles are faster and provide larger carrying capacity (especially cargo bicycles) over people walking.

At the same time, bicycles provide several critical advantages over motor vehicles in congested areas or areas with limited transportation network redundancy that can result in isolated neighborhoods. Bicycles offer greater maneuverability around obstacles than motor vehicles, including the ability to go off-road. Conventional bicycles are not dependent on fuel supplies or electricity networks, while electric bicycles may be charged using portable generators or alternative power sources. Bicycles can serve in situations when motor vehicles are damaged or out of fuel. These advantages make bicycles a critical tool for evacuation, supply distribution, and provision of first aid.

There are additional opportunities to use bicycles post-disaster when other systems are down. Bicycles can serve an information sharing tool, such as when communication systems have been disrupted. Bicycles may complete the “last-mile” connection to key locations such as hospitals, shelters, public transportation, and evacuation meeting locations. First responders can use bicycles for damage assessment and rescue operations. Law enforcement officers may patrol neighborhoods and enforce curfews on bicycles, particularly in areas cut off by road. During both the response and recovery phases, people may use bicycles for personal transportation when other modes are not available. For example, residents may commute to their places of employment by bicycle if their vehicle was damaged in the disaster. Table 7 presents various examples of hazards and their impacts, as well as suitable bicycle uses and safety considerations.

Table 7. Hazard types and bicycle suitability examples.

Hazard Examples	Potential Impacts and Conditions	Suitable Bicycle Uses	Bicyclist Safety Considerations
Avalanche or landslide	Impassable routes, stranded communities, power outages	Generally not suitable for bicycles (in comparison to large vehicles, all-terrain vehicles, or snow mobiles)	Bicycles equipped with fat tires for snow or studded tires for ice, mountain bikes, warm weather-appropriate clothing required
Blizzard, ice storms, or extreme winter weather	Extreme cold temperatures, heavy or freezing precipitation, high wind speeds/gusts, low or no visibility, impassable routes, stranded communities, power outages	Generally not suitable for bicycles (in comparison to large vehicles, all-terrain vehicles, or snow mobiles)	Bicycles equipped with fat tires for snow or studded tires for ice, warm weather-appropriate clothing required, exposure to extreme cold may cause hypothermia or frostbite
Chemical, biological, radiological, and nuclear hazards	Unsafe conditions within a set radius or downwind of exposure site	Generally not suitable for bicycles	Unsafe exposure to hazard is a health threat
Cyber attack	Out of service systems such as communications, power, traffic control, security, etc.	Communications/information gathering and delivery, alternative transportation mode	Unsafe interactions with vehicles on roads (and at intersections specifically) if traffic control is inoperative
Earthquake	Debris on roads, damaged roads, or bridges, disrupted power and communications systems, supply lines or communities cut off	Communications/information gathering and delivery, search and rescue, supply pick-up or delivery, security, and law enforcement patrols	Unstable or unsafe roads and adjacent buildings, falling debris, downed powerlines, fires

Hazard Examples	Potential Impacts and Conditions	Suitable Bicycle Uses	Bicyclist Safety Considerations
Extreme temperatures	Prolonged period of high heat and humidity above 90°F (extreme heat); Temperatures and wind chill below 0°F (extreme cold)	Generally not suitable for bicycles	Prolonged outdoor exposure is a health threat
Flooding (coastal, riverine, flash)	Roads covered with standing water, bridges and road sections washed out, downed power lines and power outages, debris on roadways, landslides, delayed flooding, dam/levee failures	Communications/information gathering and delivery, search and rescue, security, and law enforcement patrols	Poor or unstable roadway conditions, flooded or washed out roads, downed live power lines, contaminated floodwater, rising waters may cut off egress
Hurricane	Roads covered with standing water, bridges and road sections washed out, downed power lines and power outages, debris on roadways, supply lines or communities cut off, delayed flooding, dam/levee failures	Communications/information gathering and delivery, search and rescue, supply pick-up or delivery, security, and law enforcement patrols	Poor or unstable roadway conditions, flooded or washed out roads, contaminated floodwater, downed live power lines, rising waters may cut off egress
Wildfire	Roads cut off or blocked by debris and fire, poor air quality due to smoke and ash, susceptible to landslides and flash flooding post-event	Impromptu or ad hoc evacuation (during), search and rescue, security, and law enforcement patrols	Rapidly evolving conditions, routes may become cut off or impassable, more likely in rural areas with less road connectivity, exposure to smoke and ash is a health threat

Bicycle Types

Not every bicycle type will be appropriate for every task. The feasibility of using a specific type of bicycle is dependent on the task they perform, the terrain they traverse, and the conditions under which they operate. The main types are conventional, electric, cargo, and trailer-mounted bicycles.

Conventional bicycles are bicycles with two or more wheels that are powered solely by the rider pedaling (including mountain bicycles). At the individual level, conventional bikes can be used as personal mobility devices for evacuation, transporting supplies, and everyday transportation post-disaster. Conventional bicycles also can serve as messengers, perform damage assessments, and transport people in locations not easily accessible by motor vehicles. In circumstances where transportation networks have been disrupted, the smaller and lighter the bicycle, the more maneuverable it will be. First responders and law enforcement also may use conventional bicycles to rapidly access areas in need and ensure safety during civic unrest situations. Mountain bicycles should be considered in regions with mountainous terrain or in situations where bicycles are traversing off-road.

Electric or electric-assist bicycles are equipped with an electric motor that assists the rider with pedaling and propulsion, powered by a rechargeable battery mounted on the bicycle. Importantly, an electric bicycle differs from a motor vehicle (such as moped or motorcycle) because pedaling is still required for motion. Electric bicycles can improve the efficiency and speed of evacuating people and accessing areas in need, especially in hilly areas. With the additional power provided by electric bicycles, people with limited physical abilities also may travel longer distances. However, there are concerns about the use of electric bicycles due to their dependency on the power grid for charging. Hazards are often accompanied with disruptions to the power grid, which could compromise the feasibility of electric bicycles.

Cargo bicycles are bicycles specifically designed to transport large or heavy loads, such as large quantities of food, water, and medicine. However, cargo bikes are typically more expensive and less prevalent than conventional bikes. One alternative is to mount a trailer onto a conventional bicycle to increase carrying capacity, which would allow more bicycle volunteers to participate. To support the use of cargo and trailer bicycles during disaster relief, communities could maintain a registry of cargo bicycle owners, establish tool lending libraries that provide trailers prior to and during disasters, and provide instructional blueprints for do-it-yourself trailers. Communities also could procure a small fleet of cargo bicycles or trailers, develop pre-event trailer distribution plans, and provide training for volunteers. The electrification of cargo bikes also can support more efficient distribution of supplies, although practitioners must again consider the dependency on the electric grid.

Regardless of the bicycle type, registries of individuals with maintenance skills and the provision of disaster kits for bicycle maintenance (including parts and tools) could contribute towards feasible bicycle use in disaster preparedness and response.

Bicycle Ownership Models

Bicycle use in disasters also will depend on who owns the bicycles, and whether the owners are public agencies, private companies, nonprofit organizations, or individuals. Bicycles used by

law enforcement and first responder agencies are typically owned by those public agencies. When resident volunteers participate in disaster relief, they tend to use their own bicycles. Other alternatives include bicycle rideshare companies or bicycles donated (either temporarily or permanently) by bicycle shops or manufacturers.

For roles involving citizen response, a greater number of privately owned bicycles will likely be available in communities that currently are bicycle friendly, such as having a high number of bicycle commuters and established on- and off-road bicycle infrastructure. Alternatively, a community could integrate bicycles into disaster preparedness and response by establishing partnerships with bicycle ridesharing companies, shops, and manufacturers for both provision and maintenance of bicycles. One potential limitation of bicycle ridesharing programs is dependency on the power grid to unlock bicycles from docking stations.

Proper Training and Integration

Regardless of conditions, tasks, bicycle types, or owners, there is one essential resource required to use bicycles in disaster relief: people. It is critical to ensure that those responding to a disaster (regardless of their role) are properly trained and working in coordination with other disaster relief efforts. While integration of first responders on bicycles is straightforward, the inclusion of volunteer bicyclists in disaster preparedness and response requires careful planning.

Incorporating local resident bicyclists into disaster relief can multiply available human capital while leveraging local knowledge and relationships.[70] However, concerns have been raised by emergency management officials about volunteer bicyclists, including safely and effectively integrating efforts into overall planning and operations. Other concerns included insurance, liability, and potential loss of motivation of trained volunteers when not called upon for a long period.[69]

Volunteer bicyclists could be disruptive to operations when not properly trained and integrated into disaster preparedness and response. Volunteer bicyclists should receive both disaster- and bicycle-related trainings including first aid, safe riding practices, rules of the road, use of communication tools, light search and rescue, and team organization.

In addition, emergency response officials and planners may incorporate specific bicycle volunteer tasks into comprehensive and operational disaster plans, collaborating with volunteer organizations to ensure smooth integration. Programs such as DRTs can be implemented for community volunteer training purposes. Alternatively, a community could use its existing programs and organizations, such as the Red Cross, CERT, or bicycle advisory groups, to deliver disaster relief bicycle trainings. The specifics of engagement, training, and integration into disaster planning will depend on the characteristics, organizational structure and capacity, and goals of a specific community.

Chapter 5. Next Steps and Considerations

Bicycles appear to be an underleveraged resource in disaster response. While ad hoc examples of their value exist, the absence of planning for their use in disaster response is limiting opportunities for improved outcomes for those affected by disasters. Given the limited examples, there remains an uncertain return on investment in efforts to incorporate bicycles in response efforts. Nonetheless, the investment is relatively low, and the evidence found in this DRMS suggests substantial benefits in many circumstances.

The value of bicycles in disaster response is sensitive to many variables, for example, geography, population density, employment density, demographics, levels of vehicle ownership, development patterns, hazard types and relative vulnerability, active transportation infrastructure, pre-existing level of emergency preparedness and planning, and available resources (money, time, staff, skills, knowledge).

Potential Next Steps

The suggestions for improvement arising from the DRMS are organized into three categories: Planning and Preparedness, Vulnerability Assessments, and Related Items.

Planning and Preparedness

Opportunities to Advance Local Community Preparedness

1. Local communities can plan for scenarios in which to use active transportation modes in response plans and emergency preparedness efforts, including defined goals for bicycles and answering the questions of why, how, when, where, by whom, and with what equipment.
    a. The viability and use of bicycles in disaster response is community-driven, will vary widely by location, and depends on the type of disaster and response activity.
    b. Identify what disaster response or related first responder or volunteer organizations already exist in the community, then leverage and build upon their initiatives. Examples include DRT participants, developing or expanding role of CERT, or organizations that already own and maintain bicycle fleets.
    c. Carefully consider and plan for integrating volunteer bicyclists into disaster planning and response. Those with little or no training, or lacking suitable equipment (e.g., a helmet, well-maintained bicycles, lights) may be disruptive, unsafe, or introduce unnecessary risk. Incorporating volunteers should be proactive, intentional, and meaningful.
    d. Build partnerships with agencies, organizations, and groups who are responsible for or adjacent to disaster response and who may benefit from bicycle use. In collaboration efforts, clarify who is leading the planning efforts (e.g., DOT, MPO, local emergency management agency, etc.).
2. Consider opportunities to leverage bicycle shops, bicycle rental shops, and bike rideshare programs for distribution and maintenance hubs. These organizations and businesses have access to bicycle fleets, repair and maintenance services and equipment, and may have access to volunteer lists, activity groups, and are known areas of congregation for bicycle advocates.

Bicycle Training

1. Develop training modules for bicycles in disaster relief for many types of users, including law enforcement, community organizations (e.g., CERTs), and citizen volunteers.

    a. Encourage existing training programs add a section on disaster response planning and tactics.
2. Integrate bicycle safety and operations in any preparedness/planning efforts, including importance of bicycle helmets, traffic and merging, situational awareness, traction and surface conditions, and physical limitations.
    a. Provide clear guidance to volunteers on risks of providing support traveling on active transportation assets that have not been certified/cleared as navigable (under water, roads/sidewalks that have been damaged, etc.).
3. Support the expansion of DRT or related programs to train and prepare for bicycle use in disaster response.

Bicycle Equipment and Use

1. Build a registry of existing publicly, privately, and individually owned cargo bikes and provide training to cargo bike owners as supply volunteers.
    a. Add a cargo bike category to the CERT Spontaneous Untrained Volunteer form.
    b. Provide guidance on weight considerations for cargo bikes and expectations for volunteers.
    c. Consider financial incentives for cargo bike purchases and maintenance for readiness.
2. Acquire and maintain bike trailers for readiness during disaster response and recovery, such as for use by first responder organizations or as a "lending library" to citizen volunteers.

Bicycle Infrastructure

1. Invest in bicycle infrastructure to contribute to the diversity and redundancy of resiliency efforts. In particular, separated bike infrastructure that may provide alternative access when roads are impassable.
2. Designate bicycle evaluation routes, including both on-road (shoulders, bike lanes) and off-road (separated bike lanes, sidewalks, trails, shared use paths, etc.).
    a. Enhance designated bicycle evacuation routes to be more resilient, which has implications for priority maintenance, debris removal, and funding.

Vulnerability Assessments

Execute two or more full pilots of the methodology with local communities. This would include local stakeholder engagement for input into the criticality criteria, network elements, and factor weighting. The vulnerability assessment may also incorporate different VAST indicators of particular relevance to local community stakeholders. The pilot efforts will also serve to extend the proof-of-concept, validate the suitability of publicly available data, and inform refinements to the methodology.

Policy

1. Incorporate active transportation infrastructure into community vulnerability assessments.
    a. Develop a basis for inclusion knowing that they won't be comparable to other transportation facilities from a regional/community mobility perspective.
    b. Provide guidance on which communities and characteristics may be more amendable to active transportation in disaster response. This will leverage a new resource in the form of a nationwide active transportation criticality dataset and map.

c. Address shortcomings and limitations of active transportation response for various hazard types. This acknowledges that the available active transportation is subject to substantial change during disaster response.

2. Further address equity in active transportation vulnerability assessments. Although initiated in the DRMS, there are many more opportunities to leverage. These can be layered into network criticality determinations to align with strategic goals.
   a. Leverage other nationwide data sources related to equity and active transportation infrastructure within a community. For example, consistent with Justice40, the Federal definition of disadvantaged communities offers dozens of unique indicators at the Census tract level. The Climate and Economic Justice Screening Tool, overseen by the Council on Environmental Quality, combines datasets and provides an interactive map to help identify communities experiencing a disproportionate range of burdens.

Programmatic

1. Develop a guidebook or add-on module to VAAF for applying the adapted methodology developed during the DRMS for active transportation. This effort would highlight the key distinctions and contrasting limitations, include best practices for VAST indicators with bicycles or other active transportation. The DRMS provided some illustrative examples for active transportation indicators.
2. Explore how Complete Streets policies, bicycle and pedestrian plans, and other active transportation efforts among local communities could address a resilient active transportation network that can support improved disaster response outcomes.
3. Promote the integration of ongoing active transportation efforts and stakeholders into disaster response planning.
4. Support the development of a national active transportation criticality resource hub. Relying on publicly available data, this resource would be a valuable stepping off point for many local communities evaluating the vulnerability of their active transportation networks and the viability of including bicycles in disaster planning and response.

Data

1. Promote inclusion of active transportation network data into national aggregated sources – identify data needs, attributes, quality, and accuracy of data collection to support vulnerability assessments.
2. Review and explore crowdsourcing and/or documenting information on known areas of concern where active transportation assets are disrupted due to hazards. This should be part of subsequent pilot efforts.

Related Items

1. In locations with private company bicycle rideshares (e.g., Citi Bike in New York City, BlueBikes in Boston), evaluate feasibility and opportunities to collaborate with bikeshares during or after a disaster. This may include public-private collaboration, agreements, assessment of electricity needs for e-bike fleets, and others.
2. Continue to collect case studies for uses of bicycles in disaster plans and response operations. Consider developing a ‘playbook’ that captures these ongoing examples and current best practices.

Open Questions and Research Needs

Aside from the suggested next steps just listed, the DRMS generated many new questions left unanswered. Here is an example subset.

- As modes and mobility technologies are ever-evolving, especially with electrification and micromobility, what are the new possibilities for leveraging these better during disaster response and recovery?
- What are the feasibility implications of various bicycle types and equipment?
  - Use of e-bikes in response when faced with risk of lack of charging availability.
  - Are three-wheel cycles to be added to reserve fleets? For instance, providing mobility for individuals with barriers, not accustomed to bicycles, injured, or otherwise unable to use a bicycle.
  - What is the optimized bicycle equipment for disaster situations? For example, fat tires for snow, tubeless (not tubular) tires for durability and lower pressure needs.
- Is there a net benefit for holding bicycles in reserve for disaster response? Next steps noted above included inventorying community cargo bikes and putting bike trailers in reserve, but not necessarily reserve fleets. Storage would include helmets, spare tires, and maintenance equipment.
- How can communities use resources (bicycles, etc.) that can be transported to impacted communities from other communities or with State or Federal Government support? Do FEMA or State Emergency Management Agencies have a role here?
- How could a vulnerability assessment assess system adaptation during disasters, e.g., a limited-access highway becoming available to bicycles when no longer accessible by motor vehicles?
- How many more people use bicycles for personal transportation after a disaster? In what use cases, e.g., biking to work because their car was lost, or public transportation is out of service? The DRMS revealed that post-disaster, bicycles were used for a wide variety of purposes during sometimes lengthy recovery periods. What are the equity issues with access to bicycles versus other transportation post-disaster?

Conclusion

The DRMS provided initial observations on how local communities can use bicycles in disaster response more proactively and across many more jurisdictions. This study lays initial key foundations for a framework and guidance on bike inclusion in response plans, but it will be local community stakeholders' responsibility to customize to their situation, conditions, hazards, and available resources.

Collaboration is essential to identify vulnerabilities and develop plans on how bicycles can be incorporated in disaster planning and response in a more formal way. Such partnerships can facilitate access to resources such as fleets and volunteer groups. These collaborations should also extend to embrace all relevant entities, including emergency response officials, first responders, bicycle clubs, and advocacy organizations for integrated planning. Communities are encouraged to organize CERTs, which can work with other organizations and programs, e.g., DRTs, to facilitate these efforts. The additional benefit of training events is that they motivate not only community engagement in response planning efforts but also promote bicycle use in addition to preparing residents for future disasters from a personal point of view.

Perhaps most importantly, communities engaging in such activities—and especially those that have recently dealt with disasters—should pursue open communication with other communities to facilitate transfer of knowledge and experience.

Appendix A. Bipartisan Infrastructure Law Section 11505

BIL, Public Law 117-58, November 2021, https://www.congress.gov/bill/117th-congress/house-bill/3684

Also known as the Infrastructure Investment and Jobs Act. Section 11505, Disaster Relief Mobilization Study, repeated here verbatim for reference:

a) DEFINITION OF LOCAL COMMUNITY.—In this section, the term ‘‘local community’’ means—
- (1) a unit of local government;
- (2) a political subdivision of a State or local government;
- (3) a metropolitan planning organization (as defined in section 134(b) of title 23, United States Code);
- (4) a rural planning organization; or
- (5) a Tribal government.

(b) STUDY.—
- (1) IN GENERAL.—The Secretary shall carry out a study to determine the utility of incorporating the use of bicycles into the disaster preparedness and disaster response plans of local communities.
- (2) REQUIREMENTS.—The study carried out under paragraph (1) shall include—
  - (A) a vulnerability assessment of the infrastructure in local communities as of the date of enactment of this act that supports active transportation, including bicycling, walking, and personal mobility devices, with a particular focus on areas in local communities that—
    - (i) have low levels of vehicle ownership; and
    - (ii) lack sufficient active transportation infrastructure routes to public transportation;
  - (B) an evaluation of whether disaster preparedness and disaster response plans should include the use of bicycles by first responders, emergency workers, and community organization representatives—
    - (i) during a mandatory or voluntary evacuation ordered by a Federal, State, Tribal, or local government entity—
      - (I) to notify residents of the need to evacuate;
      - (II) to evacuate individuals and goods; and
      - (III) to reach individuals who are in need of first aid and medical assistance; and
    - (ii) after a disaster or emergency declared by a Federal, State, Tribal, or local government entity—
      - (I) to participate in search and rescue activities;
      - (II) to carry commodities to be used for lifesaving or life-sustaining purposes, including—
        - (aa) water;
        - (bb) food;
        - (cc) first aid and other medical supplies; and

(dd) power sources and electric supplies, such as cell phones, radios, lights, and batteries;

(III) to reach individuals who are in need of the commodities described in subclause (II); and

(IV) to assist with other disaster relief tasks, as appropriate; and

(C) a review of training programs for first responders, emergency workers, and community organization representatives relating to—

(i) competent bicycle skills, including the use of cargo bicycles and electric bicycles, as applicable;

(ii) basic bicycle maintenance;

(iii) compliance with relevant traffic safety laws;

(iv) methods to use bicycles to carry out the activities described in clauses (i) and (ii) of subparagraph (2)(B); and

(v) exercises conducted for the purpose of—

(I) exercising the skills described in clause (i); and

(II) maintaining bicycles and related equipment.

(c) REPORT.—Not later than 2 years after the date of enactment of this Act, the Secretary shall submit to the Committee on Environment and Public Works of the Senate and the Committee on Transportation and Infrastructure of the House of Representatives a report that—

(1) describes the results of the study carried out under subsection (b); and

(2) provides recommendations, if any, relating to—

(A) the methods by which to incorporate bicycles into disaster preparedness and disaster response plans of local communities; and

(B) improvements to training programs described in subsection (b)(2)(C).

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