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Bicycles and Micromobility for Disaster Response and Recovery

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Abstract

Bicycles and other forms of micromobility have been anecdotally used in past disasters to help save lives and improve community recovery. However, research and practice are scarce on this resilient transportation strategy, which limits its usefulness and possible benefits. To fill this gap, our paper investigates the potential role bicycles and micromobility in facilitating (or limiting) disaster response and recovery. Given the lack of exploration on the topic, we convened an online workshop where we conducted brainstorming and focus group discussions with disaster experts from various government agencies, not-for-profit organizations, academia, and policy groups. We present a synthesis of that discussion, along with a review of the existing literature. We conclude there is strong potential for bicycles and micromobility for different disaster phases, hazard types, and groups of people. However, multiple barriers exist related to implementation and safety, suggesting a need for future research and policy in the transportation and emergency management fields and practices.

1. Introduction

Human and electric-powered micromobility (lightweight vehicles used for traveling short distances such as bicycles, e-bikes, e-scooters, golf carts, etc.) have largely been studied as modes for regular, routine travel. However, they hold the potential to aid mobility in natural disaster events. Their feasibility of use depends on the specific classifications of vehicle type, disaster type, and phases of each disaster. Conventional bicycles have a few key advantages over other modes of travel during and after natural disasters. Because they are human-powered, their power source is not constrained by electricity or liquid fuel that are often limited during disasters (FEMA, 2020). In addition, forms of micromobility may have added flexibility, enabling users to navigate around potential obstacles. Micromobility is also growing in prevalence with massive growth in micromobility services (NACTO, 2022), and bike ownership around 50% (YouGov, 2023). Importantly, micromobility may give underserved populations access to transportation, which begins addressing equity challenges in evacuations (Wong, 2020).

Despite this potential, research is sparse on bicycles and other forms of micromobility in disasters. The available evidence is largely anecdotal, although compelling. For example, bicycles were critical for disaster recovery following the 2017 Mexico City Earthquake (de Jong, 2017) and Hurricane Harvey in 2017 (Dovey, 2017) and for vital transportation in several other recent disasters (Babin, 2020). The usefulness of micromobility likely depends on the disaster phase (i.e., mitigation, preparedness, response, recovery), the hazard (e.g., hurricane, wildfire, flood, tsunami, earthquake), and the geographical context. For geography, densely populated environments may better support bicycles for evacuations (Feltner et al., 2020) and recovery (e.g., Hurricane Sandy in 2012) (Kaufman et al., 2012).

To explore the feasibility of micromobility in disasters, we developed and conducted a 2-hour group workshop with leaders in the transportation and emergency fields. In this paper, we summarize the opinions expressed in the workshop and integrate available information from the literature. We also propose a set of research directions to move this stream of research forward.

2. Methods

We conducted a semi-structured, online, 2-hour workshop on November 15th, 2022 to gather thoughts and opinions about this topic. The workshop included disaster experts from a wide variety of government agencies, not-for-profit organizations, academics, and policy activists. Participants were recruited by emailing the authors' networks, and through snowball techniques from those networks. Fifty-eight people were invited and 18 people attended in addition to 5 research team members. Most attendees were from California, USA so the policy relevance is focused on California with some generalizability elsewhere. Prior to the workshop, we conducted a literature review, but found relatively sparse information. Based on the available academic literature, news, and our experiences, we generated seven questions for discussion in the workshop. One week before the workshop, we circulated a short document with exercise information (see individual brainstorm description below) and the seven discussion questions (see Appendix A) (Figure 1).

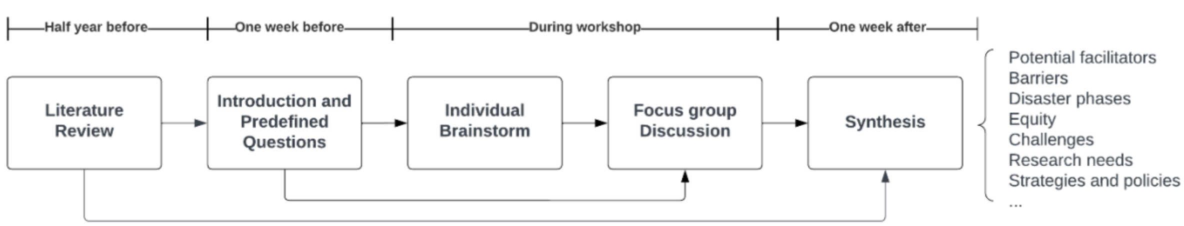

Figure 1. Project and workshop process

We led the workshop as a semi-structured focus group in two phases. In the first phase, we conducted an exercise using an online document to brainstorm thoughts, opinions, and ideas structured by tables of disaster type (wildfire, tsunami, earthquake, hurricane, flooding, other) and disaster phase (response/evacuation, recovery, preparedness, mitigation). Participants were encouraged to type in their thoughts about the use of bicycles and other micromobility for each disaster and phase, including both limitations and potential. Phase 1 lasted approximately 15 minutes.

We conducted the second phase of the workshop as a traditional focus group. We started by using the brainstorm comments as discussion prompts, and then used the predefined questions to spur additional conversation. After the workshop, we sent summary notes to invitees, and several responded with additional comments.

3. Results and Discussions

The primary theme that emerged was a general agreement that bicycles and some forms of micromobility are greatly underutilized resources for disaster conditions. In the following section, we integrate the limited literature with discussions and themes from the workshop.

3.1 *Micromobility potential for short-term disaster response*

The theme of short-term disaster response was heavily discussed during the workshop. For evacuations, many forms of micromobility can be relatively fast and can utilize off-street and informal paths for short distances. In general, micromobility avoids obstructing emergency vehicle access (especially compared to cars), and some forms can move goods in difficult terrain.

Not all micro-modes have equal potential. For evacuation, lighter and faster vehicles hold more promise, a common theme that emerged across disaster types. Another common theme was the use of micromobility for reconnaissance and goods delivery, although the necessary vehicles for each of these tasks could be quite different.

3.1.1 Wildfire evacuations

Bicycles have varying potential in the evacuation phase based on disaster conditions. A 2020 study tested the evacuation efficiency of different transportation modes for a wildfire. Across simulation scenarios, bicycles consistently scored higher evacuation efficiencies than walking, although less than cars (Sun and Turkan, 2020). This evidence is partially supportive of some workshop comments that suggested bicycles are the fastest evacuation mode in some wildfire cases. However, participants also reported the challenge with communicating these benefits to people, especially auto owners who would prefer evacuating by car (Siam et al., 2022).

While motor vehicles are generally faster than bicycles, congestion may elevate bicycles as an efficient evacuation alternative (as mentioned in Litman (2006)). Recent wildfire evacuations in California have experienced heavy congestion and significant debris and impediments on roadways (Chester and Li, 2020; Wong et al., 2020), especially during the 2018 Camp Fire and the 2018 Woolsey Fire. Participants suggested that bicycles could enable evacuees to flee faster and remove the risk of getting stuck in traffic. They also offer more flexibility in cases of limited roadway evacuation routes. Specific to wildfires, one of the participants had first-hard experience evacuating a fire by bicycle. Participants also suggested that bicycles could be used to travel very quickly down hills. Despite this positive discussion, participants also indicated significant safety challenges including exposure to the fire.

3.1.2 Tsunami evacuations

As with wildfires, tsunami evacuation holds similar potential for bicycles. A 2012 study conducted in Japan analyzed the distribution of transportation modes in Natori City during the 2011 Great East Japan Earthquake. According to the study, 65% of people ended up using private or shared motor vehicles, while only 2% used bicycles, which resulted in heavy traffic congestion and vehicles getting caught in the tsunami. Evacuees trying to escape by motor vehicles may be unaware that traffic jams on evacuation routes could cause vehicles to be overtaken by the tsunami (Lindell et al., 2015). Concurrently, evacuating by bicycle could offer shorter evacuation time. A 2022 simulation study on short-notice tsunami evacuation in Waikiki, Hawaii simulated horizontal evacuations. It found that bicycle evacuees consistently scoring the lowest fatality percentage — no more than 0.19% — while the fatalities of pedestrian and automobile ranged from 5.6% to 39.4% (Kim et al., 2022).

Although the limited evidence indicates a potential for bicycles in tsunami evacuations, the workshop did not spend much time considering this specific context. Participants mentioned that bicycles could be pushed up small hills, but this could hinder evacuation speeds. Moreover, walking has become a preferred method to evacuate in tsunami events in the U.S. due to its flexibility (Chen et al., 2022). In cases of considerable congestion, micromobility was still viewed as the fastest way to evacuate by our participants, even though the public may view the opposite according to evacuation survey studies (Chen et al., 2021, 2020).

3.1.3 Flooding evacuation

For flood disasters, bicycles show potential in the evacuation phase, depending on flood severity. Beyond providing transportation, bicycles during a flood disaster can be used as a support during walking, a rack for luggage, or an improvised stretcher (Wang et al., 2021). As participants noted, bicycles can be ridden in a few feet of water or pushed through water. Research has found that bicycling is faster than walking in shallow water depths (Van Den Bulk, 2021). Participants also discussed how non-electric micromobility would be functional even after getting wet. This increases their reliability, especially compared to vehicles that can become flooded and damaged by water.

3.2 *Micromobility potential for short-term recovery*

For short-term recovery, three key ideas emerged from the workshop. First, bicycles, trikes, and emerging micro vehicles could be used to transport relief supplies and conduct first-and-last-mile deliveries. One participant commented on how the Federal Emergency Management Agency (FEMA) could use micromobility to move supplies from a landing zone to areas of need. Second, micromobility could be used for reconnaissance during early recovery. Participants described how small, light-weight vehicles could move around debris and obstacles, unlike larger motorized vehicles. Third, bicycles have the potential to act as mobile ambulances, distribute emergency first-aid, or even move victims if cargo capacity is provided. For example, one participant noted:

"State and Fed level is about large loads, but last mile delivery is needed. In earthquakes where shelter in place is common…reliance on long distances are not the problem. Landing zones are pre-identified, then a bike team could receive goods and distribute them."

The use of cargo bicycles or bicycles with trailers to deliver medical and recovery supplies was a key theme from the workshop and has been employed in practice (Shepard, 2013). The participants were particularly interested in leveraging the growth of cargo bicycles (normally used for urban goods deliveries) for emergencies. They noted that cargo bikes are relatively cheap and scattered throughout cities for flexible deployment. One participant explained that bicycles had been used to deliver relief supplies during the recovery of Hurricane Sandy. Local community disaster relief groups created bicycle-focused hubs to collect and distribute food, water, and relief supplies. The groups also set up bicycle-powered charging stations and mobile bicycle repair in neighborhoods.

Related to these short-term recovery potentials are two motivating factors. First, the widespread availability of bicycles could make everyone a potential resource for recovery, especially with the growth of larger capacity micro vehicles (i.e., cargo bicycles, bike trailers, and mini human-powered cargo vans). Second, spontaneous volunteers take on the majority of the rescue operation during disasters (Daddoust et al., 2021). As participants explained, the availability of bicycles could have life-saving potential during search and rescue.

One participant also noted the ability of bicycle trailers to turn any bicycle into a cargo bicycle with relative ease. The lack of a census on the number of available bicycles, cargo bicycles, and bicycle trailers makes the potential fleet of spontaneous volunteers on bikes unknown, which can be a future research question using computer simulation. Additionally, the group agreed that additional fabrication and testing of trailers specific to disaster recovery work would be necessary.

3.3 Barriers to micromobility in disasters

Despite their warm response to micromobility, participants were quick to describe multiple barriers. First and most problematic, bicycles and micromobility may not be effective in a number of disaster contexts. These include hurricane force winds, long-distance evacuations (e.g., for hurricanes), deep flooding, intense fires, and disaster response that focuses on shelter-in-place. Closer shelters, such as resilience hubs (Ciriaco and Wong, 2022), could improve the usability of micromobility in these situations. Additionally, for flooding evacuation, the risk of falling into the water is much higher on a bicycle, which could increase the risk of hypothermia and fatigue (Van Den Bulk, 2021). Second, micromobility is more limited in carrying capacity and speed compared to trucks and vans in many cases. However, many participants reported the dispersed nature of goods distribution needed from core hubs may be well suited for short micromobility trips, not larger vehicle trips, and that FEMA has historically focused on bringing goods and supplies to central locations without effective distribution beyond the central storage.

Another discussion in the workshop focused on the potential of using shared micromobility[1] vehicles during disaster response. However, two concerns arose. First, vehicles that rely on batteries (e-scooters, e-bicycles[2]) may not be as beneficial as conventional bicycles and tricycles that are solely human powered. Extending this concern is the growing trend of electrifying shared micromobility fleets (NACTO, 2022), indicating an uncertain future for conventional shared bicycles. Second, shared micromobility fleets (run by companies or agencies) will need to have disaster plans and coordination in place for unlocking vehicles in a disaster. Multiple people mentioned that if micromobility is not in a plan, it will not be considered.

Cultural and perceptive barriers are also likely to impact the use of bicycles and micromobility in disasters. First, bicycling in North America is and remains uncommon over the past two decades (Buehler et al., 2020), although ownership is more common. With habitual automobility, a significant challenge exists in encouraging micromobility (when safe to do so) in a disaster. Equally problematic, extensive automobile usage can lead to heavy congestion, leading to dangerous delays and risks from different hazard types (Chen et al., 2022; Siam et al., 2022). Participants agreed that breaking down cultural habits of automobile use and the desire to save belongings should be a priority, but no clear strategies emerged. Normalizing bicycling for regular daily travel through infrastructure, programs, and policies (which has been attempted in transportation planning and engineering for decades (Pucher et al., (2010)) may help people consider a bicycle in a disaster. Another strategy discussed by participants was the use of disaster relief bicycle trials to showcase the potential for bicycles to move goods ("Disaster Relief Trials," 2023). These awareness spreading trials have been run for more than 10 years in the Pacific Northwest and were noted by a participant that they are planned for demonstration in Japan:

"More things need to consider, Government regulation, liability… We really need to get bikes into disaster plans. Otherwise, it will never get funded…"

3.4 *Equity considerations*

The workshop discussion on equity focused on two themes: access to bicycles and the ability to use them for evacuation. One participant claimed bicycles are not as readily available in low-income neighborhoods. This would suggest that the potential for using bicycles in disasters is lower for underserved populations. For example, one participant noted:

[1] Bike and scooter share

[2] One participant noted that when e-bicycle batteries are depleted, they have much more limited potential (especially up hills, through rough terrain) when used by human power alone.

“Lower income people have less access compared to higher income, even though they read bike, they don’t have good quality mountain bikes…”

Participants suggested bike buying incentives and local outreach to improve availability and usage. Discussion also included a national level procurement strategy of bicycles, bicycle trailers, and other micromobility that could be distributed to people during disasters. In terms of varying abilities to use bicycles, participants noted that very young children, older adults, and individuals with disabilities could have challenges using bicycles and other micro vehicles. Alternative bike options (e.g., smaller bikes, step-through bikes, handcycles, tandem bikes, and adult-sized trailers) could help alleviate this challenge.

Table 1. Key takeaways from workshop

Disaster Type Discussed	Response	Recovery
Wildfire	Significant risks from fire, wind, and smoke, coupled with somewhat longer evacuation distances, **leading to lower feasibility**	Unhealthy air and remaining spot fires posing a danger to users when accessing resources and destinations, leading to **moderate feasibility**
Tsunami	Sufficient time to evacuate (if notification is provided) and generally shorter distances to travel, leading to **higher feasibility**	Flexible and cheap for resource movements, especially if infrastructure is not operational, leading to **higher feasibility**
Earthquake	Minimal time to evacuate due to minimal notification times though some opportunities for rapid response of resources, leading to **moderate feasibility**	Easy to navigate roads that are impassable for automobiles and trucks, leading to **higher feasibility**
Flooding	Shorter evacuation distances would enable usage, especially in escaping to higher ground, leading to **higher feasibility**	Still usable for a variety of roles following a flood as non-electric bikes can get wet and still function, leading to **higher feasibility**
Hurricane	Longer distances, high-risk winds, and deadly storm surge inhibit widespread usage beyond early evacuations, leading to **lower feasibility**	Replacement mode for suspended transit or destroyed vehicles for travel and resource gathering, especially in urban environments, leading to **higher feasibility**

4. Research Directions and Conclusions

This research uncovered two important themes: 1) micromobility has potential uses and key barriers in disasters and 2) little research has been conducted in this field. For example, bicycle trailers have been used to transport cargo during disasters (e.g., 2017 Mexico City Earthquake (Pskowski, 2017), but these examples have not been evaluated, tested, or pre-planned. Moreover, many of the ideas that emerged in the workshop were not found in the academic literature or had limited evidence.

Several open research tracks emerged from this research. First, case studies of micromobility in disasters need to be identified, analyzed, validated and shared. Second, research is needed to track the availability of micromobility assets through a census of privately-owned, public, and commercial vehicles. Third, focusing on infrastructure, research should be conducted on street design to ensure that bicycles and bicycles equipped with trailers can be accommodated in a disaster.[3] Fourth, research is needed on policy development, including mechanisms to plan for micromobility responses and recovery processes in local/state emergency response plans. Finally, broader research that spans methods (e.g., simulations, behavior analysis, spatial-temporal analysis), hazards, cultures, disaster phases, and geographic contexts is necessary.

While evidence-based research will be required for informed policy-making, early policy strategies emerged from the workshop and the literature review. Local, regional, and state agencies could:

1. Address resilience gaps in roadway design by partnering with leading transportation organizations (e.g., American Association of State Highway and Transportation Officials, National Association of City Transportation Officials, and the Transportation Research Board);
2. Incorporate Complete Street design and Vision Zero strategies related to bicycling and micromobility that complement resilience goals;
3. Integrate micromobility into existing emergency response, evacuation, and recovery plans; and
4. Develop improved partnerships with local community organizations, schools, and neighborhood groups to conduct drills or bicycling trials.

Flexible, robust, and inclusive transportation resources are vital in disasters. Micromobility offers a small but important opportunity to enhance transportation and community resilience. With significant gaps in the literature and practice, this paper suggests a call to action for more widespread and empirically-based approaches for researching and guiding the future of micromobility in disasters.

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[3] A number of research directions are possible including improved street design guides, flexible infrastructure, and integration of other resilience measures (e.g., incorporating stormwater management).

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Appendix A Workshop Discussion Questions

(1) In terms of response or short-term recovery, what micro-modes in what disaster contexts have potential? Consider:
   (a) Disaster type (wildfire, tsunami, earthquake, hurricane, flooding, etc.)
   (b) Actions (evacuation, rescue, food and water delivery, medicine and aid delivery, fuel distribution, etc.)
   (c) Vehicle availability (owned vs. shared fleets)

(2) What are the barriers that need to be overcome for bikes and micromobility to be considered in disaster planning? Consider barriers in these domains:
   (a) Policy
   (b) Government regulation
   (c) Liability
   (d) Ideological (culture and perceptions)

(3) Are there equity considerations for bikes and micromobility in emergency management? Positive or negative.

(4) Can bikes or micromobility create other types of risk during different phases of emergency management? Does using it expose people to secondary hazards?

(5) Research has found that micromobility can increase social ties and the feeling of community belonging. Does this have an indirect impact on emergency management?

(6) What are the research needs for this topic?

(7) If any, what are the strategies and policy actions to take now?