Review of Resilience Hubs and Associated Transportation Needs

Working Paper (June 2022)

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Highlights

- We reviewed concepts and examples of resilience hubs in North America.
- Resilience hubs can build social cohesion and preparedness for multiple hazards.
- Resilience hubs can operate during disasters and everyday conditions.
- Transportation is currently not integrated in hub placement, design, or planning.
- No metrics or empirical evidence currently guide the implementation of hubs.

Abstract

Rapid urban growth and the devastating impacts of disasters and emergencies have challenged infrastructure and social systems in many communities. Recently, the nascent concept of "resilience hubs" has emerged to help communities overcome these challenges and improve well-being during disasters and everyday conditions. This paper provides an early conceptual understanding of resilience hubs, in particular their associated transportation needs, through a comprehensive literature review. The review identified characteristics and needs for planning hubs by focusing on their current definitions and related concepts (e.g., evacuation shelters, mobility hubs). In all, the review identified that resilience hubs could be a successful tool for communities in addressing the important needs of residents, evacuees, and survivors. However, we found that the placement of hubs is not methodical or optimized, and hubs have yet to be evaluated using metrics or key performance indicators. Critically, most literature and examples of resilience hubs fail to consider: 1) how people and relief supplies will travel to/from hubs, or 2) potential transportation services that could be offered by hubs. We recommend that programs that identify, design, and create resilience hubs should emphasize mechanisms for providing reliable and equitable transportation for people and relief supplies.

Key Words: resilience hubs, community resilience, evacuations, accessibility, disaster preparedness

1. Introduction

Due to unprecedented changes in the global climate, many communities around the world are facing more frequent extreme weather events (e.g. floods, wildfires, heatwaves, and severe storms (Temmer et al., 2019). Some cities are also susceptible to non-climate-related events that require an emergency response, such as earthquakes, tsunamis, tornadoes, volcanos, chemical/toxic accidents, and terrorist attacks. However, the impacts of climate change and non-climate-related disasters differ depending on the local context. For example, Wong-Parodi and Berlin Rubin (2022) found that the way people understand extreme events can be explained by their own experiences and perceptions about climate change. Moreover, the United Nations Human Settlements Programme (UN-Habitat, 2020) determined that people living in informal settlements and those already marginalized are the most vulnerable to disasters. This challenge is growing as the number of urban residents living in these areas has increased due to rapid urbanization. The United Nations (UN) reported in 2018 that more than half of the world's population lives in urban areas, and by 2050, it is estimated to increase to 68% (United Nations, 2019). Altogether, the impacts of extreme weather events and other hazards in many communities will become more severe and costly over the coming decades.

Consequently, many cities have been altering their planning, designs, and infrastructure to improve preparedness, response, and recovery in emergencies. The concept of resilience – largely considered the capacity for people and cities to survive and adapt to hazards – has recently emerged and has guided policymakers, professional practitioners, and researchers in recent decades (see Meerow et al. (2015), Meerow and Stults (2016), Keenan (2018) for more discussion). To help communities bounce to their former state or even forward following disasters, new ideas and tools need to ensure that residents both survive *and* thrive. However, this type of resilience-building is intricate, interdisciplinary, and multi-layered because cities are complex and dynamic systems. Many studies have shown several crucial and complex requirements for governments that continue to arise in most disasters including evacuating people, operating shelters, and distributing resources (Twigg et al., 2011; Kohn et al., 2012; Wong et al., 2018; Lindell et al., 2019; Chen et al., 2020; Kotani et al., 2020; Wong, 2020; Kim et al., 2021; Nagarajan and Shaw, 2021; Wong et al., 2021). These needs in disasters are often facilitated by transportation infrastructure and response strategies (e.g., evacuation plans, transit-based evacuations, contraflow, relief distribution).

In this context of resilience in urban areas, one unique and emerging idea is to develop "resilience hubs" where people and resources could be gathered to increase safety and quality of life. However, this idea remains largely undefined as a concept, lacking in characteristics or functions, and under-researched in terms of its connection to transportation and land use. This gap in research and practice motivated several research questions:

1) What are resilience hubs, especially when considering other types of hubs or centres for disasters and everyday conditions?
2) How are resilience hubs currently being used and what are their functions?
3) What are the transportation needs of resilience hubs?

To answer these research questions, this paper provides early conceptual understanding and transportation needs of resilience hubs through a comprehensive literature review that can guide future pilots, programs, and designs. Through keyword searching of "resilience hubs" and related hubs (e.g., mobility hubs, evacuation shelters, community hubs) via Elsevier's Scopus, Web of Science, and Google Scholar, we identified the current state of the literature on the topic. The search yielded a number of academic research and papers, which were supplemented by additional keyword searching for frameworks, reports, information available on trusted

government websites, and white papers related to resilience hubs. In addition, we reviewed the literature from a transportation perspective to determine what mobility options, operations, and planning might be necessary to facilitate the movement of people and goods to/from the resilience hubs.

The paper is organized as follows. First, we present the concept of resilience hubs, and include information about the placement of resilience hubs, function modes, and characteristics. Next, we provide background on preceding hubs to contextualize resilience hubs. We end the paper with a discussion about emerging needs, policy recommendations, and a conclusion.

2. Resilience hubs

This section describes elements of resilience hubs. In the first subsection, the concept of resilience hubs is presented, followed by their elements.

2.1 Concept

Resilience hubs were first described by Baja (2016) and more formally defined by Baja (2018) in the report "*Resilience Hubs: Shifting Power to Communities and Increasing Community Capacity*" prepared for Urban Sustainability Directors Network (USDN). Most of the studies about resilience hubs found in the literature review mention the concept of resilience hubs defined by Baja (2018) or present a very similar definition (Sandoval, 2019; Vibrant Hawaii, 2019; Breton-Carbonneau and Griffiths, 2020; City of Houston, 2020; de Roode and Martinac, 2020; Lou, 2020; Resilience Hub Community Committee, 2020; Baltimore Office of Sustainability, 2021; Kirwan et al., 2021; Mardis et al., 2021). Generally, resilience hubs are community-serving physical spaces – a building and related infrastructure – created to support residents, coordinate communication and services, and provide resources distribution before, during, or after a disaster (Baja, 2018). Aiming for various physical, ecological, and social goals, resilience hubs provide opportunities for communities by improving quality of life, increasing equity and mobility, reducing greenhouse gas emissions (GHGs), and providing more efficient emergency management and climate change mitigation (Baja, 2018). Kirwan et al. (2021) and Sandoval (2019) describe how resilience hubs can be a promising mechanism to build neighborhood resilience to overcome these challenges. In addition, Baja (2022) highlighted that focusing resilience on community necessities and self-determination can enhance social alliance and partnerships by supplying superior access to resources such as food, water, childcare, and Internet. Indeed, research by Aldrich and Meyer (2015) on social capital and community resilience uncovered that policy responses for preparedness should go beyond physical infrastructures to include social infrastructures (e.g., social capital and social cohesion). For instance, social cohesion promotes a sense of inclusion for all members of a community, valuing the diversity of its residents, promoting equal access to opportunity for people of all backgrounds, and developing strong and positive relationships among its residents (de Roode and Martinac, 2020).

Regarding a similar concept, Kirwan et al. (2021) described that hubs should be designed and organized to make them attractive places, even in a non-emergency scenario. Throughout the year, resilience hubs can act as places for community gathering, social support services, information and communication coordination, education of community members in climate preparedness best practices, and other purposes to improve quality of life (Sandoval, 2019; Mardis et al., 2021). During a disaster, hubs can shift in purpose by functioning as emergency shelters and even cooling and warming centers for extreme heat or cold events (Sandoval, 2019). Although hubs tend to be implemented in urban areas and dense suburban regions,

especially in areas with a high concentration of vulnerable people, they can also operate in rural areas. Baja (2022) mentions that resilience hubs that are not walkable serve mostly during emergency events (i.e., classified as response and recovery hubs). Regardless of geography, the effectiveness of resilience hubs depends on multiple community-oriented factors including: community co-development, individual knowledge of resources and services at a hub, trust in the hub and its staff, and the ability of resources to meet community needs during extreme events (Baja, 2018).

2.1.1 Placement of Resilience Hubs

Placement of resilience hubs is critical to ensuring sufficient community trust and easy access (Baja, 2019). The initial criterium for hubs is the identification of existing well-known and well-utilized places, such as community centers, recreation facilities, libraries, universities, and/or government buildings that can be converted into a resilience hub. Key literature has also stressed that the hubs' locations should enable service to communities every day *and* specifically during disasters (Sandoval, 2019; Kirwan et al., 2021; Mardis et al., 2021).

Research by Mazereeuw and Yarina (2017) in Japan and other Pacific countries demonstrated that combining disaster features with everyday amenities at community buildings improved recovery. Moreover, mixed-use places were more likely to be known by the public and used in disasters. Idziorek (2020) determined that public spaces should be sufficiently adapted to serve the community not only during disasters but also daily. Based on Idziorek (2020) and Mazereeuw and Yarina (2017) findings, it is notable that selecting well-known and well-used places for resilience hubs can increase the likelihood that people will use them in times of disaster. While literature generally suggests places that have been pre-established, Baja (2022) noted that constructing new buildings may be an option for communities, especially if residents contribute to the site selection and design process.

In addition to urban-focused resilience hubs, Mardis et al. (2021) described that in rural areas, public libraries are ideal resilience hubs, because they provide a variety of informational, educational, social, and personal services. Bishop and Veil (2013) and McShane and Coffey (2022) highlighted that public libraries can serve as critical agents in all phases of disaster response and in post-crisis recovery, helping the communities with their critical needs. For example, after a disaster, people can receive physical aid and/or shelter at public libraries, while librarians can assist the communities by connecting them with emergency information, partner organizations that provide relief during disasters (e.g. Red Cross, food banks), and government services (Bishop and Veil, 2013; Mardis et al., 2021; McShane and Coffey, 2022).

Regarding transportation and mobility, only Baja (2019) cited two transportation characteristics that should be considered for resilience hubs' site selection. The first focuses on placing a hub that can be easily accessed by -many residents on foot. Second, Baja (2019) recommended that hubs should be near evacuation routes or major roads. Beyond this planning guidance, the review did not uncover any other transportation considerations for hub placement.

2.1.2 Other Considerations for Resilience Hubs

In addition to placement, Sandoval (2019) described that the types and dimensions of disasters must play a central role in resilience hub design and operations. Hubs can also significantly differ based on the climate region, geographic characteristics, and cultural context (Sandoval, 2019). For example, a tsunami-prone community in Southeast Asia may require significantly different needs than a wildfire prone community in North America. Breton-Carbonneau and Griffiths (2020) uncovered that some communities prioritized language support services as a

crucial resource for resilience hubs in non-English speaking communities. Resilience hubs can also focus on internal resources. The Federal Emergency Management Agency (FEMA) in the U.S. determined that resilient communities should identify and leverage their own resources to recover from a disaster, rather than depend on external resources (FEMA, 2011).

Beyond these considerations, it is difficult to define a resilience hub in a more concrete sense, because hubs can be uniquely designed to serve community needs. When locating and planning for resilience hubs, literature has found that planners should consider the needs of neighborhoods and designed based on surrounding land use (Baja, 2019; Georgetown Climate Center, 2022). Moreover, planning for resilience hubs can be seen as a dynamic and evolving process that changes depending on preparedness, response, and recovery activities specific to the community and its hazards (Small Planet Networks, 2022).

2.1.3 Resilience Hub Function Modes

Within the conceptual framing of resilience hubs, functionality was a common theme. Resilience hubs can operate in three modes (Baja, 2019; Resilience Hub Community Committee, 2020): (1) everyday or normal mode (non-disruption); (2) response or disruption mode (both short- and long-term disruption); and (3) recovery mode (post-disruption).
For most days, resilience hubs function in normal mode, acting as reliable community places that offer a variety of community-determined services and programming to overcome daily stressor such as access to health, food, water, internet, childcare, activities for seniors (Baja, 2019; Northampton Massachusetts, 2020). In the event of a disaster, hubs transition from normal mode to response mode, reacting and responding to the disruption and improving operations to better meet the immediate needs of the community. After a disruption, they switch into recovery mode, serving as relief distribution centers.

During the response mode, which is activated when an emergency event occurs (i.e., either short- or long-term disruptions), resilience hubs can help reunite families, supply resources, share information, and provide medical support (Mazereeuw and Yarina, 2017). They can also be a gathering place where community members can offer/provide support and prioritize services to those most vulnerable (Baja, 2019). For longer-term disruption, hubs can also offer overnight accommodations for evacuees (similar to evacuation shelters). The demand for these accommodations will be dependent on disaster, demographic, and shelter characteristics (Das, 2018; Asgary and Azimi, 2019).

Similar factors will determine the duration that a hub will function in recovery mode. During this phase, the hub can remain a point for gathering that shares information and offers resources (Vancouver, 2022b). In addition, they can provide services that assist residents and local business owners to apply for government recovery assistance (Bishop and Veil, 2013).

2.2 Resilience Hub Elements

Moving from the concept and functionality of resilience hubs, Baja (2022) and Breton-Carbonneau and Griffiths (2020) describe five foundational elements of hubs:

(1) Services and Programming: offer services and programs that support community preparedness and response, and improve their quality of life
(2) Communications: provide accessible, reliable, and easily understood information in all three operation modes to increase community cohesion and connectivity.
(3) Building and Landscape: identify existing well-known and well-utilized buildings and strengthen them with the utilization of surrounding landscape (e.g., water capture and reused, air filtration, urban gardening) that can safeguard their function in disasters.

(4) Power Systems: provide uninterrupted power during a disaster using systems (e.g., solar panels, backup generators, batteries) that are aligned with resilience hubs goals.
(5) Operations: have a capable team and processes to guarantee that the hub operates daily and can be a safe and accessible site for all residents of the service area.

Table 1 shows services, programs and resources identified by the literature as possible options to be provided by a resilience hub. In addition, the table presents examples of known resilience hubs in North America that are currently functioning or are being designed.

Table 1 - Services, programs and resources provided by current resilience hubs

Services, Programs, and Resources	Description	Examples in Current Hubs	Sources
Community emergency response training	Critical communication and information that help educate community members about hazards	Vancouver, BC; Tallahassee, FL; Hawaii; Texas**, San Francisco, CA; Ontario, CA; AZ; CA; CO; GA; IA; IL; KS; KY; ME; MA; MI; MN; NC; NJ; NM; NY; OH; OR; RI; VA; VT; WI; Detroit, MI	(Neighborhood Empowerment Network, 2018; Vibrant Hawaii, 2020, 2021; CREW, 2021; Higgins, 2021; Sands, 2021; City of Tallahassee, 2022; Oak Park Neighbourhood Centre, 2022; Vancouver, 2022a)
Heating and/or cooling	Heating in extreme cold days and/or cooling in heat waves	Vancouver, BC; Detroit, MI; San Francisco, CA	(Neighborhood Empowerment Network, 2018; Sands, 2021; Vancouver, 2022a)
Wi-Fi access	Free Wi-Fi access to the Internet and key communications	Vancouver, BC; Tallahassee, FL; Hawaii; Detroit, MI	(Vibrant Hawaii, 2020, 2021; Sands, 2021; City of Tallahassee, 2022; Vancouver, 2022a)
Food and water distribution	Food and water resources, which are offered daily or only during a disaster	Hawaii; Texas*; Detroit, MI; Baltimore, MD; Millvale, PA; San Francisco, CA; Ann Arbor, MI; Ontario, CA	(Baltimore Office of Sustainability, 2021; Higgins, 2021; Hussain and Zetkulic, 2021; Neighborhood Empowerment Network, 2018; Oak Park Neighbourhood Centre, 2022; Sands, 2021; Stanton, 2020; Vibrant Hawaii, 2020, 2021)
Meal services	Daily meal distribution or selective meals during a disaster	Hawaii; Texas*	(Vibrant Hawaii, 2020, 2021; Higgins, 2021)
Health services/basic medical supplies	Medical services and care, dentists, and pharmacies	Tallahassee, FL; Detroit, MI	(Sands, 2021; City of Tallahassee, 2022)
Mental health experts	Mental health and wellbeing support programs	Tallahassee, FL	(City of Tallahassee, 2022)
Showers and restrooms	Access to showers and restrooms	Vancouver, BC; TX*	(Higgins, 2021; Vancouver, 2022a)
Solar power	Power delivered to the hub via solar panels for improved resilience in disasters	Baltimore, MD*; Detroit, MI* Millvale, PA; Ann Arbor, MI	(Baltimore Office of Sustainability, 2021; Higgins, 2021; Hussain and Zetkulic, 2021; Sands, 2021; Stanton, 2020)
Information desk	Information about: (1) activities and services available daily and during disaster and (2) government programs aimed to assist the recovery of those affected by the disaster	Vancouver, BC; Hawaii; TX*; San Francisco, CA; Ontario, CA; AZ; CA; CO; GA; IA; IL; KS; KY; ME; MA; MI; MN; NC; NJ; NM; NY; OH; OR; RI; VA; VT; WI	(Neighborhood Empowerment Network, 2018; Vibrant Hawaii, 2020, 2021; CREW, 2021; Higgins, 2021; Oak Park Neighbourhood Centre, 2022; Vancouver, 2022a)
Support for reuniting families	Reuniting place for families during a disaster	Vancouver, BC;	(Vancouver, 2022a)
Computers	Access to computers for communication and information	Vancouver, BC; Hawaii; Detroit, MI	(Vibrant Hawaii, 2020, 2021; Sands, 2021; Vancouver, 2022a)
Fitness facilities	Gym, swimming pool, sports courts	Vancouver, BC; Tallahassee, FL; Detroit, MI	(Sands, 2021; City of Tallahassee, 2022; Vancouver, 2022a)
Gathering places for group activities	Fitness center, squares, group activities, games, family	Vancouver, BC; Tallahassee, FL; Hawaii; TX*; Detroit,	(City of Tallahassee, 2022; Higgins, 2021; Hussain and Zetkulic, 2021; Neighborhood

	breakfast/lunch/dinner, restaurants, and arenas	MI; Millvale, PA; San Francisco, CA; Ontario, CA	Empowerment Network, 2018; Oak Park Neighbourhood Centre, 2022; Sands, 2021; Vancouver, 2022a; Vibrant Hawaii, 2020, 2021)
Community arts and culture	Music and arts classes and expositions	Vancouver, BC; Tallahassee, FL; Hawaii; Detroit, MI; Ontario, CA	(Vibrant Hawaii, 2020, 2021; Sands, 2021; City of Tallahassee, 2022; Oak Park Neighbourhood Centre, 2022; Vancouver, 2022a)
Coordinated childcare	Childcare services and pre-school	Vancouver, BC; Hawaii; Ontario, CA	(Vibrant Hawaii, 2020, 2021; Sands, 2021; Oak Park Neighbourhood Centre, 2022; Vancouver, 2022a)
Older adult services and program	Yoga, meditation, sports, fitness facilities, group meetings, language classes, and technology classes for older adults	Vancouver, BC; Tallahassee, FL; San Francisco, CA; Ontario, CA	(Neighborhood Empowerment Network, 2018; City of Tallahassee, 2022; Oak Park Neighbourhood Centre, 2022; Vancouver, 2022a)
Youth and child programs	Children's before and/or after school programs	Vancouver, BC; Tallahassee, FL; Detroit, MI; Ontario, CA	(Sands, 2021; City of Tallahassee, 2022; Oak Park Neighbourhood Centre, 2022; Vancouver, 2022a)
Job training programs	Opportunities to learn additional skills for jobs	Hawaii	(Vibrant Hawaii, 2020, 2021)
Trainings on how to manage finances	Workshops about financial management	Hawaii	(Vibrant Hawaii, 2020, 2021)
Growth of fresh and local food	Place to grow and/or access fresh and local food	Vancouver, BC; Hawaii	(Vibrant Hawaii, 2020, 2021; Vancouver, 2022a)
Horticulture courses	Courses related to growing food and plants	Vancouver, BC; Hawaii; Ontario, CA	(Vibrant Hawaii, 2020, 2021; Oak Park Neighbourhood Centre, 2022; Vancouver, 2022a)
Cooking classes	Cooking classes for different age groups	Vancouver, BC	(Vancouver, 2022a)
*Geography has hubs only in the design phase. **Geography has hubs that are already opened *and* hubs that are in the design phase.			

From Table 1, the two most common services offered by the current hubs, especially in those located in libraries (e.g., (CREW, 2021)), are community emergency response training and an information desk. These services provide emergency preparedness opportunities and communicate key resources to residents. We noticed that among the resources provided, some (but not all) of the hubs provided food and water (Baltimore Office of Sustainability, 2021; Higgins, 2021; Hussain and Zetkulic, 2021; Neighborhood Empowerment Network, 2018; Oak Park Neighbourhood Centre, 2022; Sands, 2021; Stanton, 2020; Vibrant Hawaii, 2020, 2021). For example, 14 resilience hubs in Hawaii focused only on food distribution (Vibrant Hawaii, 2020) while none of the disaster support hubs in Vancouver reported this service (Vancouver, 2022a). This may be due to the different functionalities that were designed for these hubs and the needs of the community where they are located. This gap indicates that some hubs may not be able to meet basic needs during a disaster.

Other important resources during emergency situations are physical and mental health services and basic medical supplies. However, our review of current resilience hub examples did not find these to be common services, and they were observed only in Bailey Park NDC Community Resilience Hub in Detroit, MI (Sands, 2021) and in Smith-Williams Center in Tallahassee, FL (City of Tallahassee, 2022). We also did not find substantial evidence of overnight accommodation needs such as beds/cots and showers. While these resources could be allocated quickly to hubs, a lack of information indicates that overnight shelter space or hygienic facilities are not a priority for current resilience hub design.

We also observed that a decent number of resilience hubs offered everyday services and programming, especially ones located in community centers (e.g., City of Tallahassee (2022), Oak Park Neighbourhood Centre (2022), and Vancouver (2022a)). Examples of services included children's before and/or after school programs, coordinated childcare, older adult services and programming, and community arts and culture. Some resilience hubs also offered general facilities for group meetings and gatherings (City of Tallahassee, 2022; Higgins, 2021; Hussain and Zetkulic, 2021; Neighborhood Empowerment Network, 2018; Oak Park Neighbourhood Centre, 2022; Sands, 2021; Vancouver, 2022a; Vibrant Hawaii, 2020, 2021). A select few hubs offered unique programs such as job training, cooking classes, financial courses, and horticulture courses (mostly in Hawaii and Vancouver). The safe learning spaces and connectivity for distance learning for children offered by resilience hubs in Hawaii, enabled a return to school and work.

Table 1 is also informative in what resilience hubs do not provide. For example, language support services are a crucial resource for resilience hubs in communities that do not speak the official language of the country (Breton-Carbonneau and Griffiths, 2020). However, translation services were not found in the example hubs, which could produce inequitable outcomes for residents that do not speak the official local language.
Critically, our review of resilience hub examples did not find any information related to transportation services. A wide range of transportation services (e.g., public transit, shared mobility, paratransit service, point-to-point transportation to/from key destinations) could be included as services or characteristics of a resilience hub. The lack of transportation examples indicates that while there may be co-location of hubs and transportation, mobility services are not considered critical components of hubs in their current form. This also suggests that transportation – including connections to/from hubs – is not being considered as part of their functionality or usability.

3. Other Preceding Hubs

Before the concept of resilience hubs emerged, cities had adopted other types of hubs to achieve various societal goals. This section presents types of hubs that are most correlated with the current concept of resilience hub. These concepts can help inform resilience hubs or be adapted to serve as a resilience hub.

3.1 Mobility Hubs

Mobility hubs, which can also be defined as an intermodal terminal, are places where passengers can efficiently transfer between a variety of routes and modes of transportation (Anderson et al., 2017; Aono, 2019; CoMoUK, 2019; Henry and Marsh, 2008; Pitsiava-Latinopoulou and Iordanopoulos, 2012; Schemel et al., 2020). They are an opportunity to integrate various sustainable transport modes and increase a city's connectivity (Aono, 2019; Schemel et al., 2020). The type of mobility hub may vary from a single carshare space or connection between two modes to a concentration of multiple transportation modes (Anderson et al., 2017; Henry and Marsh, 2008; Schemel et al., 2020). This co-location of modes has several key benefits. First, mobility hubs can lower the cost and time of travel by enabling passengers to use a mode that suits each trip or trip segment (Henry and Marsh, 2008; Aono, 2019). Second, mobility hubs can reduce congestion by encouraging modes beyond auto travel (Pitsiava-Latinopoulou and Iordanopoulos, 2012; Portland Bureau of Transportation, 2018). Third, GHGs can be reduced since there are more active and clean transportation modes options (CoMoUK, 2019). Finally, mobility hubs can increase transportation accessibility and equity (Henry and Marsh, 2008; Anderson et al., 2017; CoMoUK, 2019).

Regarding implementation, the construction of mobility hubs requires cooperation between local governments and transportation operators (National Commission on Intermodal Transportation, 1994; Aono, 2019). Some factors are considered essential to ensure the success of hubs (Aono, 2019; Bell, 2019; Pitsiava-Latinopoulou and Iordanopoulos, 2012). For example, mobility hubs need adequate accessibility for all users; reliable service from operators; safety and security across modes; a sense of place that values the community; and sufficient parking (if necessary). Moreover, mobility hubs can encompass some amenities which support passengers and transform the hubs from a place of transition to a destination (Schemel et al., 2020). Examples of these multi-use hubs can be found in across Europe and North America (Arnold et al., 2022; Henry and Marsh, 2008; SmartHubs, 2022). Basic services that are offered by these multi-use mobility hubs include (but are not limited to): information desks, washrooms, storage lockers, mail/courier service, Wi-Fi, electric vehicle charging station, food courts, stores, gyms, and banks. Hubs can also function as transit-oriented developments (TODs) with residences and commercial space. Other co-located destinations can include supermarkets, stadiums, and medical facilities.

As mobility hubs continue to evolve, their design and functions can help inform the development of resilience hubs, in particular ensuring that people are able to travel to/from the hubs in a safe and efficient way in both disaster and everyday conditions. The placement of multiple modes can allow evacuees the ability to reach resources more quickly, and a centralized hub can also serve as a staging area or a primary drop point for key relief supplies. Consequently, a mobility-centered approach for resilience hubs can help produce co-benefits that can help meet community needs.

3.2 Community Hubs

Community hubs, whose precursors were early guilds, religious organizations, civic organizations, sporting clubs, and community houses (e.g., Chicago's Hull House) (McShane and Coffey, 2022), are sometimes called community centers, neighborhood associations/centers, and community leagues. They are multi-purpose institutions that provide a central access for a variety of services (e.g., education, social, and health) in conjunction with more common cultural, recreational, and other activities to increase community well-being (McShane and Coffey, 2022; Palumbo, 2016; Pitre, 2015). A key element of community hubs is their ability to create social infrastructure and networks, which can address vulnerabilities and better meet localized needs (McShane and Coffey, 2022).

Due to the increase in frequency and magnitude of climate change extreme events, community hubs have made some recent adaptations to prepare for the impact of disasters. Services such as emergency refuges, emergency accommodation, information centers, community kitchens, and response and recovery services have been adopted by some community hubs (McShane and Coffey, 2022), which aligns with resilience hub objectives. The recent COVID-19 pandemic has also altered the role of community hubs. For example, the community hubs initiative in Calgary - Canada reported a change in the services that their communities needed during the pandemic (United Way, 2021). Moreover, they noted that certain types of community hub support, such as basic needs (e.g. food hampers, meals, and hygiene items) faced an increase of over seven times (United Way, 2021). This switch from recreation and culture to key emergency response during the COVID-19 pandemic indicate a new shift in thinking that can extend to recovery and climate preparedness for resilience hubs.

Community hubs have been located in a variety of spaces and buildings including schools (Pitre, 2015; Grand Erie District School Board, 2022), libraries (Pitre, 2015; Ontario, 2017;

First 5 El Dorado, 2022), older adult and senior care centers (Pitre, 2015; Primary Care Network, 2018), community health centers (Pitre, 2015; Ontario, 2017), and government buildings (Pitre, 2015). According to McShane and Coffey (2022), the placement of hubs are crucial as poor planning may result in inappropriate placement of community hubs regarding accessibility and vulnerability. Hubs should be generally designed to meet the needs of the community through local services and resources. Guidance can be taken from McGee et al. (2021) on services for Indigenous communities in wildfire evacuations. Assistance during disasters for First Nations, Métis, and Inuit should offer foods that are part of the specific Indigenous culture, consider the financial needs of the population, and provide healthcare related to the health challenges that are predominant in those Indigenous communities (McGee et al., 2021).

Community hubs have a range of benefits. For example, they have been shown to: improve learning opportunities and well-being for students, enhance response to local needs, improve access to services, increase connectivity and social cohesion in the community, and allow neighbors to build a cooperative vision for the future of their community (Pitre, 2015; United Way, 2021). The community hubs initiative in Calgary cited that 40% of their hub activities involved collaborating with community patterns, 84% of residents felt a sense of community connectedness, and 92% of the volunteers felt connected to their hubs (United Way, 2021). These characteristics of community hubs – particularly related to social cohesion – can serve as key guidance for resilience hubs.

3.3 Evacuation Shelters

In the event of a disaster or emergency, evacuations that move people away from a hazard are common. To ensure that evacuees have a safe destination, evacuation shelters are often opened in nearby communities to the disaster (Sheu and Pan, 2014; Bayram and Yaman, 2018). Evacuation shelters can be categorized in different types according to the period of time that people need to stay in the shelter from the commencement of the disaster event. Quarantelli (1995), Johnson (2007), Chou et al. (2013), and Félix et al. (2013) grouped them into four types of shelters: (1) emergency sheltering (i.e., short period of time during the emergency peak); (2) temporary sheltering (i.e., a few days/weeks after the peak); (3) temporary housing (i.e., long term but not a final residence); and (4) permanent housing (i.e., existing, renovated, or rebuilt housing).

Depending on the type of disaster, the evacuation shelter can be planned for an open place (e.g., parks, playgrounds, squares, parking lots) or a safe indoor place (e.g., schools, churches, temples, libraries, recreation centers, government buildings). Indoor locations are most common, as structures can protect people from multiple hazard risks. In evacuations, people seek shelter in a variety of places, most commonly a family member's or friend's residence or a hotel/motel (Lindell et al., 2019; Wong, 2020). In addition, some evacuees shelter at a second residence, inside their portable vehicle, or even with a peer-to-peer service (e.g., Airbnb), as described by Wong et al. (2020a). Evacuation shelters are predominantly public shelters where anyone may seek safety. These tend to be lower used options, with literature indicating that 2% to 11% of evacuees go to public shelters (Cheng et al., 2011; Lindell, 2018; Smith and McCarty, 2009; Whitehead, 2003; Wilmot and Gudishala, 2013; Wong et al., 2018; Wong, 2020; Wu et al., 2012; Yin et al., 2014). These low numbers are partially a result of poor public perception of evacuation shelters. Wong et al. (2018) that found that 31% of the people that did not evacuate from Hurricane Irma in 2018 cited their decision as partially not wanting to go to a public shelter. Evacuation shelters are often perceived as uncomfortable, unsafe, and lacking in necessary resources (Asgary and Azimi, 2019; McGee et al., 2021).

Despite this perception, evacuation shelters are critical in disasters, especially for those without reliable transportation or nearby social connections. Research has found that low-income residents often choose to not evacuate because of the cost and are more likely to use local and free public shelters if they do evacuate (Karaye et al., 2020; Perkins, 1996; Wong, 2020). Consequently, public shelters should provide free resources (e.g., food, water, personal hygiene facilities, healthcare) (Lindell et al., 2019), especially given that their users have less financial capability to buy essential items for survival. Many of these resources parallel functions for resilience hubs, which can help bolster outcomes in disasters by increasing the probability that people will use public shelters. To improve evacuation compliance and nudge non-evacuee behavior, Wong et al. (2021) also recommended that jurisdictions should improve shelter conditions to make them safer and more comfortable for a variety of populations. Other pre-planned mechanisms can increase transportation reliability for carless individuals in evacuations. For example, city-assisted evacuation plans have established pickup locations and sufficient public transit to/from registration centers and shelters (City of New Orleans, 2022).

When considering transportation for evacuation shelters (and resilience hubs), a few other key transportation options exist to improve equity. Chen et al. (2020) cited that carpooling with neighbors was an effective solution that could reduce traffic congestion during the evacuation and assist older adults, people with mobility challenges, and low-income households. Moreover, Wong et al. (2020a) and Borowski and Stathopoulos (2020) identified that recent advancements of ridesourcing companies, such as Uber and Lyft, have made them a possible transportation alternative for evacuations, especially in small-scale evacuations. Wong et al. (2020a) describes the evolution of this shared resource opportunity provided by companies or residents (e.g., peer-to-peer). For example, Uber and Lyft have both developed initiatives that offer ride credits to/from evacuation shelters (Hawkins, 2018; Lyft, 2018).

Evacuation shelters are also undergoing a change in concept. According to Kotani et al. (2020) some shelters have poor accessibility and do not have sufficient capacity to assist everyone who needs to evacuate. Kotani et al. (2020) studied an alternative option of evacuation shelter in a case study in Kobe, Japan and demonstrated that shopping streets with disaster-proof buildings have the capability to be an evacuation shelter, offer food distribution, and improve accessibility. Moreover, Wong et al. (2020a) pointed out that peer-to-peer homesharing, such as through Airbnb's Open Homes Program, could improve the quality and quantity of shelters in an evacuation. Upwards of 29% of respondents for a future wildfire evacuation (Wong et al., 2020b) and 19% of respondents for a future hurricane evacuations (Wong et al., 2020a) were found to be extremely likely to share their home for free with another evacuee.

3.4 Other Disaster Response Centers

Mazereeuw and Yarina (2017) expanded the concept of evacuation shelters more broadly to consist of decentralized emergency preparedness hubs in open areas (*Bosaikoen* in Japanese), which are planned in collaboration with local partners and in consultation with the surrounding community. Functioning daily as parks/playgrounds, *and* during/after an emergency as a reuniting location where people could access supplies and information. With the increase in the effects of climate change, studies have shown that excessive heat exposure can increase risk of morbidity and mortality (Semenza et al., 1996; Curriero, 2002; Ostro et al., 2009; Vaneckova et al, 2010; Tobias et al., 2012; Berko et al., 2014; Berisha et al., 2017). To help prevent illness and death caused by extreme weather conditions, some governments and communities sponsor warming and cooling centers for at risk communities. during heat waves and extreme cold days (Toronto, 2017a, 2017b; California, 2021; City of Oshawa, 2021; Chicago, 2022; City of

Edmonton, 2022; City of London, 2022; City of New York, 2022; City of Niagara Falls, 2022; City of St. Louis, 2022; Connecticut State, 2022; Vancouver, 2022c) These facilities are equipped with air-conditioning and/or heating, and they have also been used to provide water and medical support (Fraser Health Authority, 2021; New York State, 2022). Examples of places that have served as cooling/warming centers are libraries, community centers, schools, shopping malls, supermarkets, facilities that have indoor or outdoor swimming pools, and recreation centers. It is noteworthy that some of these locations are also identified as resilience hubs (Maricopa County, 2022; New York State, 2022).

Recent wildfires in California have prompted the utilization of other centers, such as clean air centers to escape the effects of smoke. For instance, recently American Rescue Plan Act funding has been used to develop clean air and cooling center by retrofitting schools' heating, ventilation, and cooling systems in the San Francisco Bay Area (Giarmoleo, 2021). These upgrades improve students' environment, while simultaneously creating a center that can be used by the community during smoke events.

Utilities in California have also implemented public safety power shutoff (PSPS) events by de-energizing parts of the electric grid to reduce wildfire risk. As part of these events, utilities have also activated over 500 fixed and mobile community resource centers since 2017 (Wong et al., 2022) that provide PSPS information, electronic charging, accessible restrooms and hand-washing stations, basic medical equipment charging, and key resources (e.g., water, snacks, Wi-Fi, personal protective equipment) (Pacific Gas and Electric Company, 2022; Southern California Edison, 2022; Wong et al., 2022). Additionally, the indoor centers offer air-conditioning or heating, seating, and ice (Pacific Gas and Electric Company, 2022).

4. Discussion and Policy Recommendations

Our literature review uncovered key concepts related to resilience hubs and associated hubs (e.g., mobility community hubs, evacuation shelters). We determined that resilience hubs remain an understudied idea, though elements of mobility hubs (e.g., transportation), community hubs (e.g., social infrastructure and cohesion), and evacuation shelters (e.g., disaster response) could inform the design and planning of resilience hubs. In this section, we discuss our observations from the review and recommendations for improved implementation.

4.1 Resilience Hubs as a Concept

One important observation from our literature review was that the functionality and characteristics of resilience hubs are generally well-known. The implementation of resilience hubs across multiple states and provinces in North America indicate a general understanding by jurisdictions on how hubs can be designed. The growing number of examples also suggests that jurisdictions are generally willing to plan and implement resilience hubs. However, it remains unclear if the jurisdictions are matching the needs of the community with the functionality of the hubs. While some jurisdictions do point to community input (City of Tallahassee, 2022; Higgins, 2021; Hussain and Zetkulic, 2021; Neighborhood Empowerment Network, 2018; Sands, 2021; Vibrant Hawaii, 2020, 2021), we recommend that governments conduct a needs assessment of their community to determine what is most practical and critical for both everyday and disaster conditions.

Second, we found some literature on the placement of resilience hubs within communities. Literature suggests that these facilities must be allocated in well-known and well-utilized existing places (Baja, 2019; Sandoval, 2019; Kirwan et al., 2021; Mardis et al., 2021). However, the characteristics of these places are vague, site selection appears unrelated to city evacuation

plan, and placement does not address how resources will reach the hub during a disaster. To overcome this gap, we recommended that resilience hubs should be planned ahead of time (similar to evacuation shelters) to ensure that they are included in an evacuation plan. The plan should include clear information on the location of the hubs, how resources will reach the hub, what entities will provide resources, and if pre-positioning will occur.

Though placement has been discussed, only a few empirically-based studies on ideal locations for resilience hubs have been conducted, specifically based on important criteria. For instance, de Roode and Martinac (2020) and Kirwan et al. (2021) used hazard and sociodemographic variables to identify high-risk locations for resilience hubs in Maui, Hawaii and Ypsilanti, Michigan, respectively. However, research has not yet optimized the location of hubs based on a variety of factors nor have studies considered transportation networks, accessibility, or mobility equity. We recommend that surveys about travel behavior and networks analyses be conducted to better choose locations that can benefit community residents, especially those most vulnerable.

Fourth, despite the planning guidance for resilience hubs, literature and current examples have not offered metrics or key performance indicators that are guiding their implementation. For example, most resilience hubs have not provided information on the number of people served nor who they serve. To prevent them from having the same problems perceived in public shelters, such as discomfort, insecurity and lack of necessary resources (Wong et al., 2018; Asgary and Azimi, 2019; McGee et al., 2021), we recommend that governments conduct an assessment of the number of people expected to use the hubs daily and during disasters to determine the amount of resources (e.g., meals, food, water, hygiene products, and beds) and the number of staff needed. Moreover, any evaluation of resilience hubs should provide a broad range of metrics related to equity, accessibility, and quality-of-life to indicate their effectiveness in meeting community needs.

Finally, we did not find evidence that community hubs or mobility hubs have been informing the development of resilience hubs. Indeed, the everyday benefits of community hubs and the accessibility benefits of mobility hubs could help guide planning such that resources and benefits are co-located. While Baja (2018) discusses the importance of multiple functionalities of resilience hubs, the specific attributes of other hub examples, especially related to transportation, remain largely absent from the literature and current resilience hubs in North America. We recommend that these hub concepts begin to be framed together (in conjunction with evacuation shelters) in future discussions and policies for resilience hubs.

4.2 Transportation and Accessibility

One significant takeaway from the literature review was that transportation is rarely considered in the planning, design, or implementation of resilience hubs. While Baja (2019) briefly described two transportation elements for resilience hubs (i.e., centrally located for walkability and placement near evacuation routes or major roads), the discussion is limited to the phase of identifying and evaluating sites. Moreover, we were unable to find considerations of transportation or residents' mobility needs in current examples of resilience hubs. This presents a clear gap in research and practice, as people and resources must safely and effectively travel to/from resilience hubs. Within the planning phase of resilience hubs, we recommend that jurisdictions identify the transportation needs, responses, strategies, and resources to facilitate evacuations and relief distribution. For example, resilience hubs can promote accessible transportation by prioritizing public transit (Bish, 2011), integrating shared mobility for point-

to-point transportation (Wong et al., 2020a), and enabling cycling and walking as viable and safe modes of transportation (Chen et al., 2020).

Second, we found that planning and implementation of resilience hubs have not yet considered everyday transportation needs, particularly of vulnerable populations. Without addressing accessibility to/from hubs, jurisdictions may struggle matching services with populations who need resources the most (e.g., carless, transit-dependent, low-income), creating inequities related to climate and disaster preparedness. Reorienting a community's transportation systems to link resilience hubs with residents can serve to improve access under normal and disaster conditions. For example, public transit routes that incorporate resilience hubs can help people reach services *and* reduce the need for special bus operations in a disaster. Consequently, we recommend that resilience hubs lean on the design and implementation of mobility hubs (Schemel et al., 2020; Arnold et al., 2022), especially more recent versions that have also incorporated shared mobility services (e.g., bikeshare, scootershare) that have been shown to improve equitable outcomes (Anderson et al., 2017; Shaheen et al., 2017). Cues should also be taken for ensuring accessible and reliable transportation in disasters for individuals with disabilities (Renne et al., 2011).

Third, we observed that there is no information about how people should evacuate to resilience hubs and minimal integration of hubs into evacuation or emergency response planning. While some examples indicate usage during a disaster (e.g., Vancouver), elements are focused primarily on a gathering place in a disaster. This obscures the multiple steps that must be taken to evacuate people effectively and efficiently from a disaster (see Lindell et al. 2019 for extensive background on evacuations). It should also be noted that residents in an evacuation require information on where they can go, such as a list of evacuation shelters with pet policies, hygiene facilities, and capacities. In addition, residents need to know how they should get to a resilience hub (i.e., transportation mode) and if those options are available. This gap requires a broader focus on identifying residents' transportation needs and expected travel behavior via surveys and other data collection tools. Using these data, we recommend that jurisdictions conduct simple transportation network analyses or more complex evacuation simulations to determine transportation responses and routes needed for the hub. Moreover, if the city already has an evacuation plan, we recommend stronger integration of resilience hubs and public-facing information such that hubs are well-defined, easy to understand, and well-known by residents.

Finally, the literature stressed that the resilience hubs' locations should provide sufficient services for disaster conditions (Sandoval, 2019; Kirwan et al., 2021; Mardis et al., 2021). However, key questions related to relief distribution (e.g., how supplies are distributed to hubs, if hubs can accept the supplies, who distributes the supplies) remain unanswered. Moreover, in some cases, the resilience hub may be unable to provide all necessary resources to residents, especially in the event of a major disaster. However, literature did not provide strategies to transport evacuees to other destinations, such as healthcare facilities, shopping facilities (e.g., for basic supplies), or government facilities (e.g., to receive recovery information and assistance). We recommend that resilience hubs consider relief distribution, supply chain procedures, post-evacuation transportation (including reentry to affected areas) in their design and implementation. Current memorandum of understanding (MOUs) in emergency response plans, guidance from mobility hubs, and available reentry plans could be especially useful.

5. Conclusions

This literature review uncovered early conceptual understanding of resilience hubs, a mechanism to co-locate resources for everyday and disaster conditions. Most existing literature

focuses on explaining the resilience hub's concept, characteristics, and functionalities. We found multiple examples across North America where communities were receiving key services from resilience hubs for everyday and disaster conditions. Recent guidance for resilience hub design, placement, and services has focused on building a familiar, well-resourced, and flexible place for the local community. These spaces can help communities increase their resilience to climate change, while also building social cohesion and preparedness for a variety of emergencies.

Despite these encouraging results, the design, planning, and implementation of resilience hubs have several key limitations related to transportation. First, guidance for integrating hubs within a community's transportation system has been minimal. Second, resilience hubs have not considered the everyday needs of vulnerable populations. Third, hubs have not been sufficiently integrated into evacuation or emergency response plans. Finally, transportation services and relief distribution during the recovery phase for evacuees have not been adequately described or planned.

Resilience hubs have a promising future. Opportunities exist to offer essential services for the community's needs during most times of the year, prepare the community for climate change and emergencies, and assist the community during major disasters (e.g., wildfires, hurricanes, earthquakes) or chronic disruptions (e.g., extreme heat, extreme cold, power outages, smoke events). The unique co-benefits of resilience hubs are within reach, but hubs remain a new and largely untested concept. Moreover, additional research is needed to consider the transportation components of hubs, including travel needs of people to/from hubs during evacuations, the distribution of relief supplies, and the accessibility of hubs for vulnerable populations.

6. Acknowledgments

This study was made possible through funding received by the Alberta Ecotrust Foundation and the City of Edmonton via funding from the Cities IPCC Legacy Grant Program. We would like to thank Karim El-Basyouny from the University of Alberta for his ongoing support of this work.

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