Equitable Transportation and Resilience Hubs: Analysis of Underserved Population Needs, Usage, and Travel Behaviour

Working Paper (Updated September 2024)

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ABSTRACT

Extreme weather events and other hazardous events often require a range of strategies to safely shelter people, distribute resources, and facilitate recovery efforts. This is particularly important for underserved populations who usually lack reliable access to shelters, transportation, and social networks. To begin addressing these problems and increase community capacity, resilience hubs – physical locations that support residents in emergencies and everyday conditions – have emerged as a possible equitable strategy. Despite potential benefits for underserved populations, research and practice have yet to consider how different demographic groups will use or travel to/from these hubs.

To address these gaps, we conducted an empirical study using survey data from 950 respondents in the Edmonton Metropolitan Region in Alberta, Canada. Of these respondents, we focused on several underserved groups. Simple descriptive statistics and statistical tests were used to understand the groups' needs and observe similarities and divergences between groups. We also calculated spatial statistics to identify how mode choices varied with people's preferred resilience hub locations. We found a high willingness of groups to use resilience hubs, especially in emergency conditions. However, differences between groups and with non-underserved groups were relatively moderate and varied. Respondents prioritized a range of basic services along with transportation-related elements, including accessibility for individuals with disabilities, transit connections, parking, and walkability. Moreover, our mode choice analysis highlighted the necessity of incorporating multimodal transportation options to resilience hubs. We offer several policy recommendations that inform the equitable development of resilience hubs, including the importance of local placement and needs-based services.

Keywords: Resilience Hubs, Community Resilience, Equity, Disaster Preparedness

HIGHLIGHTS

- We assessed resilience hub usage and mode by underserved groups from survey data.
- Underserved individuals would be likely to use a resilience hub during emergencies.
- Statistical differences between underserved and non-underserved groups varied.
- Certain intersecting groups exhibited unique and significant hub usage patterns.
- Varied mode choice to/from hubs indicates more multi-modal design and planning.

1) INTRODUCTION

Extreme weather events caused by climate change and non-climate-related emergencies continue to severely impact many cities around the world (USCGRP, 2017). In response, researchers, practitioners, and policymakers are calling for a new paradigm in planning, one that involves mitigation, adaptability, and recovery from change, also known as resilience planning. Recently, jurisdictions have been building or considering resilience hubs as a strategy to better protect, serve, and help residents during emergencies. For instance, Baltimore and Minneapolis have established resilience hubs through partnerships between local governments and non-governmental organizations (Rogerson & Narayan, 2020). These hubs aim to fill service and resource gaps in specific communities, enhancing their resilience throughout the year and during emergencies such as hurricanes, floods, pandemics, and heat waves (Rogerson & Narayan, 2020). Other cities that have either implemented or are considering resilience hubs include Hawaii, Vancouver, Miami, Austin, Cambridge and San Francisco (Austin, 2024; City of Vancouver, 2019; Rogerson & Narayan, 2020; USDN, 2022a, 2022b; Vancouver, 2022; Vibrant Hawaii, 2020).

Resilience hubs are defined as community-serving physical spaces that support residents, coordinate communication and services, and provide resource distribution before, during, or after disasters (Baja, 2016). They are designed to serve community members year-round through different programs (e.g., recreation, education, social, etc.). In addition to day-to-day benefits, they can also provide temporary or short-term emergency shelter during an evacuation and operate as a center for distributing relief resources. For example, the Vibrant Hawai'i resilience hub provided computers and Wi-Fi for children to access distance learning during the COVID-19 pandemic, along with prepared meals and food boxes (Vibrant Hawaii, 2020; Vibrant Hawai'i, 2022). In a comprehensive review of the current literature, Ciriaco & Wong (2022) concluded that the placement and services offered by resilience hubs were crucial features to consider in their design, implementation, and operation. As noted by the current literature (Baja, 2018; Ciriaco & Wong, 2022; Kirwan et al., 2021; Sandoval, 2019), resilience hubs have the potential to promote the well-being of communities and enhance social capital. However, there is no empirical evidence on how underserved populations might use or travel to/from resilience hubs. In order to address this gap, the study aims to answer three research questions:

1) What services do underserved populations prefer in a resilience hub?
2) How will underserved populations access resilience hubs?
3) How do underserved populations and non-underserved populations differ in hub usage?

To answer these research questions, we surveyed 950 respondents from the Edmonton Metropolitan Region in Alberta, Canada, between November 2022 and January 2023. Focused on resilience hubs, the dataset contains information on the type of services that different demographic groups prioritize, both during everyday conditions and during a disaster. Using these data, we display several key descriptive statistics (e.g., preferences for location, services, and mode choice) and conduct several simple statistical analyses of group differences in resilience hub usage. Results inform several key recommendations for resilience hub placement and transportation operations that can specifically benefit underserved populations. The methods are also relatively simple to reproduce, enabling other jurisdictions or community-based organizations (CBOs) to conduct similar analyses.

This paper is organized as follows. First, we present a brief literature review about resilience hubs and equity challenges that arise during evacuations. Subsequently, we explain the data collection and the methodology. Then, we present the results and discussions. We conclude the paper with policy recommendations and overall conclusions.

2) LITERATURE REVIEW

We organized our literature review by general areas of interest: 1) evacuations and equity challenges, 2) resilience hub design, and 3) literature gaps.

2.1) Evacuations and Equity Challenges

The impacts of climate change and non-climate-related disasters have been consistently shown to disproportionately affect underserved populations (Benevolenza & DeRigne, 2018; Levy & Patz, 2015; van Wesenbeeck et al., 2016). Low-income households, racial and ethnic minority groups, people with disabilities, older adults, women, and children are highly vulnerable to both the environmental and health consequences of climate change (Levy & Patz, 2015). These populations often lack access to reliable transportation, which can be

a major barrier to evacuating in times of disaster. For example, private and public vehicles are frequently not equipped to accommodate specialized mobility or medical equipment, which may be crucial for the evacuation of people with disabilities or older adults. Moreover, low-income residents often choose not to evacuate due to the cost, as was the case during Hurricane Katrina in New Orleans (Litman, 2006). Through an Evacuation Preparedness Rating System, (Renne & Mayorga, 2018) found that only 26% of the evacuation plans from the 50 largest cities of the United States presented strategies on how to assist underserved and transportation-disadvantaged populations during a disaster. Moreover, a study conducted in New Orleans found that while the city had established pick-up points for transit users, many of these were not strategically located close to those with the greatest need (the elderly, low-income households, and people with disabilities) (Bian & Wilmot, 2018).

Evacuation shelters often serve as the first temporary living spaces for evacuees during and after a disaster. While there is substantial research on the types of shelters people choose during an emergency (Lindell et al., 2011), many of these shelters remain unequipped to accommodate the needs of underserved populations. During Hurricane Katrina, for example, many Red Cross shelters were unable to accommodate people with disabilities (Benevolenza & DeRigne, 2018). Moreover, those who were elderly or physically frail had difficulties accessing the shelters due to long waiting lines (Saunders, 2007). Previous studies have shown that social and physical barriers in shelters can limit these populations' compliance with evacuation orders (Karaye et al., 2020). As such, agencies and jurisdictions are responsible for ensuring that shelters meet the specific needs and challenges faced by different underserved groups.

Ensuring an equitable provision of both transportation and shelter resources, along with sufficient community cohesion and social capital, are also important in disasters. In a study of the 1995 Chicago heat wave, Klinenberg (2015) found that isolated elderly individuals with few social ties were less likely to be rescued and more likely to die. Wong et al. (2020) further found that when residents of communities have high trust and compassion for others, they are more likely to share resources in a disaster. A bottom-up mechanism for social cohesion within neighbourhoods could create equitable communities where the needs of underserved populations are known and met (Idziorek et al., 2021). It is within this framework that resilience hubs can play an essential role.

2.2) Resilience Hub Design

Resilience hubs, as community-based locations, play a crucial role in providing essential services and resources during times of crisis (Baja, 2018) and offering year-round services to enhance communities' resilience and quality of life. These hubs can operate throughout the year in three different modes: 1) everyday/normal conditions, 2) response or disruption mode, and 3) recovery mode (Baja, 2019; Ciriaco & Wong, 2022; Resilience Hub Community Committee, 2020). For most of the year, hubs operate in normal mode, providing services and resources to reduce disparities in communities' preparedness for disasters, ability to mitigate climate change, and other necessities (e.g., education, health, recreation). When a disaster or emergency occurs, they shift to response mode. This might involve providing temporary shelter, offering key resources (e.g., food, water, cooling, heat, electricity), and/or serving as a communication source. In this mode, resilience hubs often resemble typical evacuation shelters. However, resilience hubs are also designed to handle non-evacuation events such as power outages, smoke events, extreme heat, or extreme cold. After the disaster, hubs operate in recovery mode to serve longer-term community needs. This could involve an extension of existing resources (from response mode) or new resources and services that better meet recovery goals.

The flexibility of resilience hubs (as described above) necessitates an understanding of a community's needs and characteristics before implementing the hubs. The most common services that can be offered are community emergency response training, information desk during emergencies, physical and mental health services and programming, specific programs for children and youths (e.g., childcare, job training, sports, music and arts programs), and resilient and sustainable infrastructure (e.g., renewable power systems and water capture and storage systems) (Baja, 2019; Ciriaco & Wong, 2022; USDN, 2022b, 2022a). To maximize their effectiveness, resilience hubs should be well-established and trusted within the community and equipped with extensive support and coordination capabilities (Baja, 2019). They can be placed in recreation centers, libraries, community halls, government buildings, schools, or large buildings (e.g., stadiums, conference centers, etc.).

Recent research has begun to highlight the role of resilience hubs in promoting social cohesion, along with significant gaps in transportation considerations (Ciriaco & Wong, 2022). The success of hubs likely depends on their ability to address community needs, diverse staffing, clear communication, and community involvement in

emergency planning (FEMA, 2011). It should be noted that resilience hubs differ from emergency or evacuation shelters. For instance, current evacuation shelters only operate during disasters and are often seen as uncomfortable, under-resourced, and unsafe (Asgary & Azimi, 2019; McGee et al., 2021). Depending on the type of disaster, evacuation shelters can be set up in an open or safe indoor location (the most common). They can also be designed and resourced based on the duration of stay, such as emergency sheltering, temporary sheltering, temporary housing, and permanent housing (Chou et al., 2013; Johnson, 2007; Quarantelli, 1995). Resilience hubs are conceptualized to function year-round, with a weaker emphasis on sheltering. This is a key limitation of hubs as they may become overwhelmed during large-scale evacuations. A robust though costly network of hubs of different sizes, along with possible evacuation shelters, could alleviate this limitation.

Strategies adopted during the planning phase of a resilience hub should consider the projections of increased frequency and intensity of extreme weather events due to climate change (Temmer & Venema, 2019). As noted in a report by FEMA (2011), developing and maintaining community relationships can lead to a deeper understanding of community dynamics and help uncover hidden vulnerabilities. For example, Vibrant Hawai'i, a community-based leadership organization, observed that communities in the County of Hawai'i were facing challenges during the COVID-19 pandemic and created resilience hubs to assist these communities. Their services assisted 41,733 households by facilitating access to a computer and Wi-Fi connectivity for distance learning for children, providing prepared meals and food boxes, and training people for jobs (Vibrant Hawaii, 2020). These hubs remain operational, adapting physical spaces to the dynamic needs of the community (Vibrant Hawai'i, 2022).

Multiple factors affect the selection of a resilience hub by community members. For instance, research has found that the perceived importance of emergency shelters by potential end users depends on factors such as safety, hygiene, proximity to friends and family, privacy, provisions of special meals, and access to the Internet (Asgary & Azimi, 2019). Another study noted that individuals with access and functional needs (AFN) must also be considered and integrated in disaster and emergency management planning (Lou, 2020). Consequently, the location of a resilience hub and its associated transportation characteristics play a key role in improving access for underserved populations during disasters and normal days.

2.3) Key Literature Gaps

The current literature has developed a strong understanding of the resilience hub's concept, characteristics, and functionalities. Literature has also identified significant challenges for underserved populations, especially related to transportation. In this context of equity, transportation, and resilience hubs, three key literature gaps exist. First, studies currently lack an equity assessment or empirical evidence on how underserved populations will use resilience hubs. Second, research has only peripherally addressed how resilience hubs should be located based on community preferences and needs. Finally, there is no evidence on how underserved populations will travel to/from these hubs. The goal of this study is to begin addressing these existing gaps and to obtain insight into the placement of and the type of services that can be offered by resilience hubs to meet the needs of diverse demographic groups. Using Edmonton, Canada, as a case study, we aim to inform policy and decision-making regarding the functionality and design of resilience hubs more broadly, especially for mid-sized North American cities (e.g., Minneapolis, St. Louis, Kansas City, Sacramento, Jacksonville, Baltimore, Salt Lake City, Cleveland, Ottawa, Winnipeg, etc.). The methodology presented in this paper is intended to be simple to use for broader case study development across diverse cultures, geographies, and places.

3) DATA COLLECTION AND METHODOLOGY

3.1) Data Collection

To focus on individual behaviour and needs, we collected survey data via the Qualtrics platform through a market research panel and a convenience sample. The market research panel sampling, also known as an online sample, is when participants are recruited from a pre-arranged group of people subscribed to a platform to participate in surveys (Qualtrics, 2023). Panel recruitment was conducted by Qualtrics as a quota sample to reflect the general population in Edmonton. Convenience sampling, also known as accidental sampling or opportunity sampling, is a non-probability sampling technique that does not require a random selection of participants (Henry, 1990). For convenience recruitment, the survey link was disseminated through social media, newsletters, and emails from community organizations and agencies such as community leagues, the City of Edmonton, and the Edmonton Food Bank.

The data was collected for the Edmonton Metropolitan Region (with a population of about 1.3 million people) from November 2022 to February 2023. Data cleaning was conducted to remove incomplete responses, extremely fast responses, and highly patterned responses, as well as participants who could not be verified as living inside the Edmonton Metropolitan Region. The final sample consisted of 950 observations. The survey questionnaire was designed to determine the respondents' socioeconomic and demographic profile (e.g., age, gender, education, income, household composition, and number of vehicles in the household) and to investigate their evacuation plans, preparedness for emergencies, risk perceptions, and opinions about resilience hubs.

To assess the underserved groups' characteristics and needs, the final sample was subdivided into seven groups based on socioeconomic and demographic characteristics, including people with disabilities, older adults (65 years and over), women, households with children, carless, low-income households (household income under $50,000 CAD), and visible minorities. According to the Employment Equity Act in Canada, visible minorities are "persons, other than Aboriginal peoples, who are non-Caucasian in race or non-white in colour" (Employment Equity Act, 1995). We note that not *all* members of each group are necessarily underserved. Moreover, there are other populations that were not included in this analysis (e.g., non-English speakers, houseless, recent immigrants). However, we chose these groups because: 1) they or their household traditionally experience increased vulnerability in disasters and 2) there was sufficient data to analyze them as a group. As a note, we use the term "underserved" rather than "vulnerable" to denote systematic barriers, though this wording may change in the future. Moreover, as one respondent can be part of more than one underserved group, we checked their correlation and association.

3.2) Methods of Analysis

Statistical analysis was used to investigate the services and resources desired by underserved groups for resilience hubs and the suitability of existing buildings for retrofitting into resilience hubs. Additionally, statistical analysis was done to understand the usage of resilience hubs by underserved groups during normal conditions and emergencies. Levene's tests and T-tests were conducted using Python to analyze if the underserved group behaved differently from their intersectionality with other underserved groups and from non-intersectionality. Subsequently, we analyzed how underserved groups intend to travel to resilience hubs during normal conditions and emergencies. We also employed a simple spatial calculation to examine Euclidean distance from a location proposed by respondents to allocate hubs and their residences, with a segmentation of mode choice. Moreover, we compared underserved and non-underserved groups using cross-tabulations and Pearson chi-square tests to identify different uses of resilience hubs. Future work can extend these methods by leveraging spatial optimization, discrete choice analysis, and accessibility analyses.

The final step of this study was to identify equitable policy recommendations and strategies for resilience hub location and design. The flowchart below (Figure 1) summarizes the methodological process followed in this study. The methodology is designed to be modular, allowing for the selection of different analyses for replication by other communities using local survey data.

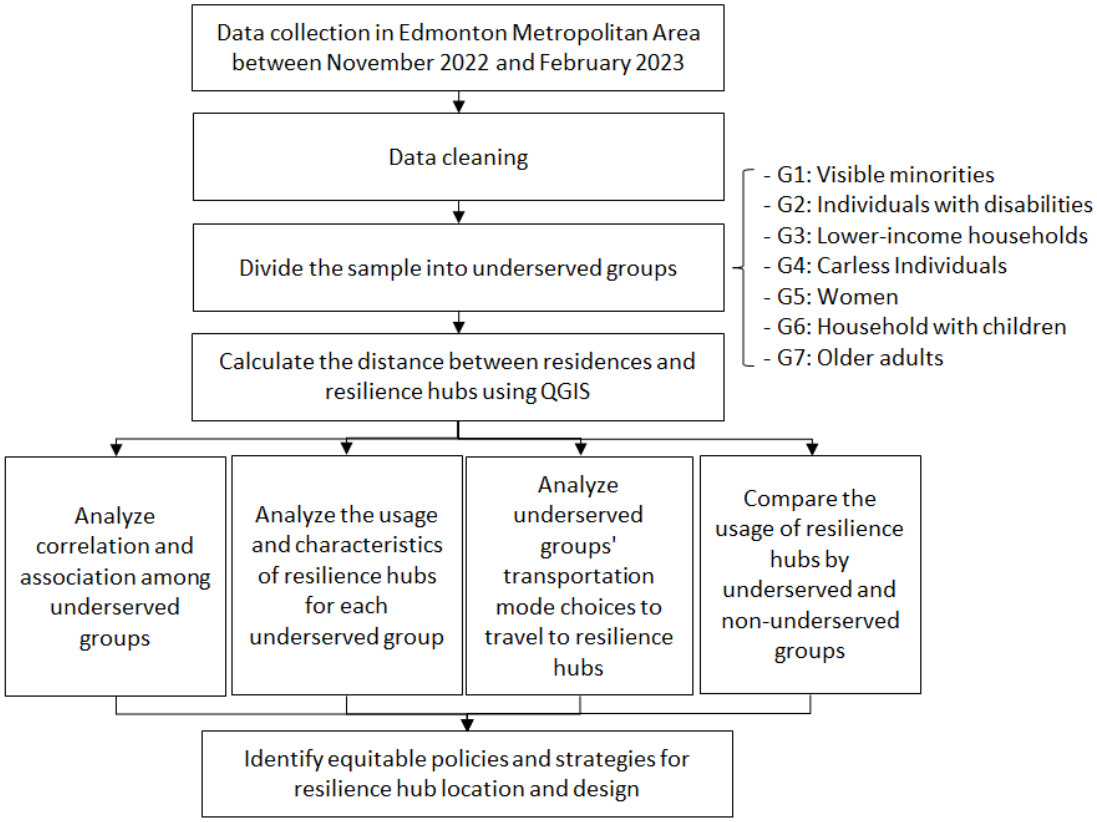

Figure 1 - Flowchart of the methodology

3.3) Survey Data Demographic Characteristics

The demographics in the survey data (n = 950) produced a good (but not ideal) general population sample for the Edmonton Metropolitan Region. The respondents had an average age of 38, which aligns with the average age of 38.8 found in the 2021 Canadian Census for the Edmonton Metropolitan Area residents (Statistics Canada, 2023). However, only 4% of the respondents in our sample were older adults (≥65 years). More than half of the respondents in our survey identified as women (54.4%), 43.3% as men, and other genders (e.g., non-binary, two-spirit, transgender) comprised 0.9% of the respondents. The majority of the respondents in our survey were white (54.5%). According to the survey data, 26.5% of the population belonged to visible minorities, which is very close to the census figure of 33%. With regard to car ownership, only 4.9% did not have an automobile, whereas the rest of the respondents had at least one automobile in their households. In our survey, 22.8% had an income under $50,000, 43.3% had an income between 50,000 and $100,000, and 29.1% had an income of $100,000 and over. The income distribution observed in our survey is similar to that noted in the Canadian Census. Moreover, 71.8% of the survey respondents had completed a diploma, bachelor's, graduate or professional degree, or doctorate. According to the survey, 26.1% of the respondents had a disability, which is close to the 23% reported by the Census in 2017.

3.4) Intersectionality of Underserved Groups

Two tables were created to analyze the distribution of individuals within the seven underserved groups. The first table (Table 1) shows the number of individuals in a specific underserved group who are exclusively part of that group or are also part of 2 to 5 other underserved groups. 35% of the sample belong to two groups (based on our previously defined underserved groups), with an additional 21% intersecting across three groups. Notably, a significant percentage of older adults, women, visible minorities, and households with children belong to two underserved groups, ranging from 41% to 43.9%.

Table 1 – Distribution of individuals across underserved groups

Underserved group	Sample size	Number of underserved groups that an individual is part of				
		1	2	3	4	5
Total sample	950	284	337	196	48	5
Visible minorities	280	46	116	86	30	2
Individual with disability	232	20	70	101	36	5
Low-income household	186	27	44	78	33	4
Carless	47	5	9	16	13	4
Women	523	92	219	164	43	5
Household with children	456	91	200	131	30	4
Older adults	39	3	16	12	7	1

To gain further details about the type of intersectionality, Table 2 specifies the number of people who are part of two underserved groups. Percentages are provided to identify the magnitude of this intersectionality within the chosen group. Percentages do not add to 100% since intersections are not mutually exclusive. Regarding the distribution presented in Table 2, all underserved groups (except visible minorities) present the highest intersection with women. For the visible minority and women groups, the highest intersectionality is observed in households with children, which is the second highest intersectionality for low-income households and people with disabilities. For older adults, women, and carless groups, the second highest intersectionality is observed in individuals with disabilities. Moreover, there is no intersection between households with children and older adults.

Table 2 - Percentage of underserved groups encompassed in one specific underserved group

Quantity and percentage of underserved groups encompassed in one specific underserved group*

Underserved group	Sample size	Intersection with						
		Visible minorities	Individual with disability	Low-income household	Carless	Women	Household with children	Older adults
Visible minorities	280	46 (16.4%)	53 (18.9%)	38 (13.6%)	10 (3.6%)	136 (48.6%)	140 (50.0%)	9 (3.2%)
Individual with disability	232	53 (22.8%)	20 (8.6%)	65 (28.0%)	22 (9.5%)	148 (63.8%)	93 (40.1%)	19 (8.2%)
Low-income household	186	38 (20.4%)	65 (34.9%)	27 (14.5%)	21 (11.3%)	110 (59.1%)	69 (37.1%)	12 (6.5%)
Carless	47	10 (21.3%)	22 (46.8%)	21 (44.7%)	5 (10.6%)	27 (57.4%)	14 (29.8%)	2 (4.3%)
Women	523	136 (26.0%)	148 (28.3%)	110 (21.0%)	27 (5.2%)	92 (17.6%)	252 (48.2%)	23 (4.4%)
Household with children	456	140 (30.7%)	93 (20.4%)	69 (15.1%)	14 (3.1%)	252 (55.3%)	91 (20.0%)	0 (0.0%)
Older adults	39	9 (23.1%)	19 (48.7%)	12 (30.8%)	2 (5.1%)	23 (59.0%)	0 (0.0%)	3 (7.7%)

* Diagonals represent people who are only in that specific underserved group

Percentages represent the proportion of the [column name] underserved group within the [row name] underserved group

As some of these groups have high intersection percentages, we ran statistical tests to analyze the Pearson correlation coefficient and the association between underserved groups. Initially, we conducted a correlation matrix (Table 3), which revealed that there was no high correlation. The positive values ranged from 0.002 to 0.144, while the negative values ranged from -0.199 to -0.029. For the visible minority group, only one value was

positive (household with children). Conversely, for the women group, only one value was negative (visible minorities).

Table 3 – Correlation matrix

	Visible minorities	Individual with disability	Low-income household	Carless	Women	Household with children	Older adults
Visible minorities	1	-0.083	-0.098	-0.041	-0.084	0.026	-0.029
Individual with disability	-0.083	1	0.121	0.119	0.100	-0.090	0.117
Low-income household	-0.098	0.121	1	0.144	0.041	-0.108	0.058
Carless	-0.041	0.119	0.144	1	0.011	-0.083	0.002
Women	-0.084	0.100	0.041	0.011	1	0.004	0.016
Household with children	0.026	-0.090	-0.108	-0.083	0.004	1	-0.199
Older adults	-0.029	0.117	0.058	0.002	0.016	-0.199	1

A chi-square test was run to test the association between underserved groups (Table 4). Analyzing the chi-square (p-values), we conclude that individuals with a disability are significantly associated with all other six underserved groups. In addition, the following significant associations were observed:

- Visible minorities and Women
- Visible minorities and Low-income households
- Low-income households and Carless
- Low-income households and households with children
- Carless and households with children
- Older adults and households with children

Table 4 - Chi-square test p-values

Underserved group	Visible minorities	Individual with disability	Low-income household	Carless	Women	Household with children	Older adults
Visible minorities	-	0.011*	0.003**	0.206	0.009**	0.425	0.371
Individual with disability	0.011*	-	0.000**	0.000**	0.002**	0.006**	0.000**
Low-income household	0.003**	0.000**	-	0.000**	0.211	0.001**	0.072
Carless	0.206	0.000**	0.000**	-	0.735	0.010**	0.958
Women	0.009**	0.002**	0.211	0.735	-	0.900	0.615
Household with children	0.425	0.006**	0.001**	0.010**	0.900	-	0.000**
Older adults	0.371	0.000**	0.072	0.958	0.615	0.000**	-

** 99% significance level; * 95% significance level

Aiming to measure the strength of the associations, a Phi coefficient was calculated. Table 5 presents the results, where the values in gray cells are the phi coefficients and those in blue cells are the p-values. The Phi coefficients indicated statistical significance in the same associations observed in the chi-square test. The test also revealed that these associations were positive. All associations were generally weak, with phi ranging from 0.078 to 0.193. Together, the results indicate some unique intersectionality, though analysis by individual groups was determined to be more informative.

Table 5 - Phi coefficient and p-values

	Visible minority	Individual with disability	Low-income household	Carless	Woman	Household with children	Older adult
Visible minority	-	0.080	0.095	0.036	0.082	0.024	0.023
Individual with disability	0.014*	-	0.118	0.113	0.097	0.088	0.111
Low-income household	0.003**	0.000**	-	0.138	0.038	0.105	0.052
Carless	0.271	0.000**	0.000**	-	0.006	0.078	0.000
Woman	0.012*	0.003**	0.243	0.851	-	0.002	0.011
Household with children	0.468	0.007**	0.001**	0.016*	0.952	-	0.193
Older adult	0.474	0.001**	0.111	1.000	0.735	0.000**	-

Gray cells are the phi coefficients, and blue cells are the p-values
** 99% significance level; *95% significance level

4) RESULTS

In this section, we explore specific topics related to the resilience hub, including its characteristics, usage, and accessibility. We compare the results for each underserved group and end the section with a comparison of underserved and non-underserved groups.

4.1) Resilience Hub Characteristics Based on Underserved Groups

This section provides an overview of key resilience hub characteristics selected by underserved groups in our survey. Figures 2 to 5 summarize each underserved group's preference for resilience hub location, basic and emergency services, and transportation services to be considered in a resilience hub design. For each of these topics, the respondents were asked to rank each option using a Likert scale. The percentages shown in the figures are the sum of the very satisfied/mostly satisfied or very important/mostly important. It is important to note that the participants were introduced to the concept of resilience hubs before answering these questions.

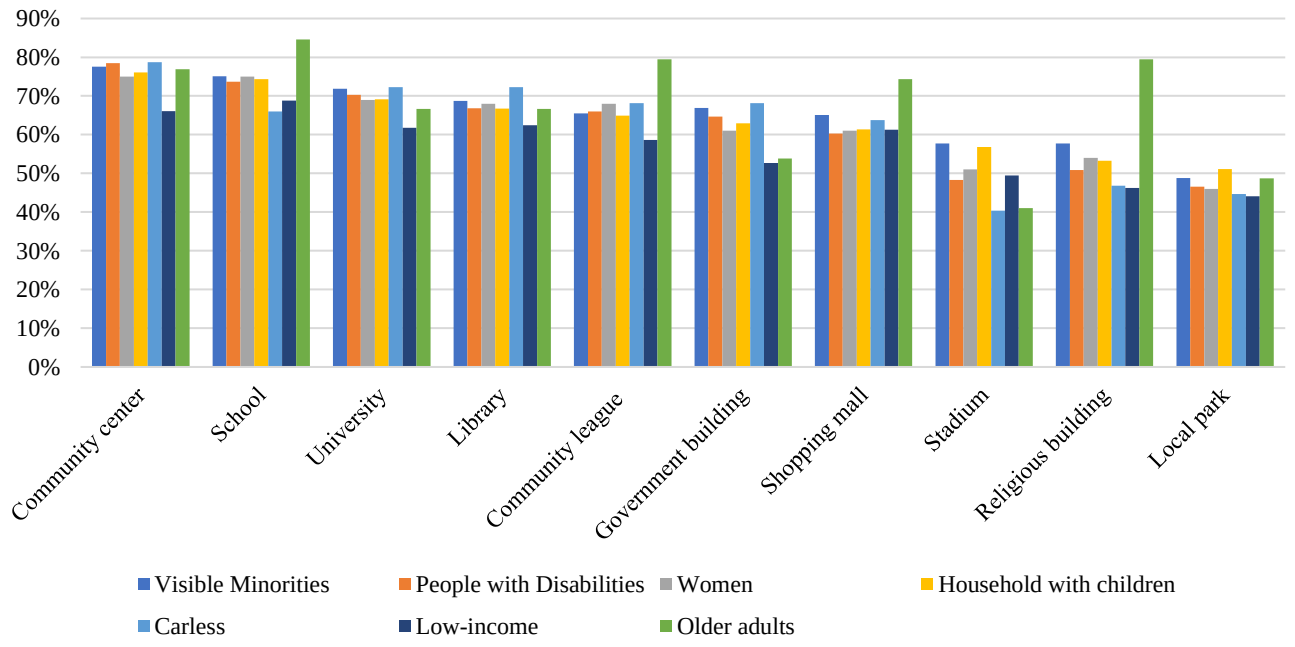

Figure 2 – Places where a resilience hub could be located (very and somewhat satisfied)

Based on the survey responses (see Figure 2), several potential locations for resilience hubs were identified. Five out of seven underserved groups expressed the highest satisfaction with community centers, with percentages ranging from 75.1% to 78.7%. Low-income households and older adults had community centers as their second and fourth highest percentage, respectively. For these two underserved groups, schools were the location with the highest percentage at 68.8% and 84.6%, respectively. Among visible minorities, people with disabilities, women, and households with children, the top four preferred locations were community leagues[1], schools, universities, and libraries. For these underserved groups, the fifth most popular option was community leagues, with the exception of visible minorities. The patterns of low-income households and older adults differed from those of other underserved groups. Low-income households shared the top four locations with visible minorities, people with disabilities, women, and households with children, but in a different order. In contrast, older adults had a different rank and showed higher levels of satisfaction compared to the other underserved groups. Additionally, for older adults, community leagues and religious buildings had the second highest percentage of satisfaction at 79.5%, and shopping malls were among the top five locations. Across most locations and across groups, underserved groups were generally satisfied at high levels. Differences were relatively minor.

Regarding transportation services provided by resilience hubs (Figure 3), accessibility for individuals with disabilities was considered the most important service for all underserved groups. This was especially true for older adults, people with disabilities, and those without access to a car. A high number of older adults (66.7%) further indicated that it was very/mostly important for resilience hubs to be located within walking distance from residences. The idea of having a resilience hub within walking distance of their residence was the second most popular option for low-income households (57.5%) and the third most popular for individuals without cars (57.5%). The lowest percentage was observed among visible minorities at 49.8%. Carless residents and households with children placed high importance on transit connections (61.7% and 59.4%). Transit connections and car parking were equally important for visible minorities (54.1%). Car parking was also important for women and people with disabilities, with percentages of 60.6% and 58.2%, respectively. For all underserved groups, heated bus stops were more important than parking for electric vehicles. Moreover, all underserved groups had low inclinations for selecting bike sharing and bike parking as important for resilience hubs. Low-income households accounted for the highest number of respondents who selected both bike sharing and bike parking services as very/mostly important (35.5% and 34.4%, respectively).

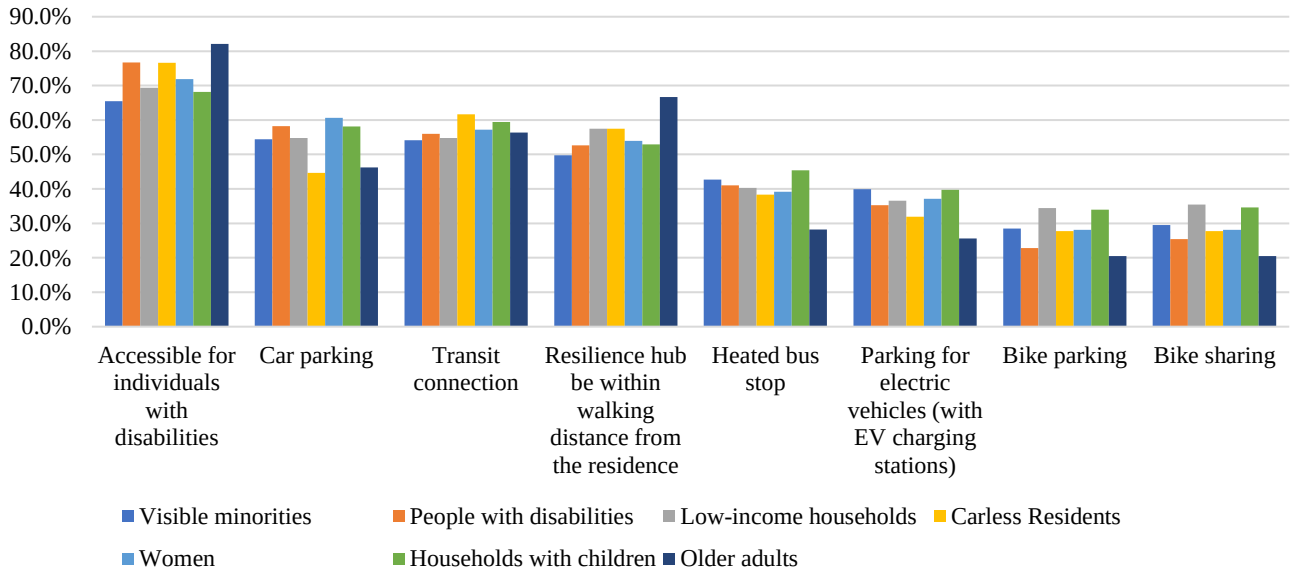

Figure 3 - Transportation services and resources at resilience hubs (very and mostly important)

[1] Community leagues are neighbourhood-based, non-profit organizations created under the Societies Act of Alberta, Canada, to meet community needs (Hairsine, 2015). They often have their own facilities, including a community hall.

Apart from transportation services, respondents indicated the importance of different types of emergency services at resilience hubs (Figure 4). During a disaster, providing temporary shelters was the top priority for five out of the seven underserved groups, with percentages ranging from 89.3% to 71.2%. These groups also showed a high preference for backup and emergency power. Only carless individuals and older adults ranked backup and emergency power as their first choice, with shelter as their second choice. All underserved groups were less inclined to select community emergency response training as one of the critical services to be provided by resilience hubs, with percentages ranging from 66.9% to 57.5% (lowest values among emergency services). Moreover, for most emergency services and resources, the highest percentage of importance was observed in older adults.

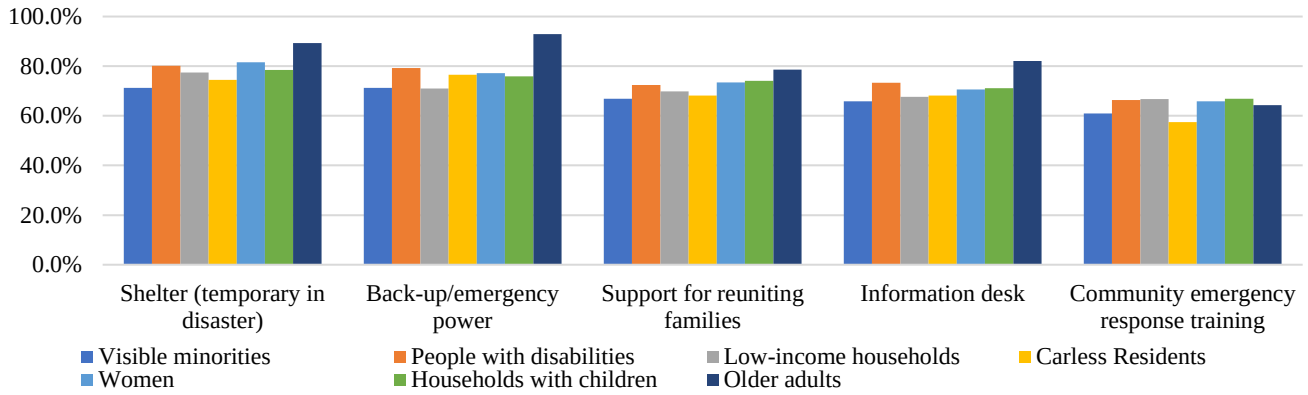

Figure 4 – Emergency services and resources for resilience hubs (very and mostly important)

Regarding basic services and resources (Figure 5), the results indicated that water is crucial for most underserved groups. Carless individuals placed the highest importance on showers (85.1%), while older adults placed the highest importance on restrooms (96.4%). Food banks were considered a top five essential services across all underserved groups. Basic health services were especially important for older adults (92.9%) and people with disabilities (82.8%). The percentage varied between 78.7% and 74% for other underserved groups. Moreover, all underserved groups placed more importance on warming centers than cooling centers, with percentages ranging from 77.2% to 85.7% and 61.7% to 68.1%, respectively. This trend may differ in cities with milder winters and harsher summers.

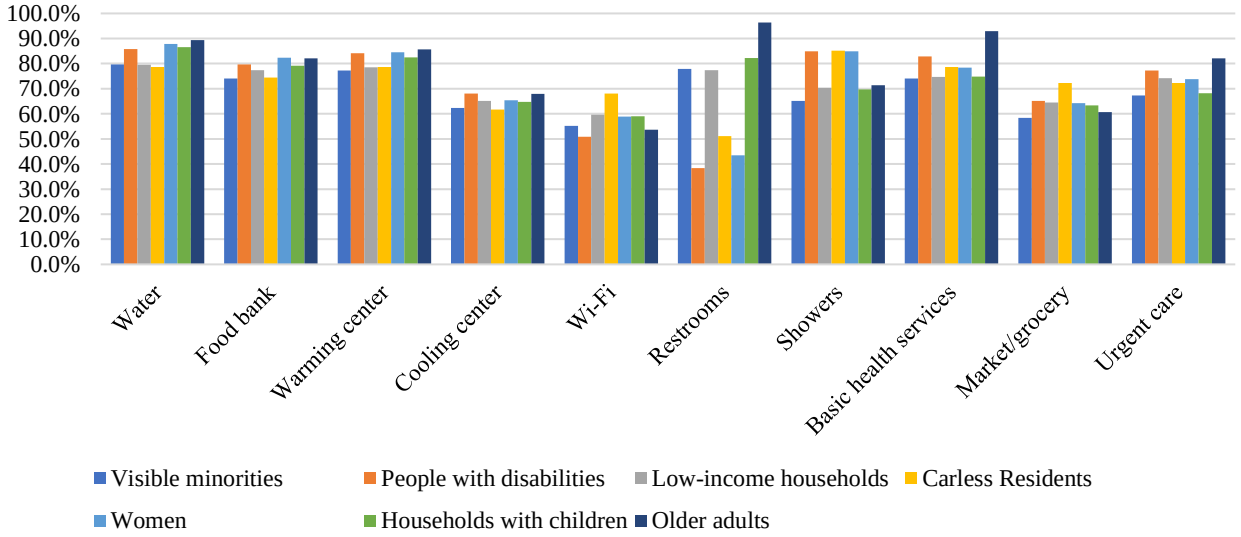

Figure 5 – Basic services and resources for resilience hubs (very and mostly important)

4.2) Intended Resilience Hub Usage by Underserved Groups

This section presents an overview of how each underserved group would use a resilience hub during normal conditions and during a disaster. Table 6 shows that underserved groups' usage of resilience hubs will likely depend on the circumstance. For example, only 31.6% of the older adults indicated that they were very or somewhat likely to use a resilience hub during normal conditions. On the other hand, during emergency conditions, 76.9% of the older adult group were very or somewhat likely to use resilience hubs as temporary evacuation shelters. All underserved groups were more likely to use a resilience hub during emergencies than during normal conditions. Low-income households had the highest likelihood of using a resilience hub under normal conditions at 51.1%. In contrast, older adults and carless individuals were the least likely groups to use a resilience hub under normal conditions, at 31.6% and 34.1%, respectively. For other underserved groups, usage under normal conditions ranged from 40.5% to 45.4%.

Table 6 - Resilience Hub Usage by Underserved Groups

Underserved Groups		**Visible minorities**	**People with disabilities**	**Low-income households**	**Carless Residents**	**Women**	**Households with children**	**Older adults**
Likelihood of using a resilience hub *(Very likely and somewhat likely)*	Under normal conditions	44.2%	40.5%	51.1%	34.1%	40.7%	45.4%	31.6%
	As a temporary evacuation shelter	66.5%	69.8%	62.9%	70.2%	64.1%	64.3%	76.9%
	As a place to gather critical resources during a disaster	63.0%	71.6%	67.2%	68.1%	67.9%	66.7%	74.4%
	As a place to meet with neighbours during a disaster	43.4%	38.4%	34.9%	34.0%	39.0%	43.4%	53.8%
	As a place to gather information about the disaster	73.0%	74.1%	66.7%	74.5%	72.8%	73.5%	84.6%
		Visible minorities	**People with disabilities**	**Low-income households**	**Carless Residents**	**Women**	**Households with children**	**Older adults**
Volunteer at the resilience hub *(Very likely and somewhat likely)*	During normal days	47.0%	41.8%	47.3%	57.5%	44.4%	48.5%	48.7%
	During relief efforts	61.9%	62.9%	64.0%	36.2%	62.7%	61.2%	82.0%
A resilience hub would help *(Very likely and somewhat likely)*	Increase social cohesion in my neighbourhood	62.6%	61.6%	54.3%	59.6%	58.7%	61.2%	71.6%
	Meet the needs of neighbours on a daily basis	55.9%	56.0%	52.7%	55.3%	55.8%	58.8%	48.7%
	Community to be more resilient	66.5%	66.0%	65.0%	63.8%	65.6%	65.6%	69.2%

In the event of a disaster or emergency, all underserved groups, except for low-income households, were more likely to use a resilience hub as a place to gather information about the disaster. For the low-income group, the highest percentage was found in using a resilience hub to gather critical resources during a disaster, with

gathering information as the second highest use. The group least likely to use a hub as a place to gather critical resources were visible minorities (63%). Older adults had the highest likelihood of using a hub during a disaster for all scenarios. Overall, people were less likely to use a resilience hub as a place to meet with neighbours during a disaster. For using resilience hubs as temporary evacuation shelters, likelihood rates varied between older adults (76.9% very/mostly likely) and low-income households (62.9% very/mostly likely).

The underserved groups also showed varying levels of likelihood to volunteer at a resilience hub. During normal days, carless residents accounted for the most significant percentage of those who would volunteer at a resilience hub (57.5%), whereas people with disabilities comprised the lowest (41.8%). During relief efforts, however, the likelihood of volunteering significantly decreased among carless individuals to 36.2%. On the other hand, other underserved groups showed a higher likelihood of volunteering during relief efforts, with older adults at the highest level (82.0%). For hub benefits, a high number of older adults (71.6%) indicated that resilience hubs would foster increased social cohesion in their neighbourhoods, though only 54.3% of the low-income households agreed with this statement. Despite these subtle differences, nearly all groups across all three questions (Table 6) answered positively to resilience hub benefits, indicating strong potential to meet community needs.

4.3) Intersectionality Testing of Hub Usage

To analyze whether the intersecting groups would behave differently from their respective underserved groups and non-intersecting groups, t-tests were run to compare the means of hub usage (very/somewhat likely). In the independent t-test, the null hypothesis is that the means are the same, while the alternative hypothesis indicates that the means are different. Before running the t-test, a Levene test was conducted to determine whether the variances were equal. The Levene test null hypothesis (H0) assumes that the variances are equal, while the alternative hypothesis (H1) indicates that the variances are different. If the variances were equal, the independent t-test was run assuming equal variances; otherwise, the t-test assumed unequal variances. The Levene test and the t-test were conducted using Python. Table 7 presents the t-test p-values and indicates whether the Levene test found equal variance or not.

Using the Levene test for variance and t-tests for mean, we identified that out of 225 combinations of groups, only 30 showed differences in the behaviour of the compared groups (Table 7). A few key results were found. First, no differences were observed when using a resilience hub to meet with neighbours during a disaster. Second, the usage of a resilience hub as a temporary shelter and as a place to gather critical resources during a disaster exhibited the most statistical differences among groups. Third, no behavioural differences were observed among intersection combinations of visible minorities & low-income households or visible minorities and individuals with disabilities and their respective underserved groups and non-intersecting groups. Fourth, for all t-tests with significant results (p-value < 0.05), the usage percentage was higher for the intersectional group compared to related groups. One exception was in the comparison between only low-income households and the intersectionality group composed of individuals with disabilities & low-income households, where the non-intersectionality low-income households had a higher usage percentage under normal conditions. Fifth, most of the combinations that had behavioural differences were those involving the entire women underserved group, only women, or only households with children.

For instance, only women (non-intersectional) were less likely to use the resilience hub under normal conditions and as a temporary shelter during a disaster compared to the underserved group of all women. Similarly, only households with children were less likely to use a hub as a temporary shelter and as a place to gather critical resources during a disaster than the underserved group of households with children. Regarding comparisons of only women and intersectionality groups, in all cases that they had different behaviour, only women were less likely to use the resilience hub than the intersectionality group. For example, only women were less likely to use a hub during normal conditions or as an evacuation shelter than the intersectionality visible minorities & women. Moreover, intersectionality groups encompassing households with children (e.g., visible minorities & households with children) had at least one significant p-value, with most of them being in using a resilience hub as a place to gather critical resources during a disaster.

Table 7 – Levene's test and T-test p-values

Intersectional groups	Underserved or non-intersectional group	Under normal conditions		As a temporary evacuation shelter		As a place to gather critical resources during a disaster		As a place to meet with neighbours during a disaster		As a place to gather information about the disaster	
		Equal variance	T-test *(p-value)*	Equal variance	T-test *(p-value)*	Equal variance	T-test *(p-value)*	Equal variance	T-test *(p-value)*	Equal variance	T-test *(p-value)*
Visible minorities & Individual with disability	Visible minorities	Y	0.38	Y	0.63	Y	0.86	Y	0.78	Y	0.91
	Individual with disability	Y	0.71	Y	1.00	Y	0.29	Y	0.67	Y	0.93
	Only visible minorities	Y	0.32	Y	0.36	Y	0.74	Y	0.85	Y	0.97
	Only individual with disability	Y	0.86	Y	0.24	Y	0.48	Y	0.79	Y	0.27
Visible minorities & Low-income households	Visible minorities	Y	0.51	Y	0.81	Y	0.78	Y	0.09	Y	0.57
	Low-income households	Y	0.90	Y	0.52	Y	0.43	Y	0.48	Y	0.83
	Only visible minorities	Y	0.85	Y	0.48	Y	0.52	Y	0.17	Y	0.58
	Only low-income households	Y	0.31	Y	0.30	Y	0.69	Y	0.71	Y	0.18
Visible minorities & Women	Visible minorities	Y	0.38	Y	0.62	Y	0.52	Y	0.64	Y	0.74
	Women	Y	0.83	Y	0.99	Y	0.07	Y	0.65	Y	0.72
	Only visible minorities	Y	0.34	Y	0.71	Y	0.35	Y	0.79	Y	0.74
	Only women	N	0.02*	Y	0.01**	Y	0.72	Y	0.33	Y	0.33
Visible minorities & Households with children	Visible minorities	Y	0.68	Y	0.30	Y	0.39	Y	0.49	Y	0.53
	Households with children	Y	0.83	Y	0.12	Y	0.92	Y	0.44	Y	0.60
	Only visible minorities	Y	0.87	Y	0.18	Y	0.98	Y	0.67	Y	0.81
	Only households with children	Y	0.49	N	0.00**	N	0.02*	Y	0.76	Y	0.37
Individuals with disability & Low-income households	Individual with disability	Y	0.77	Y	0.88	Y	0.06	Y	0.99	Y	0.84
	Low-income households	Y	0.08	Y	0.25	N	0.01**	Y	0.61	Y	0.19
	Only individual with disability	Y	0.90	Y	0.19	N	0.03*	Y	0.61	Y	0.19
	Only low-income households	Y	0.03*	Y	0.16	N	0.02*	Y	0.65	N	0.04*
Individuals with disability & Women	Individual with disability	Y	1.00	Y	0.28	Y	0.56	Y	0.87	Y	0.16
	Women	Y	0.97	N	0.01**	Y	0.13	Y	0.97	Y	0.06
	Only individual with disability	Y	0.96	Y	0.06	Y	0.07	Y	0.62	N	0.10
	Only women	N	0.01**	N	0.00**	N	0.05*	Y	0.50	N	0.01**

		Under normal conditions		As a temporary evacuation shelter		As a place to gather critical resources during a disaster		As a place to meet with neighbours during a disaster		As a place to gather information about the disaster	
		Equal variance	T-test *(p-value)*	Equal variance	T-test *(p-value)*	Equal variance	T-test *(p-value)*	Equal variance	T-test *(p-value)*	Equal variance	T-test *(p-value)*
Individuals with disability & Households with children	Individual with disability	Y	0.44	Y	0.99	Y	0.78	Y	0.55	Y	0.85
	Households with children	Y	0.97	Y	0.30	Y	0.23	Y	0.79	Y	0.95
	Only individual with disability	Y	0.68	Y	0.20	Y	0.11	Y	0.80	Y	0.25
	Only households with children	Y	0.64	N	0.00**	N	0.00**	Y	0.67	Y	0.68
Low-income households & Women	Low-income households	Y	0.78	Y	0.36	Y	0.41	Y	0.93	Y	0.28
	Women	Y	0.02*	Y	0.41	Y	0.42	Y	0.49	Y	0.98
	Only low-income households	Y	0.34	Y	0.22	Y	0.10	Y	0.84	N	0.06
	Only women	N	0.00**	N	0.00**	Y	0.14	Y	0.92	Y	0.25
Low-income households & Households with children	Low-income household	Y	0.44	Y	0.90	Y	0.56	Y	0.85	Y	0.51
	Households with children	Y	0.08	Y	0.94	Y	0.47	Y	0.26	Y	0.67
	Only low-income household	Y	0.57	Y	0.46	Y	0.15	Y	0.79	Y	0.08
	Only households with children	Y	0.06	Y	0.05	N	0.01**	Y	0.26	Y	0.93
Women & Households with children	Women	Y	0.28	Y	0.17	Y	0.12	Y	0.26	Y	0.38
	Households with children	Y	0.89	Y	0.20	Y	0.06	Y	0.97	Y	0.50
	Only women	N	0.00**	N	0.00**	N	0.05*	Y	0.16	Y	0.05*
	Only households with children	Y	0.61	N	0.00**	N	0.00**	Y	0.77	Y	0.31
Non-intersectional groups	**Underserved groups**										
Only visible minorities	Visible minorities	Y	0.66	Y	0.46	Y	0.56	Y	0.99	Y	0.88
Only individual with disability	Individual with disability	Y	0.96	Y	0.17	Y	0.12	Y	0.56	Y	0.17
Only low-income households	Low-income households	Y	0.25	Y	0.46	Y	0.24	Y	0.87	Y	0.13
Only women	Women	N	0.00**	N	0.00**	Y	0.27	Y	0.44	Y	0.13
Only households with children	Households with children	Y	0.53	N	0.01**	N	0.01**	Y	0.77	Y	0.54

The Levene's test was conducted to determine if the variances were equal or not. Subsequently, the t-test was run based on the variance result.
Levene hypothesis: H0: equal variances; H1: unequal variance (p-values<0.05).
T-test hypothesis: H0: equal means; H1: different means (p-values<0.05)
*95% significance level; **99% significance level

Y = yes; N = no
Intersectionality group: a group whose individuals belong to the two underserved groups that named it
Non-intersectionality: a group whose individuals belong to only one underserved group
Underserved group: a group whose individuals identify as at least one underserved group

4.4) Hub Usage Differences Between Underserved and Non-Underserved Groups

Next, we employed a cross-tabulation analysis and conducted Pearson's chi-square tests to determine the usage difference between underserved and non-underserved groups. Here, we define non-underserved as all people who are not in the underserved group (not considering intersectionality). For example, we compare visible minorities with non-visible minorities. The Pearson chi-square null hypothesis (H0) posits that there is no association between the classification of individuals and their usage of resilience hubs, while the alternative hypothesis suggests that such an association exists. It is worth noting that none of the crosstab cells had an expected count of less than 5, ensuring that the assumptions for chi-square testing were satisfied. Table 8 presents the p-values from the Pearson chi-square test.

Table 8 - P-values of the Person chi-square test of underserved groups with resilience hub usage (binary categorization)

	Visible minority	People with disability	Low-income	Carless	Women	Household with children	Older adult
Would volunteer at a resilience hub during relief effort	0.521	0.330	0.242	0.691	0.081	0.556	0.004*
Would volunteer at a resilience hub during normal days	0.343	0.357	0.376	0.243	0.966	0.016*	0.581
Would use resilience hub during normal days	0.238	0.762	0.003*	0.296	0.657	0.015*	0.298
Would use resilience hub during a disaster as a temporary shelter	0.031*	0.002*	0.586	0.191	0.043*	0.060	0.039*
Would use resilience hub during a disaster as a place to gather critical resources	0.667	0.005*	0.295	0.540	0.005*	0.087	0.165
Would use resilience hub during a disaster as a place to meet neighbours	0.104	0.663	0.150	0.426	0.689	0.020*	0.063
Would use resilience hub during a disaster as a place to gather information during a disaster	0.183	0.097	0.301	0.474	0.023*	0.018*	0.039*

* 95% significance

H0: there is no association between the variables (independent); H1: there is an association between the variables (dependent)

Table 8 reveals important findings regarding the utilization of resilience hubs by underserved and non-underserved groups in various scenarios, both during disasters and in normal conditions. First, households with children had the highest number of significant associations, four in total, followed by women and older adults with three significant associations each. In terms of usage, using a hub as a shelter had the most associations, four in total, followed by using a hub as a place to gather information during a disaster, three in total. Moreover, all usage modes had at least one association, and carless was the only categorization without an association.

The results indicated that there was a significant association between being a visible minority and the willingness to use a resilience hub as a temporary shelter in case of a disaster. It suggests that willingness to utilize these resources may vary based on visible minority identity. The same association was observed in the following categorizations: people with disabilities, women, and older adults. In Figure 6, which shows the percentage of the intended usage of a resilience hub as a temporary shelter, we observed that all underserved groups were more likely to use a hub as a temporary shelter when compared to their respective non-underserved group. For example, 76.9% of older adults were willing to use a hub as a temporary shelter, while 60.5% of non-older adults considered using a resilience hub as a temporary shelter. This indicates a disparity where a larger proportion of older adults rely on temporary shelter than non-older adults. This information is crucial for policymakers to address the needs of diverse communities more effectively during times of crisis.

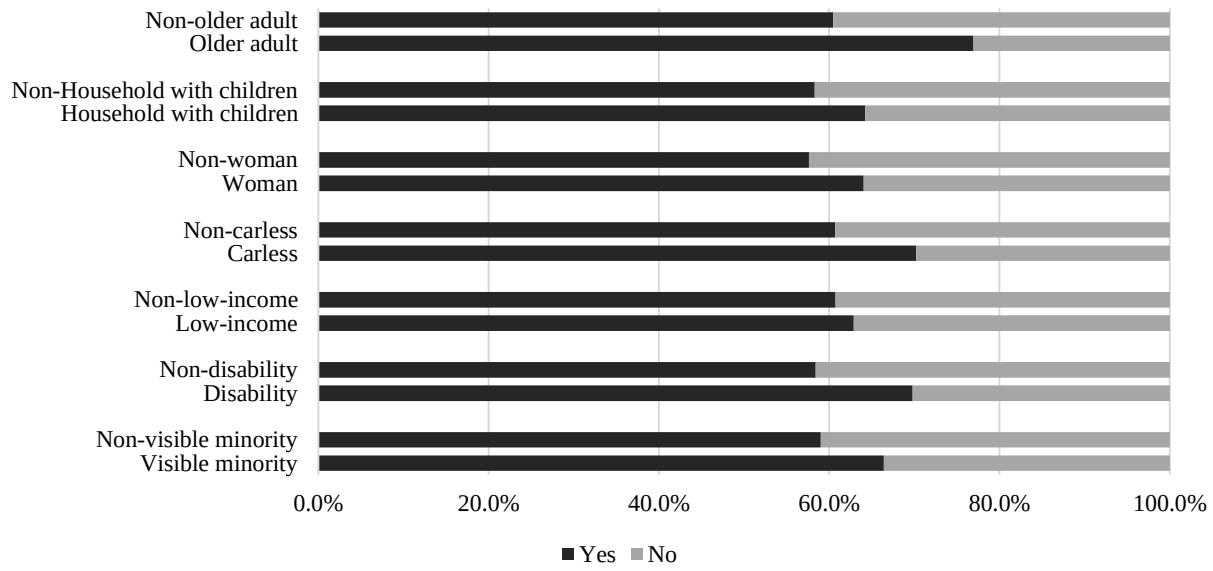

Figure 6 - Usage of resilience hub as a temporary shelter during a disaster

During normal conditions, households with children, low-income households and visible minorities were more likely to use a hub than their respective non-underserved groups (Figure 7). The chi-square tests (Table 8) indicated associations between using a resilience hub during normal days and households with children and low-income households. For all other groups, the non-underserved group was more likely to use a hub during normal conditions.

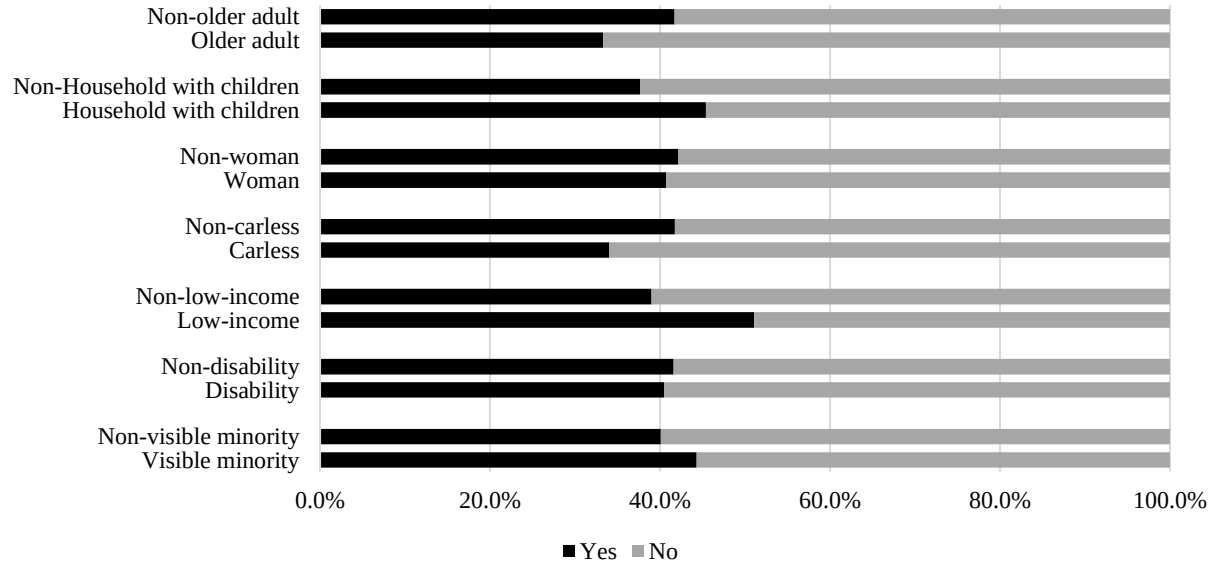

Figure 7 - Usage of resilience hub during normal conditions

Regarding volunteering at resilience hubs, there was an association in the older adult category for volunteering during relief efforts. The results indicated that 82% of older adults exhibited a tendency to volunteer during disasters, while only 59.3% of non-old adults were willing to volunteer during relief

efforts. This suggests that older adults may be more inclined towards community involvement during crises. For volunteering at resilience hubs during normal conditions, an association was observed in the category of households with children.

According to the chi-square test results, a significant association exists between the willingness to use a resilience hub to gather critical resources and being categorized as "People with disabilities" and "Women". Moreover, there was a significant association between the willingness to use a resilience hub as a place to gather information and being categorized as women, households with children, and/or older adults. Figure 8 displays the percentage of intended usage of a resilience hub to gather information about disasters. The results indicated that those classified as women, households with children or older adults had higher percentages of likelihood to use a hub as an information center during a disaster than their respective non-underserved groups (non-women, non-household with children, non-older adult). Additionally, low-income was the only underserved group whose percentage was smaller compared to its respective non-underserved group.

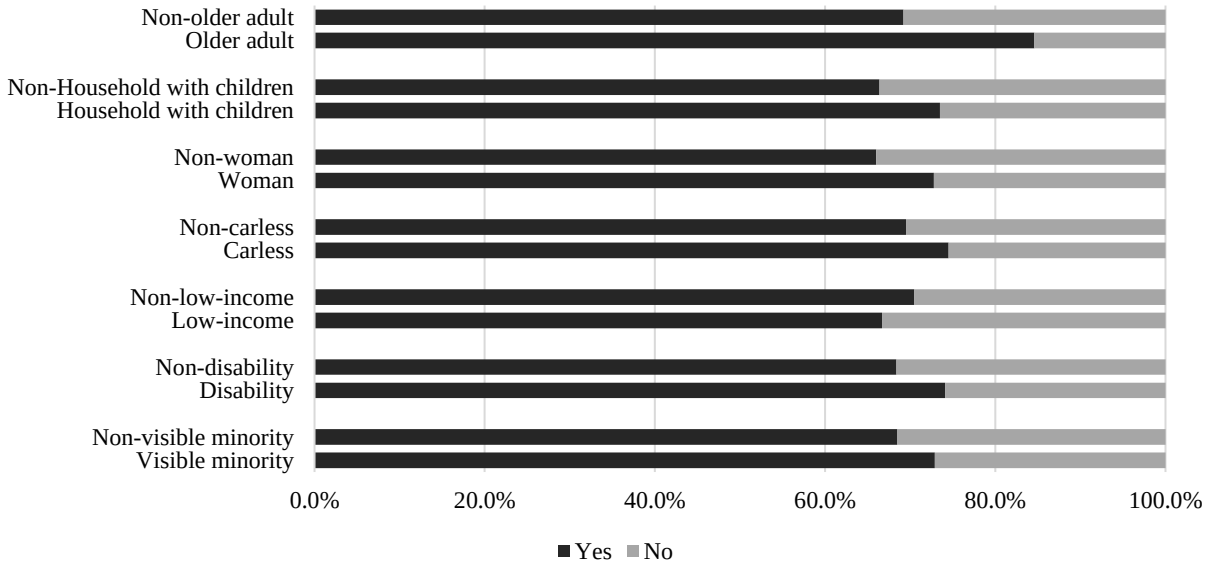

Figure 8 - Would use a resilience hub as a place to gather information during a disaster

4.5) Resilience Hub Accessibility by Underserved Group

We summarized the stated preference of mode choice selection during normal conditions and emergencies by the survey respondents in Table 9. Additionally, we calculated the Euclidean distance between participants' residences and the place that they chose as a potential location for a resilience hub. To understand the results better for each group, we used median distance as a measure of central tendency instead of average distance, which is more sensitive to extreme values. We highlight that the survey respondents could select any location for a resilience hub within their neighbourhood. The location could be a landmark, a building, or an address.

Table 9 - Mode choice during normal conditions and emergency conditions by underserved group

	Visible minorities	**People with disabilities**	**Low-income households**	**Carless residents**	**Women**	**Households with children**	**Older adults**
Distance (median in km) between resilience hub and residence	**2.2**	**1.5**	**1.7**	**2.4**	**1.5**	**1.7**	**1.6**
Sample size	*240*	*184*	*146*	*40*	*428*	*377*	*28*

Median distance between residence and resilience hub by mode in normal condition (km)							
Personal vehicle	**2.7** *N = 160*	**1.5** *N = 123*	**1.4** *N=92*	**5.7*** *N=9*	**1.7** *N=286*	**2.1** *N = 252*	**1.1** *N=15*
Public Transit (Bus, rail, micro-transit)	**3.1** *N = 19*	**2.5** *N =18*	**2.8** *N=12*	**2.7** *N=11*	**2.3** *N=26*	**1.6** *N = 30*	-
Walk	**0.6** *N = 26*	**0.7** *N=26*	**0.7** *N=22*	**0.7** *N=15*	**0.6** *N=75*	**0.6** *N = 44*	**0.4** *N=13*
Shared mobility (Carpooling, Ridesourcing, Carsharing, rental car)	**1.9** *N = 12*	**3.2** *N=7*	**2.3** *N=6*	**4.4** *N=6*	**1.8** *N=10*	**1.5** *N = 20*	-
Other	-	-	**14.4** *N=2*	-	**1.3** *N=1*	**5.2** *N = 2*	-
Mode Choice - Normal condition							
Personal vehicle	72.2%	66.8%	71.2%	20.5%*	71.1%	72.0%	51.6%
Public Transit (Bus, rail, micro-transit)	9.4%	10.9%	7.7%	27.3%	7.1%	9.2%	0.0%
Walk	11.4%	16.1%	15.3%	38.6%	17.9%	11.4%	44.7%
Shared mobility (Carpooling, Ridesourcing, Carsharing, rental car)	6.9%	6.2%	4.7 %	13.6%	3.8%	6.8%	2.6%
Other	0.0%	0.0%	1.2%	0.0%	0.2%	0.5%	0.0%
Sample size	*245*	*211*	*170*	*44*	*476*	*411*	*38*
Mode Choice - Emergency condition							
Personal vehicle	82.2%	75.5%	73.8 %	16.0%*	81.1%	79.5%	78.6%
Public Transit (Bus, rail, micro-transit)	2.7%	6.4%	5.6 %	16.0%	4.0%	3.5%	0.0%
Walk	8.9%	11.8%	11.2%	48.0%	7.3%	5.7%	17.9%
Shared mobility (Carpooling, Ridesourcing, Carsharing, rental car)	4.8%	2.7%	9.4 %	12.0%	5.2%	8.7%	3.6 %
Other	1.4%	3.6%	0.0%	8.0%	2.4%	2.6%	0.0%
Sample size	*146*	*110*	*107*	*25*	*248*	*229*	*28*

**Individuals may have misinterpreted the mode choice question ("Please indicate what would be your first 2 options of transportation mode to go to this resilience hub during normal conditions and during an evacuation") or considered access to a vehicle (e.g., via someone they knew) as a personal vehicle.*

The analysis of the distance between resilience hubs and respondents' residences revealed that individuals from all underserved groups tended to choose nearby locations, generally due to the construction of the question (asking for a hub location within their neighbourhood). When looking at the distance based on mode of transportation, those who preferred walking to reach the resilience hub selected locations even closer to their residences, ranging from 0.4 to 0.7 km. Individuals relying on public transit were more likely to choose locations further away than those who would walk or use personal vehicles to travel to a resilience hub. For instance, visible minorities who would use personal vehicles chose locations 4.5 times further away than those who would walk. Moreover, they were the underserved group with the longest median distance within the public transit and personal vehicle categories, while carless individuals had the longest median distance for shared mobility. Women were the only underserved group whose median distance for public transit was shorter than the distance for personal vehicles.

During normal conditions, using a personal vehicle was the first preferred mode choice for all underserved groups, except carless individuals. About 72% of the individuals belonging to visible minorities, low-income households, women, and households with children would use personal vehicles to reach the resilience hub. Walking emerged as a popular mode among older adults (44.7%) after personal vehicles (51.6%). Furthermore, it was the first option for the carless group (38.6%) and the second option for all other groups. This suggests that these groups would benefit if resilience hubs were closer to their residences. Carless residents presented the highest percentage of likelihood to use public transit to reach resilience hubs during normal conditions compared to other underserved groups. However, public transit would meet key mobility needs for some participants of all groups, ranging between 7.1% to 10.9% for each group.

During an emergency, personal vehicles remained the most popular mode choice for all groups except carless individuals. Walking emerged as the primary choice for carless individuals (48.0%) and the second most chosen mode for all other groups, except households with children who preferred shared mobility. In comparison to other underserved groups, carless residents accounted for the highest percentage of those who would use public transit to access resilience hubs during an emergency. Noting differences in the mode choice under normal and disruptive conditions, transit choice decreased among all the underserved groups during an emergency, and the use of personal vehicles increased among groups with the exception of the carless group who showed an increase in walking.

5) POLICY RECOMMENDATIONS

Based on the survey results and our analysis, we offer several key recommendations to assist in developing and implementing resilience hubs. These recommendations are based on the following factors: 1) resilience hub location, 2) resilience hub services, 3) access to resilience hubs, and 4) resilience hub usage. We first discuss general recommendations for all underserved groups, followed by specific recommendations for each underserved group. A summary of the recommendations can be found in Table 10, which also includes evidence from the survey results that supports them.

5.1) Location and Transportation Services

While the process of prioritizing locations will differ with each jurisdiction, previous literature has shown that resilience hubs should be established in already well-utilized locations (Baja, 2019; Ciriaco & Wong, 2022). As such, we recommend that jurisdictions select locations that are well-known by the community, especially by underserved groups, to promote higher usage during normal conditions and emergency scenarios. In addition, existing locations such as community centers, community leagues, and libraries could be retrofitted to serve as resilience hubs. This will ensure a cost-effective approach to creating resilience hubs while leveraging locations that are already well-established and familiar to the surrounding communities. Regarding the distance, all underserved groups preferred resilience hubs relatively close to their residences, with low-income households and older adults preferring the closest resilience hubs. Therefore, jurisdictions should prioritize building resilience hubs near underserved groups to equitably meet the needs of community members.

In the design and selection of resilience hubs, accessibility and connectivity play crucial roles. Integrating transportation systems such as bus routes, rail lines, and other public transportation options is essential to ensure easy and safe travel between hubs and residences (Trivedi, 2018). Moreover, previous research has shown that multimodal transportation options play a vital role in addressing social equity issues (Wang et al., 2021). This is because they offer accessible and affordable transportation choices, regardless of individuals' socioeconomic background (Carpentieri et al., 2020). Our results indicate that public transit would remain a likely transportation option in both normal and emergency conditions, especially for certain underserved groups, such as carless individuals and people with disabilities. As such, we recommend that jurisdictions integrate public transportation systems into both resilience hub and evacuation planning to ensure equitable travel during emergencies. This will ensure that underserved groups, particularly those with limited access to private vehicles, can reach resilience hubs during normal conditions and emergencies and receive the necessary support and resources. For long-term benefits, co-planning and co-locating transit centers, mobility hubs, and affordable housing with resilience hubs could lead to important sustainability, resilience, and equity benefits (Zhou et al., 2019). Additionally, shared mobility options should be included in evacuation plans as they were the second most selected option for households with children during emergencies.

Finally, among transportation services and resources for resilience hubs, underserved groups, particularly older adults, people with disabilities, and carless residents, prioritized individual accessibility features. As such, we recommend that public transit and other transportation systems connected to resilience hubs be equipped with accessible features such as lifts, low-floor buses, and priority seating. Partnerships

with paratransit vehicles may prove effective in meeting the transportation needs of people with disabilities and older adults, especially in emergency scenarios.

5.2) Hub Services and Usage

Regarding services during an emergency scenario, three main services were prioritized by all underserved groups within our study: temporary shelters during disasters, backup power, and support for reuniting families. As noted by Mardis et al. (2021), hazard risks vary across locations and population groups. Therefore, we recommend that jurisdictions perform risk assessments to develop an understanding of temporary shelter requirements and emergency resources considering current and future hazards in their particular locations. Moreover, we recommend that the shelters accommodate older adults and people with disabilities' needs, ensure that information can be easily accessed by visible minorities that may not speak the country's official language, and is easily accessible by different modes of transportation to accommodate carless individuals needs, as these are the underserved groups that presented highest percentages of likelihood to use a hub as a shelter. The location infrastructure and operational capacity should be sufficient to serve as a temporary shelter during a disaster, though additional shelters may be needed for overnight stays. In communities with a higher number of low-income families, the resilience hub will need to ensure sufficient distribution of critical resources during a disaster, due to this group's high usage of hubs.

During normal conditions, basic services such as water, food banks, and showers were highly prioritized by underserved populations. Providing these basic needs at resilience hubs has been shown to promote equity and resilience in jurisdictions such as Hawai'i, San Francisco, and Detroit (Neighborhood Empowerment Network, 2018; Sands, 2021; Vibrant Hawaii, 2020). We recommend that resilience hubs connect with food banks and integrate the growth of local foods to cater to the resident's basic needs. The provision and maintenance of showers and restrooms are also essential to the operation of resilience hubs both during normal conditions and during disasters. We recommend that resilience hubs located in low-income communities ensure daily basic services, as they are the group most likely to use resilience hubs during a normal day.

Table 10 - Policy recommendations

Policy Recommendations	Highest benefiting underserved group (s)	Evidence
Locate resilience hubs within neighborhoods	All underserved groups	Underserved groups generally indicated a preference for having resilience hubs close to their residences with people with disabilities and women selecting the lowest median distance of 1.5 km between resilience hubs and residences.
Locations selected for retrofitting into resilience hubs should be well-known and already well-utilized by the community (e.g., community centers)		Underserved groups exhibited high satisfaction in retrofitting community centers, recreation centers, community leagues, libraries, and schools/universities into resilience hubs.
Integrate multimodal transportation systems into resilience hub design		Walking was the second most-chosen option for accessing resilience hubs during a disaster across most underserved groups. Public transit and shared mobility were also moderately chosen by several groups (e.g., carless

		residents, households with children).
Ensure the presence of key services and programs that support the community during normal conditions (e.g., food banks, basic health services)		Basic services such as water, showers, and foodbanks were considered important across all underserved groups. Health services and urgent care were particularly ranked as important by older adults (92.9%) and people with disabilities (82.8%).
Resilience hubs should offer emergency services (e.g., shelters back-up power, critical resources) and may be included in evacuation planning to strengthen community resilience during emergency events		A significant number of participants from all underserved groups stated that they would likely use a resilience hub during a disaster with many ranking temporary shelters and back-up power as very/mostly important emergency services.
Ensure public transit routes are available to travel to/from resilience hubs	Carless residents, low-income households, older adults	Transit connections to resilience hubs were considered important by underserved groups, particularly carless residents (61.7%).
Resilience hubs should be accessible through safe and well-designed active transportation infrastructure, including sidewalks, crosswalks, bike lanes, and bike parking facilities		Carless residents (57.5%), low-income households (57.5%), and older adults (66.7%) strongly indicated that it was very/mostly important for resilience hubs to be located within walking distance from residences. Many carless residents (38.6%) and older adults (44.7%) would walk to resilience hub during normal conditions, and almost half of the carless individuals (48.0%) would walk to a hub during an emergency. Low-income households ranked bike sharing and bike parking services as very/mostly important (35.5% and 34.4%, respectively).
Design resilience hubs to meet accessibility standards for individuals with disabilities, and older adults, and/or ensure universal design	Individuals with disabilities, older adults	Accessibility for individuals with disabilities was considered an important transportation service for resilience hubs by most survey participants, particularly older adults (82.1%) and people with disabilities (76.7%). 56.4% of older adults and 56.0% of people with disabilities considered transit connections to resilience hubs as very/mostly important.
Public transit and other transportation systems connected to resilience hubs should be equipped with accessibility features (e.g., lifts, low-floor buses, and priority seating) to accommodate people with disabilities and older adults		
Train public transit staff to support individuals with disabilities and		

older adults during an evacuation in the event of a disaster		
Ensure that resilience hubs feature sufficient car parking spaces including those that meet accessibility standards for individuals with disabilities	Women, individuals with disabilities	More than 70% of women surveyed would use personal vehicles to access resilience hubs during normal and emergency conditions. Women (60.6%) and people with disabilities (58.2%) identified car parking as an important resilience hub feature.
Resilience hubs should offer support for reuniting families during an emergency event	Households with children	Households with children (74.1%) ranked family reunification as an important service to be offered by resilience hubs during emergencies.
During emergencies, resilience hubs should provide critical resources as well as up-to-date information in different languages to accommodate non-English speakers.	Low-income households, visible minorities	Low-income households (67.2%) were most likely to use a resilience hub as a place to gather critical resources during disasters, compared to other groups. Visible minorities (73.0%) were highly likely to use resilience hubs to gather information about disasters.

6) LIMITATIONS

Despite the important insights obtained in this study, several limitations should be noted. First, because the survey utilized an online format, individuals without reliable internet access and those with limited digital literacy may have been excluded from participation. To reduce this issue, we collaborated with community leagues, the Edmonton Food Bank, and the City of Edmonton for survey distribution. Second, the convenience data collection may have self-selection bias since people opted into the survey. Furthermore, some underserved groups (i.e., older adults and carless residents) were underrepresented in the study, which could affect the generalizability of results. Future studies should employ surveys with specific quotas for each underserved group to ensure that each group has enough observations that are representative. Furthermore, this research was conducted for the Edmonton Metropolitan Region which may not be representative of a variety of other metropolitan areas in North America. Specific studies in each region are likely required.

We also recognize limitations in the spatial calculations employed in this study. First, the distance between the respondents' selected resilience hub location and their residence was calculated based on Euclidean distance which may not accurately reflect travel distance or travel time. Additionally, some participants were excluded from the analysis since they: 1) did not select a location for either their residence or the resilience hub; or 2) selected hub locations that were outside the Edmonton Metropolitan Region. Finally, we acknowledge that a spatial optimization of the respondents' residences was not conducted when identifying potential resilience hub locations. Future studies should consider optimizing resilience hub locations based on community-led criteria and the spatial distribution of underserved groups. This spatial understanding could be further coupled with discrete choice analysis models that better predict the underserved groups' behaviour and mode choices in relation to resilience hubs.

7) CONCLUSION

This study contributes to the understanding of resilience hubs and their role in promoting community resilience during emergency situations and normal conditions. By investigating the needs and behaviour of underserved groups, including low-income households, older adults, households with

children, visible minorities, people with disabilities, and carless individuals, we identified key characteristics that these groups seek in a resilience hub. Our findings provide valuable insights into the design and implementation of resilience hubs to effectively meet diverse socio-demographic needs. We also investigated how underserved groups differ from their respective non-underserved group regarding resilience hub usage. Furthermore, we analyze how underserved groups behave differently from their respective intersectionality groups and non-intersectionality groups.

The results found that most survey participants are part of one (29.9%), two (35.5%) or three (20.6%) underserved groups. The chi-square testing indicated multiple associations among underserved groups, especially among people with disabilities. However, the Phi test uncovered that these associations were weak. Due to possible intersectionality, we ran t-tests to investigate if individuals who are part of intersectionality would behave differently from the component underserved groups and from the non-intersectionality groups. The result uncovered that only 13.3% of the possible combinations were statistically significant (had different means), indicating that most groups do not behave differently regarding resilience hub usage. Some key results of our study regarding usage, transportation, and services include the following:

- Participants of underserved groups exhibited high willingness to use a resilience hub during an emergency.
- Among all underserved groups, low-income households would use resilience hubs more frequently during normal conditions.
- While mode choice to/from hubs generally reflects the community's existing mode share, carless individuals have much higher walk and public transit shares compared to other groups.
- Public transit usage was lower for emergency conditions than normal conditions.
- All underserved groups identified accessibility for individuals with disabilities as the most important transportation-related service/resource at resilience hubs.
- The use of a resilience hub as a temporary shelter and a gathering place for critical resources during a disaster showed the most significant statistical differences among comparisons of underserved groups, intersectionality and non-intersectionality.
- During normal conditions, households with children, low-income households and visible minorities would be more likely to use a hub than their respective non-underserved groups.
- Visible minorities, people with disabilities, women, and older adults would be more likely to use a resilience hub as an emergency shelter than their respective non-underserved groups.

Based on our results, we recommend that resilience hubs be located within the community and prioritize essential services such as the availability of water, restrooms, food banks, accessibility for people with disabilities, and back-up power. Additionally, these hubs should serve as temporary shelters during disasters, given underserved groups' willingness to use hubs in this situation. Our modal analysis highlights the unique needs of each group during normal conditions and an emergency and continues to suggest the important of multi-modality in fulfilling trips. Altogether, the research points to a clear need to integrate transportation with resilience hub design and placement. This includes both site-specific and network-level changes to make resilience hubs operational and useful for those who need them most.

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.

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