Travel Behavior and Community Needs for Resilience Hubs

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ABSTRACT

Communities continue to experience significant and damaging disasters, which has prompted governments to devise solutions to protect lives and reduce overall impacts. One emerging strategy is the development of resilience hubs, which can serve the community during disasters and everyday conditions. However, most research and guidance for resilience hubs remains largely theoretical and do not account for community needs. Moreover, research and practice have not fully integrated transportation into resilience hub design, such as how travel to and from resilience hubs is facilitated.

Consequently, we conducted an empirical study leveraging statistical tools and models using data from a survey of Edmonton, Canada residents (n=950), conducted between November 2022 and February 2023. Through descriptive statistics and discrete choice models, we uncover important results related to resilience hub usage, transportation design, and mode choice in both normal and disaster conditions. Modeling results found a strong influence of household characteristics on the normal usage of resilience hubs, while individual characteristics were more influential on hub usage as a temporary shelter. No clear patterns of variables influenced mode choice (travel to/from a resilience hub), except the insignificance of resilience hub usage (i.e., trip purpose). For mode, the results showed a strong preference for private vehicles, yet still a relatively high multi-modal split (e.g., walking, transit, shared mobility). Residents also preferred highly localized resilience hubs with a variety of transportation options, services, and amenities. Using these results, we provide a series of practice-oriented recommendations for communities in the design and operations of resilience hubs.

Keywords: Resilience hubs, disasters, community resilience, accessibility, equity, travel behavior

1. INTRODUCTION

In recent years, communities have been challenged by multiple disasters (climate and non-climate related), requiring them to rethink their planning, design, and infrastructure to improve preparedness, response, and recovery. One key challenge is providing sufficient resources, shelter, and information to people affected by a disaster, which requires coordination and transportation access. In this context, one nascent idea is to create resilience hubs, which act as localized, physical places for people to receive assistance and temporary accommodations during disasters *and* provide a range of services during everyday conditions (*1*, *2*). Resilience hubs aim to increase a community's resilience and preparedness, while also increasing social connection within the area (*1–4*).

Multiple communities, particularly in the United States, are building or considering implementing resilience hubs to serve communities daily and during disasters (*5–9*). A literature review conducted by (*2*) uncovered that the majority of existing research and practice has focused on resilience hubs' concepts, characteristics, and functionalities. At the same time, the review also determined that transportation is not being integrated or considered into resilience hub design or operations. For example, little evidence exists on how the communities' needs were assessed, how the hub location was determined, and if accessibility, mobility, or the overall transportation network were considered for the hubs. Consequently, a lack of empirical evidence exists on how resilience hubs might be designed to meet communities' needs and how individuals are going to travel to and from resilience hubs. This gap in research and practice motivated several research questions:

1) How will people use resilience hubs in disasters and everyday conditions?
2) What types of transportation services and resources should be considered in resilience hubs designs, planning, and operations?
3) What modes of transportation will be used by individuals to access a resilience hub in disasters and everyday conditions?

To answer these questions, we surveyed 950 residents of the Edmonton Metropolitan Area in Alberta, Canada between September 2022 and February 2023. We first start this paper by briefly reviewing the literature on resilience hubs. We then explain the data collection and methodology, which leverages simple descriptive statistics and discrete choice modeling to identify resilience hub usage, transportation needs, and factors that influence the usage of resilience hubs and mode choice. After presenting the results of our analysis, we end the paper with discussions, policy recommendations, and a conclusion.

2. LITERATURE REVIEW

Resilience hubs are community-serving facilities developed to support residents, by providing communication coordination, social support services and programs, and resource distribution before, during, or after a disaster (*1–4*, *10*, *11*). Studies have revealed that these spaces encompass a variety of goals, such as improving residents' quality of life, increasing communities' preparedness for emergencies, providing climate change mitigation, and increasing social cohesion, equity, and mobility (*1–4*). Additionally, literature suggests that resilience hubs may have three operational modes (*12*, *13*): 1) normal mode; 2) response mode; and 3) recovery mode. Most of the year, resilience hubs operate in normal mode, switching to response mode when the community needs to react to a disruption. After the disruption, the operational mode transitions to recovery mode and converts back to the normal mode after the community has recovered.

Regarding placement, literature has found that location is a critical aspect of the resilience hub planning phase to ensure community trust and accessibility (*2*, *4*, *12*). Thus, most literature suggests that existing well-known and well-utilized places (e.g., recreation centres, libraries, universities, government buildings) should be prioritized to be retrofitted (or newly built) as resilience hubs. Moreover, literature recommends that the selected locations should be able to serve the community year-round *and* support

residents during a disaster (*3*, *4*, *11*). The construction of a new building to serve as a resilience hub can also be an option, but it may require more financial investment.

As resilience hubs are designed to meet community needs, neighborhoods with different characteristics may have different hubs with varying characteristics. Moreover, hubs can differ based on the type and severity of disasters that impact communities, cultural contexts, and land use (*4*, *12*, *14*). Although, resilience hub design may be unique, literature pointed to key elements that should be considered (*2*, *15*, *16*). For instance, resilience hubs should offer services and programs that improves community's resilience, preparedness, and quality of life. Hubs should also be located in a safe location (from the hazard) and provide reliable communication to increase response, preparedness, and community cohesion. More specific elements that have been provided by current existing resilience hubs can be found in (*1*, *2*, *12*) .

Transportation services are essential to enable people and goods to reach resilience hubs during normal conditions and during an emergency. Two transportation elements were cited by (*12*) to provide guidance for hub placement: 1) locating hubs near accessible pedestrian areas, and 2) placing hubs close to evacuation routes or major roads (*12*). Despite these two guidelines, the literature review on resilience hubs conducted by (*2*) found that there is a lack of information, understanding, and analysis on how transportation services are being integrated into the functionality of resilience hubs. Moreover, we find a general disconnect of the transportation field to the resilience hub field, despite transportation's critical role in the success of hubs. To our knowledge, an empirical analysis of transportation needs, travel behavior, and resilience usage (more broadly) has not yet been conducted in either field. As such, we conduct this analysis by using survey responses from community residents, which can be replicated across different geographies, hazard types, and contexts.

3. METHODOLOGY

In this section, we present the data collection method, descriptive statistics, and the discrete choice modeling methodology.

3.1. Data Collection

To conduct an empirical study focused on resilience hubs, we collected data for the Edmonton Metropolitan Area, Canada, which is one of the largest, northern-most regions in North America (populated with 1.4 million people). With a diversified economy and serving as the primary gateway to northern Canada, the Edmonton Metropolitan Area is a key region for Canadian and international business, education, and industry. While the Edmonton region does not have consistent or large-scale disasters, hazards including flooding, wildfires, smoke, tornados, blizzards, and extreme cold can still cause significant and region-wide disruptions. Edmonton also has a significant amount of industrial activities (especially related to oil and gas) and logistics via major highways and railways, which increases vulnerability related to hazardous materials, chemical spills, and industrial fires.

Our data collection in the Edmonton Metropolitan Area was conducted from September 2022 to February 2023 through convenience and market research panel samples. The convenience survey was distributed online with the help of local agencies and organizations such as community leagues, the City of Edmonton, and the Edmonton Food Bank. Organizations shared the survey link via social media, websites, newsletters, and other digital platforms. The convenience survey gathered 162 total viable responses after removing for people outside of the metropolitan area. Respondents were incentivized with the opportunity to win one of the ten $100 (Canadian dollar) gift cards. To increase sample size, a market research panel was conducted by Qualtrics, who contacted people living in the Edmonton Metropolitan Area to fill out the survey. Respondents were provided an incentive to participate through a rewards program. The panel gathered 944 responses.

Both surveys were carried out via the Qualtrics survey platform, and the questionnaire was designed to ask about individuals'/households' sociodemographic characteristics, their evacuation behaviours, and opinions about resilience hubs. Data cleaning was conducted to remove uncompleted responses, fast responses (≤ 3min), patterned/inconsistent responses, and responses that provide a location outside the Edmonton Metropolitan Area. The final sample consisted of 950 respondents.

3.2. Descriptive Statistics and Discrete Choice Analysis

Descriptive statistics were conducted to understand the residents' needs and travel behavior. Statistics were developed for resilience hub placement and transportation needs. We also asked a question about where respondents would place a resilience hub. We used this proposed hub location and the respondent's residential location to calculate the Euclidian distance (via a Python code), which we then broke down by mode choice. To better understand individuals' willingness to use a resilience hub within their neighbourhood, we developed three binary logit models. For the analysis, we divided the decision to use the hub into a binary variable, with choice 1 being very or somewhat likely to use a resilience hub and choice 0 being all other options. We first added all independent sociodemographic variables that were not correlated to each other (correlation coefficients under 0.3), variables related to travel behaviour, and trust and compassion variables. After this, we followed guidance from (*17*) in variable selection for factors that were behavioural relevant, statistically significant, or met a priori expectations. We note that we retained some statistically insignificant variables due to their behavioural relevance and because we opted for decreased model bias (rather than high efficiency). The models developed for the 950 respondents were:

- Use of resilience hub during normal conditions;
- Use of resilience hub as a temporary shelter during a disaster; and
- Use of resilience hub as a place to gather critical resources during a disaster.

In addition, we developed two multinomial logit (MNL) models to assess mode choice to reach resilience hubs during normal conditions and emergencies. The mode choices were clustered as personal vehicles, public transit, sharing mobilities, and active modes. For multinomial models, we excluded those that did not selected one of the available mode choices. This changed our sample size, particularly for mode choice during an emergency. Our models use a sample of 856 observations for normal conditions and 492 observations for emergencies. We believe that the reduction in observations for emergency conditions was due to the similarity in questions, leading people to skip the emergency question. We followed the same approach as the binary logit models related to correlation removal, variable section, and model finalization.

We used the Python package Biogeme 3.11 (*18*) to develop the binary and multinomial logit models. As a limitation, we note that we decided on simpler models as they are behaviorally consistent, parsimonious, and easy to interpret for government agencies, policymakers, and decision-makers. Future research can use the same dataset for other modeling analyses, including testing other discrete choice modeling forms and hypotheses.

4. RESULTS

This section presents the characteristics of respondents, descriptive statistics analysis of resilience hubs, and results from the binary and multinomial logit models for the decision to use resilience hubs and mode choice.

4.1. Characteristics of Respondents

We found that despite sampling bias due to data collection methodology, key demographic characteristics are similar to the 2021 Canadian census results for Edmonton Metropolitan Area (*19*). For instance, the average age of the sample is 38 years, and the census indicated 38.8 years. Additionally, 28.3% of the respondents are visible minorities (following the Employment Equity Act specification), while the census

had 33%. In both, households have an average of 3 people. Although the survey collected household income in 2021 and the census collected household income in 2020, both show similar distribution, though our sample had a larger proportion of residents making $100,000 and over (in Canadian dollars). According to our survey and census data, most individuals are employed (78.9% and 60.0%, respectively), which indicates an undersampling of students, retirees, and unemployed individuals. Our survey was 54.5% women and 43.2% men, a slight oversampling of women compared to the 2021 Census.

Furthermore, the survey found that almost 95% of the respondents have at least one automobile in their household and 71% have at least one bicycle, which aligns with the general transportation patterns of auto-centric Edmonton. In addition, most households have access to an Internet connection (98%). Regarding level of education, 71.8% of respondents had completed a college/diploma, bachelor's, graduate or professional degree, or doctorate.

4.2. Descriptive Statistics

We first asked respondents if they had heard about resilience hubs before and asked them to select characteristics that would best describe a resilience hub. We found that most respondents had never heard about resilience hubs (**Figure 1)**. For characteristics, hubs were often described to provide emergency sheltering, be a community-serving physical space, offer response services during disasters, and be a central location to access a variety of services (see **Figure 2)**. We noted that these characteristics align with the description of resilience hub found in the literature (e.g., *1*, *2*). Regarding locations for a resilience hub (**Figure 3**), participants were very or somewhat satisfied if resilience hubs were located at a variety of different places, especially in community centers (recreation centers), schools/universities, libraries, and community leagues.

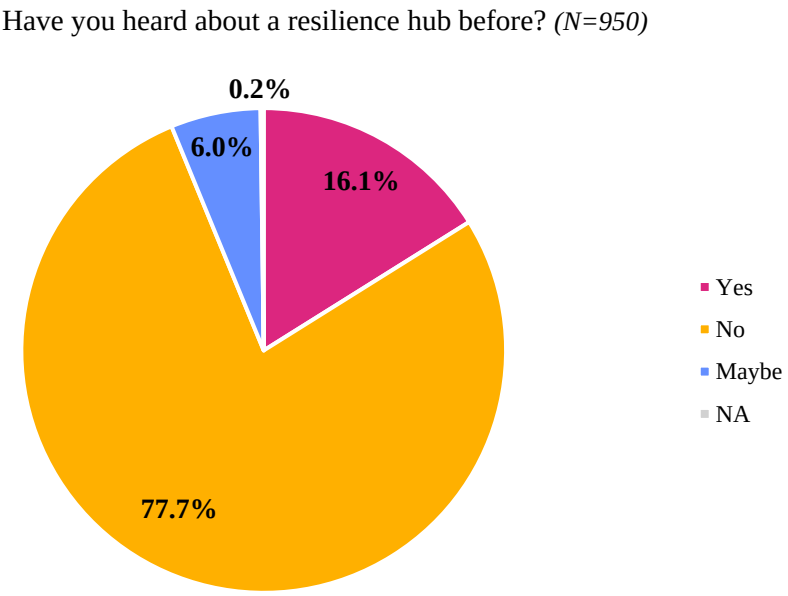

Figure 1 - Previous knowledge about resilience hub

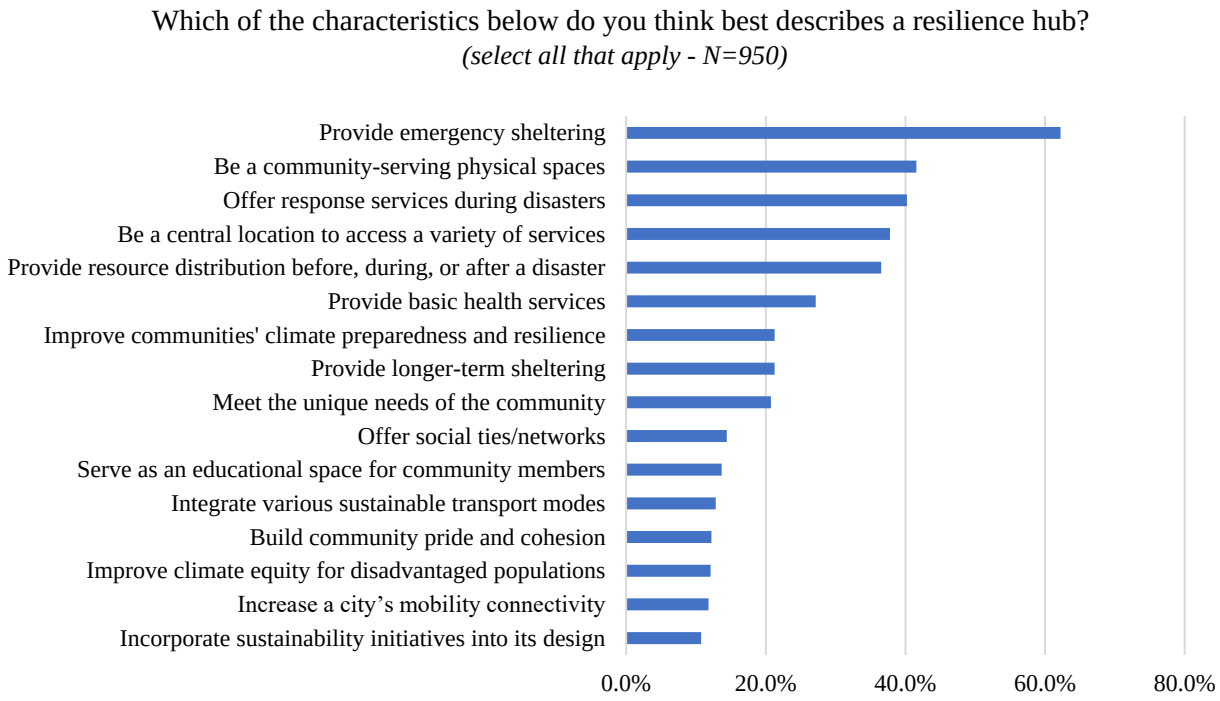

Figure 2 - Characteristics that individuals believe that best describes a resilience hub

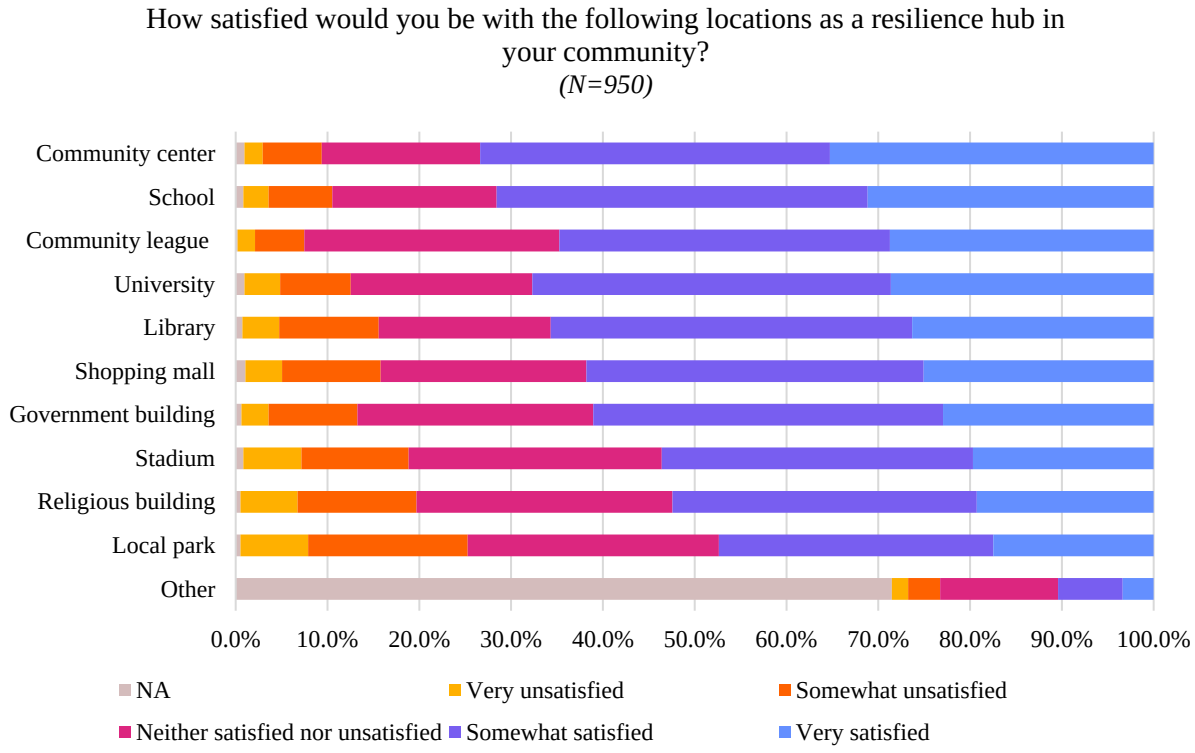

Figure 3 - Preferred places to locate a resilience hub

More than half of respondents stated that resilience hubs would be very or mostly important for their community. Further, individuals stated that resilience hubs would very likely or somewhat likely help their community to be more resilient (64.5%), meet the needs of their neighbours on a daily basis (56.0%), and increase social cohesion in their communities (58.6%). Regarding how individuals intended to use the resilience hub (**Figure 4**), 41.4% are very or somewhat likely to use it during normal conditions and 61.2% to use it as a temporary evacuation shelter. Additionally, during a disaster, individuals would be very or somewhat likely to gather information about the disaster (69.8%) and gather critical resources (63.9%) at the resilience hub. The results also suggest that they are more likely (very/somewhat) to volunteer at a resilience hub during relief efforts (60.2%) than during normal conditions (44.4%).

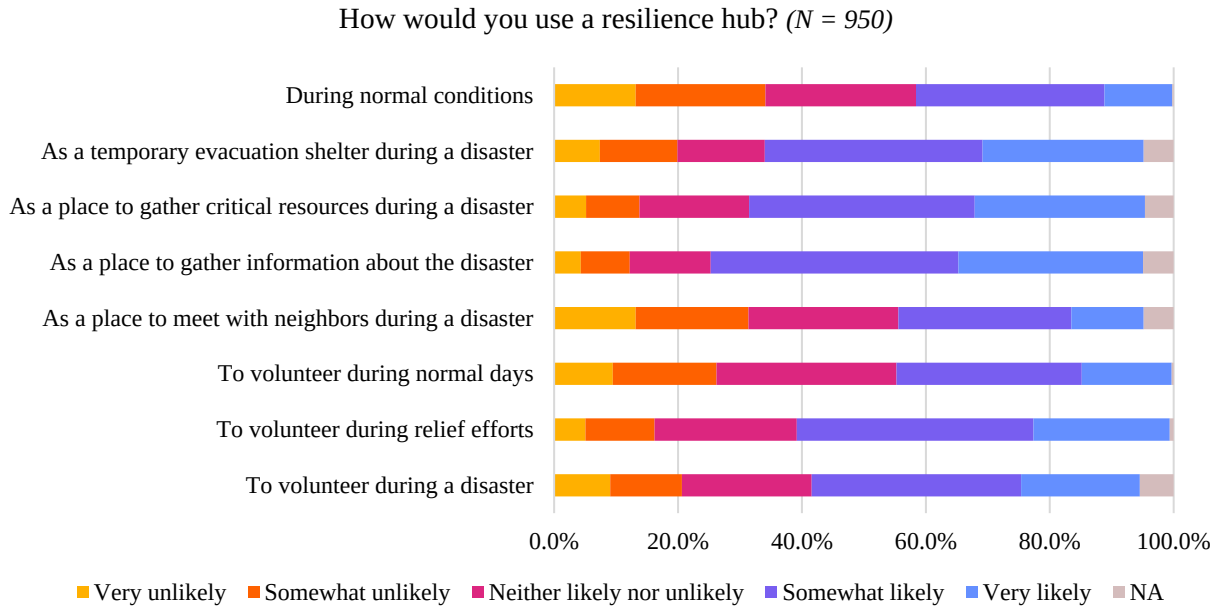

Figure 4 - Resilience hub usage

Respondents also indicated preferences for transportation services that should be provided by resilience hubs (**Figure 5**) and their primary mode choice to go to a resilience hub (**Table 1**). Accessible infrastructure for individuals with disabilities was the most prevalent service among transportation services. This service was even more important for older adults and people with disabilities, with 82.1% of older adults and 76.7% of people with disabilities indicating it as very/mostly important. As seen in **Figure 5**, car parking and public transit connection services had similar preferences. However, as noted in **Table 1**, personal vehicles would be used by a larger percentage of the respondents (70.7% under normal circumstances and 79.0% during an emergency). Within the general population, 8.1% would use public transit (e.g., bus, rail, microtransit) to reach a hub during normal days, while 27.3 % of carless individuals would use it. Moreover, transit connections were the second most important transportation service indicated by carless people. **Figure 5** also shows that individuals considered providing heated bus stop more important than bike sharing and bike parking services. Likewise, more people cited parking for electric vehicles as a very or mostly important service than services related to bicycles. The auto-centric design of the Edmonton Metropolitan Region may be affecting this prioritization.

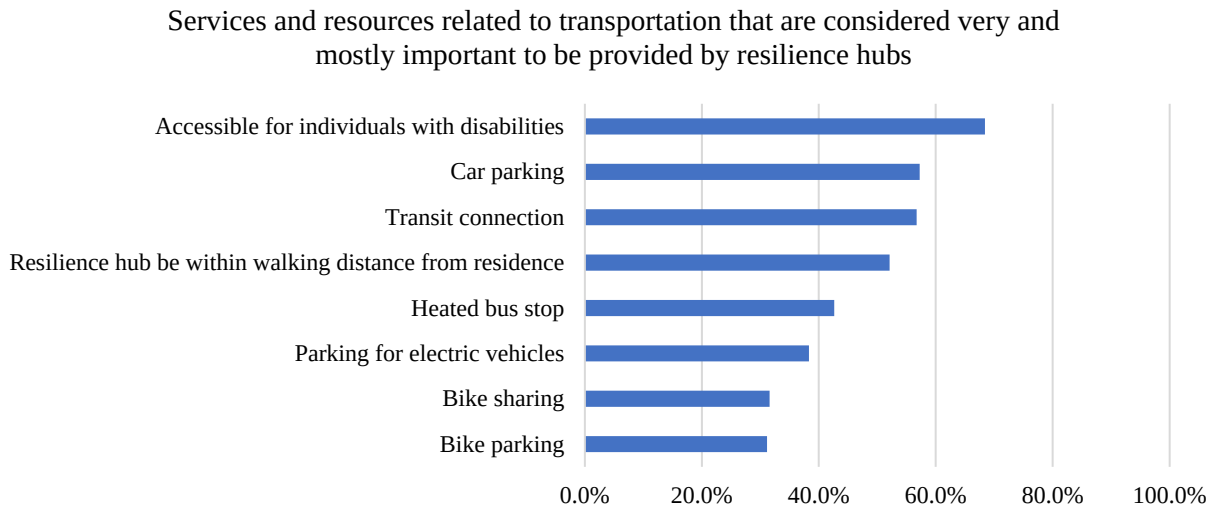

Figure 5 - Transportation services

TABLE 1 – Transportation mode choice and resilience hub distance

Distance between resilience hub and residence		
	Median (km)	**Sample size**
	1.7	779
Distance between residence and resilience hub by mode choice during normal condition		
	Median (km)	**Sample size**
Personal vehicle	2.0	512
Public Transit (Bus, rail, microtransit)	2.5	57
Walk	0.6	113
Sharing mobility (Carpool, ridesource, carsharing, rental)	1.9	34
Others (motorcycle, bike, recreational vehicle)	5.2	6
Percentage of modal choice		
	Normal condition	**Emergency condition**
Personal vehicle	70.7%	79.0%
Public Transit (Bus, rail, microtransit)	8.1%	4.0%
Walk	14.8%	8.5%
Sharing mobility (Carpool, ridesource, carsharing, rental)	5.7%	6.5%
Others (motorcycle, bike, recreational vehicle)	0.7%	2.0%
Sample size	*860*	*496*

As seen in **Figure 5**, individuals indicated that it is very or mostly important that resilience hub be within walking distance from their residences. Moreover, walking was the second preferred mode choice to reach a hub during normal conditions or disasters (**Table 1**). Surprisingly, walking was the first transportation mode choice for carless individuals during normal conditions (38.6%) or emergencies (48.0%). In addition, it had almost the same relevance as personal vehicles for older adults during normal conditions, with 51.6% choosing a personal vehicle and 44.7% choosing walking.

Regarding the distance between respondents' residences and locations selected to place a resilience hub, the median distance was 1.7 km, revealing a preference for closer locations. The median distance is smaller for people who would walk to a resilience hub, with the median being 0.6 km. An interesting finding is that those who would use public transit would be willing to travel slightly greater distances than those who would use a personal vehicle – 2.5 km and 2.0 km respectively.

4.3. Behavioural Modeling

We next present results from three binary logit models that were developed to determine the factors that influence individuals' choices related to resilience hub usage. **Table 2** presents the associated coefficients, signs, p-values, and significance level of each of these models. Since the decision to not use a resilience hub is the base choice, a positive coefficient indicates that the variable increases the likelihood to use a resilience hub under certain circumstances, while a negative coefficient denotes that the variable decreases the likelihood.

The first model explored the decision of whether or not to use a resilience hub during normal conditions. As seen in **Table 2**, all coefficients of this model are positive, indicating that all variables included in the model increase the likelihood to use a hub during normal conditions. The results show that those that are part of a community organization are more likely to use a resilience hub during normal conditions. Households with two or more members and households that had an income under $50,000 in 2021 are significantly more likely to use a resilience hub during normal conditions. Additionally, those that believe that a resilience hub would help increase social cohesion in their neighbourhoods are considerably more likely to use the hub than those who did not have this opinion.

The second model determines if individuals are likely to use a resilience hub as a shelter during a disaster. This model included several variables related to individual's characteristics, showing that visible minorities and individuals that have a disability are more likely to use resilience hubs as a temporary shelter during a disaster. On the other hand, those employed full-time or part-time are less likely to use resilience hubs as a temporary shelter. For household characteristics, we found that households with children are more likely to use a resilience hub as a shelter during an emergency. Results also found that individuals who stated that their neighbours would help them during a disaster or emergency are more likely to use resilience hubs during a disaster. Additionally, those that believe that a resilience hub would increase social cohesion in their neighbourhood are highly more likely to use hubs as a shelter.

During a disaster, streets can be impacted and consequently closed, impeding the flow of resources and making it important to understand who will use a resilience hub to gather critical resources during an emergency. The third model was developed to determine variables that influence the decision to use a resilience hub as a place to gather critical resources in a disaster. The results found that individuals employed full-time or part-time and young adults (35 years and under) are less likely to use a hub as a place to gather critical resources during a disaster. Conversely, women and individuals with a disability are more likely to use the hub. Moreover, those who would use an active mode (walk or bike) to reach a hub during an evacuation are significantly less likely to use a hub to gather critical resources. Regarding trust and compassion variables, individuals with strong compassion for others (in the form of helping others), those who mentioned that is possible to trust most people, and those who indicated that their neighbours would help them during an emergency or disaster are more likely to use a resilience hub as a place to gather critical resources.

TABLE 2 – Binary Logit models

Binary Logit Models

Choice 1: Neither likely nor unlikely, somewhat unlikely, very unlikely to use – Base

Choice 2: Somewhat likely, very likely to use

	Binary Logit Model 1			***Binary Logit Model 2***			***Binary Logit Model 3***		
	Use a resilience hub during normal condition			**Use a resilience hub during a disaster as a temporary shelter**			**Use a resilience hub during a disaster as a place to gather critical resource**		
Variable	*Estim. coef.*	*p-value*		*Estim. coef.*	*p-value*		*Estim. coef.*	*p-value*	
Constant	-1.73	0.000	**	-1.34	0.006	**	-1.61	0.003	**
Household Characteristics									
Household with 2+ people	0.63	0.000	**	------	------		-0.12	0.455	
Household income less $50,000 CAD (in 2021)	0.66	0.000	**	------	------		------	------	
Household has at least one child	------	------		0.30	0.036	*	------	------	
Individual Characteristics									
Individual is employed full time or part time	------	------		-0.44	0.015	*	-0.43	0.032	*
Individual is visible minority	------	------		0.38	0.015	*	------	------	
Individual with a disability	------	------		0.53	0.002	**	0.42	0.021	*
Age under 35 years	------	------		------	------		-0.43	0.003	**
Woman	------	------		------	------		0.36	0.017	*
Access to Internet at home	------	------		1.06	0.025	*	1.42	0.003	**
Part of a community organization/group, not including a Community League	0.41	0.007	**	------	------		------	------	
Use active mode (walk or bike) to go to a resilience hub during an evacuation	------	------		------	------		-0.86	0.010	*
Trust and compassion									
One of the activities that provides me with the most meaning to my life is helping others in the world when they need help (very and somewhat true)	------	------		------	------		0.59	0.000	**
It is possible to trust most people	------	------		------	------		0.46	0.002	**
My neighbors would help me in an emergency/disaster	------	------		0.46	0.002	**	0.31	0.040	*
Resilience hub									
A resilience hub would help increase social cohesion in my neighborhood	1.18	0.000	**	0.87	0.000	**	0.86	0.000	**
Number of observations	950			950			950		
ρ2 (fit)	0.11			0.11			0.16		
ρ2 (adjusted fit)	0.10			0.09			0.14		
Final Log-Likelihood	-588.22			-589.37			-553.26		

* 95% significance **99% significance

An interesting finding is that all models had the variable "believe that a resilience hub would help increase social cohesion in my neighbourhood" and it is significant and positive, indicating that these individuals are more likely to use a resilience hub. We also note that variables related to household characteristics have more influence on the willingness to use a hub during normal conditions than the willingness to use a hub as a temporary shelter. Moreover, variables related to individual characteristics have more influence on willingness to use a resilience hub as shelter than during normal days.

Besides the binary models, we developed multinomial logit models to understand individuals' primary mode choice to go to a resilience hub within their community during normal days and emergencies. **Table 3** and **Table 4** show the results of the normal conditions and emergency models respectively. In both models, the base choice is public transit. Thus, a positive coefficient indicates that the variable increases the likelihood to use a certain mode of transportation in comparison with public transit, while a negative coefficient denotes that the variable decreases the likelihood.

TABLE 3 – Multinomial logit model – Mode choice normal conditions

Choice 1: Personal vehicle (one or more vehicles)
Choice 2: Public transit (bus, rail, microtransit) - **Base**
Choice 3: Sharing mobility (carpool, ridesource, carsharing, rental)
Choice 4: Active mode (walk, bike)

Variable	**Personal vehicle**			**Sharing mobility**			**Active mode**		
	Estm. Coef.	*p-value*		*Estm. Coef.*	*p-value*		*Estm. Coef.*	*p-value*	
Constant	1.753	0.000	**	-0.213	0.494		1.427	0.000	**
Household characteristics									
Household with 2+ people	------	------		-1.374	0.001	**	-0.680	0.001	**
Household has at least one child	------	------		1.374	0.001	**	------	------	
Household has at least one older adult (65+)	------	------		0.758	0.036	*	------	------	
Individual characteristics									
Woman	0.461	0.024	*	------	------		0.907	0.001	**
Indigenous (i.e., First Nations, Métis, Inuit)	------	------		------	------		-0.783	0.063	
Age under 35 years	------	------		------	------		-0.594	0.007	**
Individual is employed full-time or part-time	------	------		------	------		-0.664	0.003	**
Long time resident (10+ years)	0.786	0.013	*	------	------		0.721	0.053	
Homeowner	------	------		-0.939	0.002	**	------	------	
Resilience hub									
Use a resilience hub during normal conditions (very or somewhat likely)	0.097	0.592		0.619	0.072		------	------	
Volunteer at a resilience hub during normal conditions (very or somewhat likely)	------	------		------	------		-0.642	0.003	**
Number of observations	856								
ρ2 (fit)	0.40								
ρ2 (adjusted fit)	0.38								
Final Log-Likelihood	-714.70								

* 95% significance **99% significance

Based on the constants in **Table 3**, individuals show some preference of using personal vehicles or active modes to reach a resilience hub during normal conditions when compared to public transit. Regarding household characteristics that influence mode choice, we found that households with more than two people are less likely to use sharing mobility and active mode when compared to public transit. However, if the household has at least one child or one older adult, the individual is more likely to use a sharing mobility mode than public transit.

Women are more likely to use personal vehicles or active modes compared to public transit. Individuals that are young adults (under 35) and those employed full-time or part-time are less likely to use active modes to go to a hub during normal conditions. Individuals that live in their current residence for more than ten years are more likely to use personal vehicles when compared to public transit. This may be due to the availability of vehicles and bicycles at home. Those that own their residence are less likely to use sharing mobility.

In testing variables related to how people would use a resilience hub, we found largely insignificant results. However, we found that people who are very or somewhat likely to volunteer at a resilience hub during normal conditions are less likely to use active modes. The results indicate further exploration in resilience usage (i.e., trip purpose) is needed within this context.

During an emergency (**Table 4**), the constant parameters indicates that individuals are more likely to use a personal vehicle or active mode to reach a resilience hub when compared to public transit. Households that have more than three automobiles are more likely to use a personal vehicle than public transit. They are also less likely to use sharing mobility or active modes in comparison to public transit. Households that have more than two individuals are more likely to use a personal vehicle in comparison to public transit.

Similar to normal conditions, young adults are less likely to use active modes to go to a resilience hub during an emergency. Individuals that have a disability are less likely to use sharing mobility than public transit. Additionally, individuals that own their residence are more likely to use personal vehicles.

Individuals who stated that are very or mostly prepared for an evacuation are less likely to use an active mode to reach a resilience hub during an emergency. Those that feel very or somewhat comfortable to use a resilience hub as a shelter during a disaster are less likely to use a sharing mobility when compared to public transit. Moreover, individuals that are very or somewhat likely to use a resilience hub as a place to gather critical resources during a disaster are less likely to use an active mode. While those that are very or somewhat likely to volunteer at a resilience hub are more likely to use sharing mobilities than public transit.

TABLE 4 – Multinomial logit model – Mode choice emergency conditions

Choice 1: Personal vehicle (one or more vehicles)
Choice 2: Public transit (bus, train, microtransit) - **Base**
Choice 3: Sharing mobility (carpool, ridesource, carsharing, rental)
Choice 4: Active mode (walk, bike)

	Personal vehicle			**Sharing mobility**			**Active mode**		
Variable	*Estm. Coef*	*p-value*		*Estm. Coef*	*p-value*		*Estm. Coef*	*p-value*	
Constant	2.076	0.000	**	0.196	0.722		1.757	0.000	**
Household characteristics									
Household with 2+ people	0.756	0.009	**	0.819	0.094		------	------	
Household with 3+ automobiles	6.572	0.000	**	-1.108	0.019	*	-1.861	0.000	**
Household with 1+ bike	------	------		------	------		0.538	0.121	
Individual characteristics									
Indigenous (i.e., First Nations, Métis, Inuit)	------	------		------	------		-0.931	0.170	
Age under 35 years	------	------		------	------		-1.496	0.000	**
Woman	------	------		-0.466	0.204		------	------	
Individual with a disability	------	------		-1.236	0.034	*	------	------	
Visible minority	------	------		-0.615	0.172		------	------	
Homeowner	0.547	0.029	*	------	------		------	------	
Preparedness for an emergency									
Prepared for an evacuation (very or mostly)	------	------		------	------		-1.155	0.030	*
My household will be impacted by a disaster in the next 5 years (very or somewhat likely)	------	------		0.595	0.132		------	------	
Resilience hub									
Feel comfortable to use a resilience hub as shelter (very and somewhat)	------	------		-0.841	0.049	*	------	------	
Use a resilience hub as a place to gather critical resources during a disaster (very or somewhat likely)	------	------		------	------		-0.783	0.016	*
Volunteer at a resilience hub (very or somewhat likely)	0.297	0.297		1.123	0.024	*	------	------	
Number of observations	492								
ρ2 (fit)	0.53								
ρ2 (adjusted fit)	0.50								
Final Log-Likelihood	-319.46								

* 95% significance **99% significance

5. DISCUSSION AND POLICY RECOMMENDATIONS

In this section, we leverage the results from the descriptive statistics and the discrete choice analysis to provide practice-ready policy recommendations for transportation agencies and other government entities. In summary, our modeling and descriptive statistics approach found that:

- Household characteristics influenced resilience hub usage, more so for normal conditions than as a temporary shelter. The reverse was true for individual characteristics.
- Variables related to how people would use a resilience hub were largely insignificant in mode choice.
- Trust and compassion variables had a positive impact on using a hub during a disaster, either as a temporary shelter or as a place to gather critical resources.
- Individuals that are part of a community organization, households with 3 or more people, and lower-income households are more likely to use a resilience hub during normal conditions.
- Walking was the second most chosen transportation mode to travel to/from a resilience hub during both normal conditions and a disaster. However, individuals using active transportation to travel to/from a hub during an emergency are less likely to use it as a place to gather critical resources.
- Mode choice variables were largely insignificant in the binary models related hub usage during normal conditions and as a temporary shelter. However, automobile ownership impacts the mode choice decision to travel to/from a hub during emergencies.
- Distance-based results indicate a strong preference by residents for highly localized resilience hubs, mostly for those who would walk to a hub.

We developed several recommendations related to resilience hub location, usage, and access focusing on the more detailed results. We recognize that resilience hubs are a very recent concept that lacks empirical resources regarding usage and effectiveness, and we highlight that many of these recommendations require additional research to evaluate their effectiveness. The recommendations are compiled in **Table 5**, which also provides empirical evidence from our research, some discussions, and supporting literature. The supporting literature is composed primarily of practical implementation guidance, which our research bolsters through our empirical analysis.

TABLE 5 – Recommendations from descriptive and modelling results

Resilience hub services and usage			
Recommendation	**Evidence**	**Discussion**	**Support**
Publicly share accessible emergency response and evacuation plans to residents	61.2% indicated that they were very or somewhat likely to use a resilience hub as a temporary shelter during a disaster. 69.8% indicated that they are very or somewhat likely to go to a resilience hub during a disaster to gather information about the disaster. 63.9% indicated that they were very or somewhat likely to go to a resilience hub during a disaster to gather critical resources. 62.2% described resilience hubs as a place that provides emergency sheltering, 40.2% as a place that offers	Many survey participants indicated that they were very or somewhat likely to use a resilience hub as a temporary shelter or would go there to gather services and resources during a disaster. However, less than a quarter said that they were very or mostly prepared for an evacuation. Consequently, individuals should be aware of how to evacuate to a resilience hub during an emergency. They should also be informed about mode choice options that will be available to travel to a resilience hub during a disaster. A list of resilience hubs, the area served by them, and transit services available should be open access to residents. Importantly, resilience hub management and operation teams should also be prepared to support individuals with disabilities.	(*4*)
Provide emergency shelter facilities in resilience hubs.			(*2*, *4*, *11*)
Educate the community on the risk of climate			(*3*, *4*, *15*)

change and how to be prepared	response services during disasters, and 36.5% as a place that provides resource distribution before, during, or after a disaster. Visible minorities and individuals with disabilities were very or somewhat likely to use a resilience hub as a temporary shelter (Binary Model 2)		
Increase social cohesion within the community	"Believe that a resilience hub would help increase social cohesion in my neighbourhood" was a significant positive variable presented in all binary models. Individuals who stated that their neighbours would help them during a disaster or emergency are more likely to use resilience hubs during a disaster (Binary Model 2 and Model 3)	All binary models about resilience hub usage showed that individuals that believe that a resilience hub would help increase social cohesion in their neighbourhood were more likely to use a resilience hub during normal conditions, as a temporary shelter during a disaster, or as a place to gather critical resources during a disaster. Therefore, strategies might be adopted to increase social cohesion in a community. For example, communities could have more social neighbourhood events, expand volunteer networks, increase civic pride, or develop community leagues (such as those in Edmonton). In addition, community centers and community leagues could provide more information about their services and events to engage their community, and jurisdictions could provide support and/or incentives to community centers.	(*20*)
Resilience hub placement and accessibility			
Recommendation	**Evidence**	**Discussion**	**Support**
Place resilience hubs in neighborhoods to localize resources, meet community needs, and increase usage	The median distance between residences and resilience hubs was 1.7 km. The median distance by mode of transportation ranged between 0.6 km and 5.2 km. Those that will walk to a resilience hub during normal conditions indicated a median distance of 0.6 km.	Individuals revealed a preference to have a resilience hub close to their residences. It aligns with the guidance present in the current literature. Thus, resilience hubs should be located in places within a more localized community, rather than selective points across a large city. By placing a resilience hub within the community, governments can: 1) provide resources to assist the neighbourhood to be more resilient and prepared to recover from a disaster; 2) benefit underserved communities that rely on community assistance; 3) strengthen community cohesion; 4) increase accessibility, especially for carless, low-income individuals, and elderly; 5) encourage regular usage.	(*1–3*, *12*)
Transform existing local/community buildings (e.g., recreation centres,	35.3% would be very satisfied and 38.1% somewhat satisfied with community centers being resilience hubs.	Preceding literature has indicated community centers, libraries, and recreation facilities could be retrofitted into resilience hubs. Our study emphasizes that most people would be	(*1*, *3*, *4*, *11*, *12*, *21–23*)

community leagues, libraries, and government buildings) that already meet some goals of resilience hubs through retrofits	28.7% would be very satisfied and 36.0% somewhat satisfied with community leagues being resilience hubs. 26.3% would be very satisfied and 39.4% somewhat satisfied with libraries being resilience hubs.	very or somewhat satisfied with these places. By selecting an existing well-known and well-utilized location for retrofit, communities can encourage their usage during a disaster. Rather than build new, retrofits can be effect in reducing overall cost. For any new buildings, resilience hub characteristics should be embedding in the design. It should be noted that schools and universities were mentioned by participants to serve as a resilience hub, but these facilities might not be usable during school hours and days.	
Design resilience hub design with accessibility and mobility considerations	69.4% indicated accessibility for individuals with a disability as a very or mostly important service to be provided by a resilience hub.	The survey confirmed recommendations, provided by previous literature, on locating a resilience hub in an accessible pedestrian area and close to evacuation routes. People were concerned about accessibility and mobility, especially for older adults, people with disabilities, and carless. We recommend that jurisdiction should assess community accessibility needs, implement Universal Design principles, and provide infrastructure that accommodates these groups' needs.	(*2*, *12*)
Focus mobility planning of hubs to meet underserved populations, especially older adults, people with disabilities, and carless	82.1% of older adults selected accessibility for individuals with a disability as a very or mostly important service. 76.7% of people with a disability selected accessibility for individuals with disability as a very or mostly important service. 76.6% of carless residents selected accessibility for individuals with disability as a very or mostly important service.		------
Facilitate walking to hubs through pedestrian-friendly infrastructure	Walking was the second most popular mode of transportation to travel to a resilience hub during normal conditions (14.8%) and during an emergency (8.5%). 44.7% of older adults and 38.6% of carless individuals selected walking as their primary mode choice during normal conditions. 48% of carless individuals indicated that they would walk to reach a resilience hub during an emergency. Women are more likely to walk to a resilience hub during normal conditions than use public transit (Multinomial logit model – normal conditions)	After personal vehicle, walking was the most relevant primary mode choice. When planning a resilience hub, jurisdictions should select areas where sidewalks are well structured and safe, and crosswalks are well signalized. Wide sidewalks with easy-to-use curb cuts (or continuous sidewalks) can accommodate wheelchair users. If a hub location does not meet these conditions, governments should plan infrastructure improvements to redesign and improve sidewalks and crosswalks.	(*12*)
Locate resilience hub near public transit and/or	56.7% indicated transit connection as a very or mostly important service to be provided by a resilience hub.	Public transit is important to increase equity in accessibility and mobility. Although the percentage of people in the general population indicating that would use public	(*4*)

redesign routes to increase frequency	Public transit was the third most selected mode choice to reach a resilience hub during normal conditions. 27.3% of carless individuals and 10.9% of people with disability would use public transit to go to a resilience hub during normal conditions. 16% of carless and 6.4% of people with disability would use public transit to go to a resilience hub during an emergency. Young adults are more likely to use public transit than active modes in both conditions – normal and emergency (Multinomial logit models)	transit during normal days (8.1%) and during an emergency (4.0%) was small, this mode was more important for underserved populations such as carless and people with disability. Therefore, efficient transit connections for resilience hub users should be a priority in design and location considerations. Route redesigns may be necessary to enhance transit connections and increase frequency.	
Pre-plan how critical resources will reach resilience hubs, including sharing information to the public in real-time	63.9% indicated that they were very or somewhat likely to go to a resilience hub during a disaster to gather critical resources. 61.2% indicated that they were very or somewhat likely to use a resilience hub as a temporary shelter during a disaster. Women and individuals with a disability were more likely to use the hub as a place to gather critical resources during a disaster. (Binary Model 2) Individuals were less likely to use active modes to gather critical resources at resilience hubs during disasters when compared to public transit (Multinomial logit model emergency condition)	Within the planning phase of resilience hubs, jurisdictions should assess transportation routes and strategies to guarantee that critical resources would reach the hub during an emergency. In this way, resilience hubs can help facilitate relief distribution. Moreover, resilience hub relief resources should prioritize the needs of the community. Therefore, jurisdictions should assess community needs and determine how residents will know what resources are available.	(*2*)

6. LIMITATIONS

Despite important insights related to resilience hubs usage and transportation needs, our research has several limitations associated to the data collection and methodology. First, both the convenience survey and panel survey may be biased since respondent self-select into the study. Second, the online survey may have excluded those without access to the Internet or knowledge on how to use a computer or smartphone. Regarding methodology, we note that we used simple binary and multinomial logit models (which limits our behavioural conclusions) and that other discrete choice models could be tested. Fourth, we recognize that the way we split categorical variables may miss certain behaviors, especially where there was high heterogeneity in the population. Fifth, our model related to mode choice during an emergency had a small sample size which may have affected the significance of variables. Finally, our research focuses on the case of the Edmonton Metropolitan Area, and future work will be needed to determine external validity and community context in other places in North America and globally.

7. CONCLUSIONS

In this study, we presented a comprehensive analysis of resilience hub usage, location, accessibility needs, and people's behaviour. We used descriptive statistics to understand individuals' needs and opinions related to the resilience hub. Subsequently, we developed three binary logit models for the willingness to use or not a resilience hub during normal conditions and during a disaster. Finally, we developed two multinomial logit models to assess individuals' mode choices to reach a resilience hub during normal conditions and during an emergency. All methodologies used data collected from individuals that reside in the Edmonton Metropolitan Area (n=950).

We found that individuals prefer to have a resilience hub within their neighbourhood, and most of them will use a personal vehicle to reach a hub during normal days or during an emergency. However, walking was the second most chose mode, and it was the primary option for carless individuals. Respondents also indicated that accessibility was a very or mostly important element of resilience hubs. Moreover, respondents would be very or somewhat satisfied of placing a resilience hub in community centers, community leagues, and other public buildings. They are more likely to use a resilience hub during an emergency than during normal conditions.

Binary models showed that during normal condition usage, individuals' willingness to use a hub is heavily influenced by household characteristics, while using it as shelter is influenced by individual characteristics. There was relative inconsistency in significant variables across the three usages (i.e., in normal conditions, as a shelter, for critical resources). Despite this, several unique variables were found to be significant for some of the models. For example, high levels of trust and compassion increase the likelihood of using the hub to find critical resources. People that believe that their neighbour would help them during a disaster are more likely to use a resilience hub during normal conditions. In addition, those that believe that a resilience hub would help increase social cohesion in their neighbourhood are more likely to use a hub during normal days and during a disaster.

Multinomial logit models revealed that households that have more than two individuals are more likely to use sharing mobility than public transit during an emergency. During normal days, larger households are more likely to use public transit than shared mobility. This shows that mode choice can differ depending on the context. Thus, it is important to assess transportation needs in different scenarios and plan a hub that meets both needs. We also found that young adults are more likely to use public transit than active modes in both scenarios (emergency and normal conditions). Moreover, in both conditions, a variety of variables related to household characteristics and individuals' characteristics influenced mode choice. We also note that resilience hub usage (i.e., trip purpose) generally does not influence mode choice.

Future studies are needed to determine if residents in other cities have similar behaviour related to resilience hub. However, this study is a steppingstone for resilience hub planning and design, as it provides empirical results and recommendations that guide agencies to better plan resilience hubs. Moreover, the study uncovered key transportation elements that should be considered when planning a resilience hub.

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AUTHOR CONTRIBUTIONS
The authors confirm contribution to the paper as follows: study conception and design: Thayanne G. M. Ciriaco, Stephen D. Wong; data collection: all authors; analysis and interpretation of results: all authors; draft manuscript preparation: all authors. All authors reviewed the results and approved the final version of the manuscript.

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