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RESILIENCE FINDINGS

Transportation Access Index for Remote Communities That Considers Modal Seasonality

Thomas Stringer[1,2], Amy M. Kim[2]

[1] Industrial Engineering, Tecnológico de Monterrey, [2] Civil Engineering, University of British Columbia

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Findings

In northern, remote regions, community access can differ between the seasons due to modal availability. Existing accessibility measures have not been developed within, and considering, contexts where transportation modes are seasonally available. We introduce a new accessibility index that uses a cost-based approach in accounting for seasonality, using data from the Northwest Territories, Canada. We find that fly-in communities or communities with more seasonal variation in terrestrial access tend to have higher travel costs to service centers than those connected year-round by all-weather roads.

1. Questions

Accessibility can be understood as a measure of proximity to opportunities (Levinson and King 2020), availability of transportation services (Cui et al. 2020) and affordability of travel (Koopmans et al. 2013). The seasonality of transport modes in northern regions influences availability – for example, winter roads can only be used when the ground is sufficiently frozen during key winter months, and ferry/ice crossings are only available in summer/winter and not the shoulder seasons (Hori et al. 2018). Seasonality also influences affordability, as is the case when the only ground transport access to a community is via winter road, and air transport the only remaining option available other times of the year (Government of the Northwest Territories 2010). We show that fewer months of available road transportation results in less affordable access due to increased reliance on air transportation services.

Accessibility indices developed for remote regions (Glover and Tennant 2003; Alasia et al. 2017) do not consider seasonal modal availability and affordability explicitly. To date, no measures specifically addresses seasonality in the context of quantifying accessibility in northern regions. Thus, we ask: how does modal seasonality influence transport accessibility? We propose an accessibility index that incorporates a measure of seasonality. Index scores were calculated for 31 communities in the Northwest Territories, Canada (Figure 1).

2. Methods

Data used for this study comes from fare information from airlines that operate in the Northwest Territories (Air Canada, Air Tindi, Aklak Air, Canadian North, First Air, Northwestern Air, North-Wright Airways and Westjet), from road distances from Google Maps and ferry crossing/ice road/winter road information from the Government of the Northwest Territories' Department of Infrastructure (Government of the Northwest Territories 2021).

Table 1. Community access type and number of months with road access

Community access type	Number of months of road access (M_l)
Connected by all-weather road without ferry/ice road crossing[1]	12
Connected by all-weather road with ferry crossing in the summer and ice road in the winter[2]	9
Connected by winter road	3
Disconnected from main road network	0

[1] Bridges across any and all water crossings

[2] At least one water crossing does not have a bridge; crossings are made by ferry in the warmer, ice-free months and by ice road in the winter months

First, we determine the number of months during which road access for each community l is available (M_l) and the number of months during which it is not ($12 - M_l$). Road access is defined as a physical connection by which vehicles can access major urban centers. Table 1 shows the values of M_l we have assumed for the communities in our study. To determine number of months in the table, we use an average of the opening and closing dates for winter roads, ferries and ice roads as compiled by the Government of the Northwest Territories (2023b, 2023a).

Second, we compile travel costs associated with road and air travel from each community to the two service centers for which it is the cheapest to travel to. We define the first level of service center as one with a hospital and post-secondary institution, and the second as having a population ≥250,000. For all communities, the first level of service center is either Inuvik or Yellowknife, and the second level is either Edmonton or Vancouver.

Air travel costs $\left(C_{lu}^F\right)$ between community l and level u service center are obtained directly from airlines' websites. Road travel costs are computed using the road distance between l and service center u (D_{lu}^R) and a per-kilometre rate (K), representing the total cost of using an automobile, including gas, insurance, registration, maintenance, and vehicle amortization:

$$C_{lu}^R = D_{lu}^R \cdot K \quad (1)$$

We use the Canada Revenue Agency's standard Automobile Allowance Rate of CAD 0.68 per kilometre (Canada Revenue Agency 2023), which represents an average total cost of operating a vehicle in Canada. For communities that do not have road access, only flight costs are compiled.

Third, we determine the lowest travel cost in CAD for months with road access for each level of urban center (A_{ul}):

$$A_{lu} = min(C_{lu}^F,\ C_{lu}^R) \quad (2)$$

In out sample all communities that are connected by a winter road also have an airstrip. If a community does not have an airstrip, the road travel cost is used automatically. The cheapest travel cost for months without road access availability, B_{ul}, is equal to the flight cost, since no other transport mode is available:

$$B_{lu} = C_{lu}^{F} \tag{3}$$

Finally, seasonality is integrated into the index by weighing the costs for when road access is available and when it is not:

$$C_{lu} = \frac{M_l \cdot A_{lu} + (12 - M_l) \cdot B_{lu}}{12} \tag{4}$$

where C_{ul} is the annual weighted average cost in CAD by level of service center u and community l. To generate a single-value index per community, we calculate a weighted average of the service center levels' annual weighted costs:

$$Y_l = \sum_{u=1}^{J} \theta_u \cdot C_{lu}, \quad \theta_1 + \ldots + \theta_j = 1 \tag{5}$$

where Y_l is the travel cost index (in CAD) by community l in CAD and θ_u is a weight value from 0 to 1 for each service center level u. The total number of service center levels is $J = 2$, and we use weights of $\theta_1 = 0.7$ and $\theta_2 = 0.3$. These weights were chosen with the assumption that citizens travel to a urban center with a hospital and a post-secondary educational institution at least twice as much as to a center with over 250,000 people.

3. Findings

Table 2 shows the index values, and normalized index values, calculated for the 31 communities. A higher index value means that it costs more on average to travel between a community and the service centers.

A Pearson correlation test shows a strong inverse correlation (-0.656) between index values (Y_l) and the number of months during which road access is available (M_l). Figure 1 illustrates this relationship.

Our findings suggest that if a community has fewer months of physical connectivity to Canada's southern road network, the community's citizens must rely more on air travel to travel and transport goods. Because air travel is far more costly than road travel, the overall cost of travel increases as a function of the number of months during which air travel is the only mode available. In other words, it is the lack of road availability over the course of a year that increases average travel costs. Figure 2 illustrates this finding.

Making a community more accessible depends on transportation services being available (Cui et al. 2020) and affordable (Koopmans et al. 2013). Our index shows that greater availability of road transportation throughout a year makes

Table 2. Index values for communities in the Northwest Territories, Canada, by type of road connection

Connection	Community	Population	$\mathbf{Y}_1$	$\overline{\mathbf{Y}_1}$	$\mathbf{Y}_{1_{norm}}$	$\overline{\mathbf{Y}_{1_{norm}}}$
All-weather road without ferry/ice crossing	Yellowknife	20,340	105	323	0.00	0.23
	Detah	192	122		0.02	
	Behchokò	1,746	174		0.07	
	Fort Liard	468	277		0.18	
	Fort McPherson	647	307		0.22	
	Whatì	543	311		0.22	
	Fort Providence	618	319		0.23	
	Nahanni Butte	81	339		0.25	
	Kakisa	39	358		0.27	
	Enterprise	75	375		0.29	
	Hay River	3,169	398		0.31	
	Fort Smith	2,248	425		0.34	
	Jean Marie River	63	484		0.40	
	Fort Resolution	412	531		0.45	
All-weather road with ferry/ice crossing	Inuvik	3,137	165	448	0.06	0.37
	Tsiigehtchic	138	253		0.16	
	Tuktoyaktuk	937	537		0.46	
	Fort Simpson	1,100	604		0.53	
	Wrigley	117	680		0.61	
Winter road	Aklavik	536	302	590	0.21	0.52
	Wekweètì	109	393		0.31	
	Gamètì	252	430		0.35	
	Déline	573	694		0.63	
	Norman Wells	673	694		0.63	
	Tulita	396	694		0.63	
	Colville Lake	110	731		0.67	
	Fort Good Hope	507	785		0.72	
Fly-in	Lutselk'e	333	406	720	0.32	0.66
	Paulatuk	298	613		0.54	
	Sachs Harbour	104	816		0.76	
	Ulukhaktok	408	1043		1.00	

travel more affordable. As such, building roadway connections without seasonal variation in availability, to connect previously unconnected or seasonally connected communities to the main road network, can reduce a community's dependence on air travel and decreases average transportation costs. Our findings offer policymakers and researchers a tool to evaluate access in regions where one mode of transportation is seasonally substituted by another.

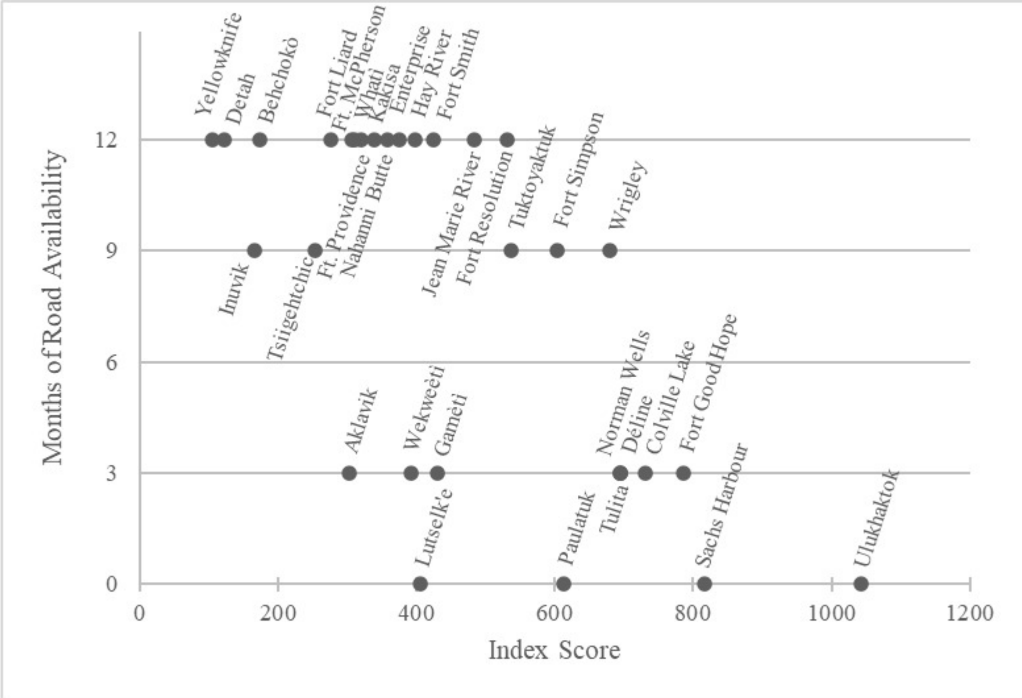

Figure 1. Communities classified by the number of months of road availability and index scores

Figure 2. Index scores for communities in the Northwest Territories

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