Across the Circumpolar Arctic, the scarcity of permanent roads appears as a common geographical theme. A cold climate prevented agriculture from spreading across arctic regions as it had across more southerly reaches of Europe, Asia, and North America. Instead, traditional livelihoods evolved around hunting and nomadic herding. Both of these livelihoods require large undeveloped expanses within which animals and people could travel freely, foraging as they moved seasonally over the landscape. Without widespread agriculture and its accompanying dense rural settlement, the economic base and social need never arose for a network infrastructure for interior surface transportation.

Arctic regions also share a history of colonization from temperate-zone capitals. In modern times, formal colonization has given way to varying degrees of integration with more southerly nation-states. However, the colonial legacy lives on through economic dependence on public spending financed from the south for education, health care, and local public services, as well as on global markets driven by southern needs for arctic resources. A third common characteristic of arctic regions is their physical remoteness from the southern political and financial capitals that control their fate. With the exception of Europe, the Arctic lies 2,000 km or more from any city with a population of at least 1 million. Travel by air from an arctic settlement to the national capital may involve a flight of more than 5,000 km, and take considerably longer than travel times needed to fly from any one capital city of an arctic state to another, even across continents.

The common themes of remoteness, sparse settlement, and history of external domination that characterize arctic regions reveal themselves in stylized patterns of local and long-distance mobility. Arctic transportation system technologies and routes have imprinted themselves throughout rural livelihoods and social relations, with important consequences for mobility and economic viability. While the system made perfect sense in a regime of inexpensive petroleum fuels, prospective continued high oil prices and the need to curb greenhouse gas emissions calls into question the sustainability of the entire structure of modern arctic social systems.

**Arctic as a remote region**

The Arctic as a circumpolar region is often defined in geophysical terms -- north of the arctic circle, average July temperature at or below 10 degrees Celsius -- and sometimes as an ecological boundary: the northern limit of treeline (NSIDC, no date). The Arctic Council uses a somewhat more complex definition (AMAP, 2013), but still based on the natural environment. For a definition based on human geography, the Arctic would better be termed the remote region occupying the northernmost expanses of Asia, Europe, and North America. Huskey and Morehouse (1992) described a remote region as an area with a unique combination of features. Remote regions

... are remote geographically, economically, and politically. They are distant from large, urban industrial and political centers, and they are sparsely settled. Most of them contain Native or indigenous populations as well as non-Native immigrants, and they have a mix of traditional and Western institutions. Typically, they have limited market economies, and they are dependent on natural resource exports, government transfers, and subsistence activities. The costs of doing public and private business are high. Important decisions affecting these areas are made in distant metropolitan centers. These remote regions lack both political autonomy and economic self-sufficiency." Huskey and Morehouse (1992): 129.
By this definition, the Circumpolar Arctic is the archetype of a remote region. Huskey and Morehouse describe geographic remoteness as having both external and internal references. While the European Arctic lies relatively close to major political and financial capitals, large portions of the North American and Asiatic North remain as inaccessible to cities -- whether measured in terms either of travel time or distance -- as any inhabited areas of the earth (Figure 1). Arctic regions appear remote by this measure both because there are few cities and because there are few roads. Low population density and expense of building surface transportation infrastructure on permafrost has meant that roads are largely absent in the Arctic (Figure 2). Air transportation provides the main access mode for long-distance travel and shipping, except for seasonal access to the coast and along large rivers during the short ice-free summer months.

Colonization and Integration with Southern Nation-States

By Huskey and Morehouse’s (1992) definition, remote regions not only lack physical access but are remote from centers of commerce and the levers of political power. Limited political economy is associated with a history of colonization from adjacent temperate-zone nation states, seeking to control resources and establish security on their northern frontiers. Both resource development and geopolitical security issues depend on global forces that rise and fall with the times. Unlike other historical frontiers, which inexorably pushed across continents as modernization progressed, the arctic frontier moves erratically out and back, giving resource exploitation and military bases a more intermittent character. Geographer David Sugden (1982) described waves of development sweeping across regions of the Arctic pushed by one particular global resource need. The waves typically subsided until replaced by a new wave driven by a new set of external needs.

Transportation across the Arctic was originally based primarily on water, along the coasts and major rivers, and only seasonally available in many places. Transportation infrastructure constructed in the North was often designed around export of a single mine or petroleum deposit or to provision a single military installation from the south. Arctic towns and cities built around exploitation of nearby resources such as gold mines tended to be highly seasonal and ephemeral. The few non-indigenous communities that did become permanent often owed their staying power directly to policies of the national government, either as centers of colonial administration of the territories such as Whitehorse, Nuuk, and Magadan, or to national defense or industrial policy, such as Murmansk, Norilsk, or Anchorage (Armstrong et al., 1978; Sugden 1982).

Once reliable air transportation became available, commercial air service quickly assumed dominance for mobility of people as well as most goods other than fuel and other bulk commodities. Major arctic resource extraction projects typically had their own single-purpose infrastructure for transporting their bulk products directly to world markets. Air transport networks, in contrast, tended to develop to meet the needs of colonial administration. The pattern of settlement of arctic indigenous peoples occurred largely as consequences -- intentional and inadvertent -- of colonial policies for air access of the states that governed these regions from distant capitals. The network of direct flights in arctic Canada (Figure 3) illustrates this principle through the north-south axis of major air routes, with minimal connections across the North except from villages to local hubs. If two arctic communities with historical cultural connections are served from different administrative hubs, the air network often separates these communities with greater distance, in terms of both flight time and costs, than from the southern city which serves each community’s local administrative hub.

Arctic Alaska shows the same general pattern of north-south connections (Figure 4), but with an important difference. Anchorage serves as the gateway for nearly all direct flights in and out of arctic Alaska; flying from an arctic Alaska community to another U.S. state generally requires changing planes in Anchorage. As an air transportation hub for all communities in Alaska, Anchorage lies much closer to arctic Inuit communities than any southern Canadian city lies to Inuit communities in Canada. Consequently, it is much less costly and takes much less time for a resident of an Alaska arctic community to fly to Anchorage, or through Anchorage to another Alaska arctic community, than for a Canadian arctic resident to fly to a city or to an community in a different area of arctic Canada.
Greenland provides perhaps an even more interesting case of constructed remoteness related to the air transport system. Airports at Kangerlussuaq and Narsarsuaq, originally built for military use during World War II, remain Greenland’s only runways long enough to serve intercontinental jet aircraft. Travelers from Copenhagen, the colonial capital, must land in one of these two airports and change to a smaller plane to reach the regional capital, Nuuk, or any other Greenland community. This peculiar arrangement separates internal connections among Greenland communities from international connections, reinforcing the remoteness of Greenland’s towns from Europe. One wonders whether this might be a factor abetting the push for independence among the younger generation of Greenlanders (Dahl 2010).

Russia’s Arctic spans a vast area, but its air transportation system more closely resembles Canada’s North-south orientation, but is highly centralized. Only Yakutsk really plays a role as a regional hub for the Sakha Republic somewhat like the role played by Anchorage for Alaska. It is nearly always easier to travel through Moscow to get from one arctic destination to another. For example, flying to Moscow from Yakutsk to get to Anadyr involves an additional 10,000 km, but is the only practical way to travel between the two towns.

Colonial patterns of arctic connectedness and disconnectedness became entrenched in regional education, health care, and social service administration. The prominence of these government services in local economies (Armstrong et al. 1978; Knapp and Huskey, 1988; Goldsmith, 2007) virtually assured that the historical patterns would reproduce themselves over time, as both government and private enterprise built supply networks around the logistics of air travel. Social, family and business ties followed connections opened up by administration and commerce. Electronic media and the internet have the capacity to mitigate the relative remoteness of communities embedded in the transportation system to some extent, but have little prospect of undoing decades of historical inertia.

The colonial arctic transportation networks and the moving costs they impose have a demonstrated effect on population movements. Two related studies of mobility of Inuit people of Alaska, Canada, and Greenland -- one of desired mobility, or place-specific migration intent, the other of actual place-to-place migration -- quantify this effect. Both studies rely on a model of voluntary individual and household mobility (Huskey et al., 2004), in which households decide whether or not to move and where to move by comparing well-being potentially available in different places with the cost of moving. Well-being attainable from living in a particular community derives from potential traditional and modern livelihood opportunities as well as amenities affecting the local quality of life.

The study for the analysis of remoteness on migration intent (Berman, 2012) used data from the Survey of Living Conditions in the Arctic (SLiCA) (Kruse et al. 2009; Poppel and Kruse 2009), which asked respondents whether they had “considered moving away within past 5 years.” More than one-fourth of SLiCA respondents in each of the four regions summarized in Poppel et al. (2007) had considered moving away from their community within the past five years. The results obtained by Berman (2012) suggested that remoteness was associated with reduced mobility if the effect was to increase moving cost, and with increased mobility if it impaired living conditions in the community. Higher cost of living relative to a national benchmark level -- an indicator of commercial remoteness in arctic communities -- was strongly associated with moving intent in Canada (the only region where sufficient data were available to test for this effect). For every 10 percent rise in the cost of living relative to Ottawa, migration intent increased by 1.6 percent (Figure 5). In Greenland, sea ice isolates some communities by making them inaccessible by boat for most of the year. Only larger communities typically have airports. Both these community attributes were associated with significantly lower rates of migration intent, after controlling for other relevant factors (Figure 5). No significant effects for relative living costs on migration intent were found for Alaska SLiCA respondents.

The study of actual moves among communities (Berman and Howe, 2012) used individual census responses for Inuit people in Alaska and Canada for mobility from 1995 to 2000 and from 1996 to
2001, respectively. While higher relative cost of living did not appear to affect migration intent for Alaska Inuit, it did strongly (negatively) affect the choice of destination for those who did move. (Figure 6). In Canada, indicators of lower moving costs -- jet service, and a winter iceroad connection -- showed strong positive effects on the choice of destinations, while the number of air segments between the origin and destination had a strong negative effect. A community with jet service from the origin had a 90 percent higher odds ratio of being selected, while the iceroad connection was associated with a three-fold increase in the odds ratio for the three Inuvialuit communities served by the winter road. Each air segment required to reach a community reduced its odds ratio of selection by 48 percent. The variables for one step up or down the hierarchy refer to the transportation tree (Figure 3), in which regional hubs lie between southern urban destinations and more remote communities. Residents of remote communities can move one step up the hierarchy to a hub, while non-arctic residents can move one step down to an arctic hub. Residents of hub communities such as Iqaluit, Rankin Inlet, and Inuvik, can move both up and down the hierarchy. Quantitatively, the effects on the probability of choosing a particular destination of moving one step up or one step down were roughly equivalent and large enough to offset the negative effects of several additional air segments. The results provide strong statistical support for the effect of the colonial transportation legacy on mobility choices.

These studies provide quantitative empirical evidence for the lingering effects of national colonial development policies for arctic regions on contemporary patterns of mobility and resettlement. Transportation networks implemented decades ago to facilitate colonial administration of the northern territories created a path-dependent dynamic for population movement in each region.

Local transportation

Until the mid 20th Century, arctic residents moved around the local landscape for much of the year using sleds pulled by reindeer or dogs. Settlement of indigenous people in permanent communities made these technologies for mobility nonviable, both because pursuit of traditional livelihoods required people to cover a greater distance more quickly and because providing food for reindeer and dogs required people to spread out across the land. People living in settlements were generally able to continue traditional livelihood pursuits. However, locally self-sufficient animal-powered transportation systems providing logistical support for these activities gave way to mechanized transport technology dependent on imported petroleum fuels.

The two-cycle gasoline engine became the technology of choice for rural residents powering snow machines, all-terrain vehicles, and outboard motors of river boats. Relatively simple, easily maintained, and often reparable in the bush, the two-cycle engine appeared to be the ideal solution to the problem of reliable off-road local transportation in an environment with few roads. Unfortunately, the two-cycle engine was highly inefficient with respect to fuel consumption, emitting as much as a third of all fuel unburned into the atmosphere. In Soviet Russia, whose autarkic planned economy proved unable to manufacture two-cycle engines, state enterprises provided helicopter support to move reindeer herders back and forth between town and pasture lands. This practice involved even greater fuel intensity, made possible only through massive fuel subsidies.

The historic rise in oil prices since 2000 brought into prominence the petroleum dependency of arctic communities, and the fuel-inefficient local transportation systems in particular. Because the fuel for local needs must be brought over long distances to the Arctic and distributed among dispersed communities, the rise in local fuel prices was much greater than the fuel price increases seen in urban areas, creating severe hardship for residents across the Circumpolar North. The local social and economic effects were particularly brutal in Russia, with the oil price spike coming soon after the collapse of the Soviet planned economy. Households served by state farms were largely left on their own to get by without the large subsidies they had received in the past to support the logistics of rural livelihoods while living in settlements. Many arctic residents with cultural and family ties to non-Arctic regions left -- as much as 25 percent of the population in some regions -- although most indigenous residents remained (Heleniak et al., 2011). The fact that more people did not leave is likely due in part
to the fact that the cost of air travel to leave also rose substantially, due to the same market and political forces.

**Conclusion: implications for sustainability**

Across Arctic, the lack of surface transportation infrastructure has led to a reliance on air carriers for long-distance movement of people and goods, and two-cycle engines and helicopters for local mobility. Colonial policies of settlement of indigenous peoples in permanent communities, connected through an air transportation network designed for colonial administration rather than internal connectedness has left a legacy that lives on through established modes of mobility and commerce. Arctic residents follow the historical air routes as they move between small rural communities where they maintain social and cultural ties, and urban areas offering better opportunities for higher education, health care, and wage employment. Small engine technologies have played a critical role in enabling arctic indigenous living permanent settlements to continue traditional rural livelihoods.

The extremely fuel-intensive nature of these modes of mobility creates severe challenges to community sustainability in an era of sustained high oil prices. The growing pressure to limit or increase costs of fossil fuels to reduce greenhouse gas emissions could further intensify the problem arctic communities face, and adds urgency to the search for solutions. Of course, transportation represents only a part of the fuel dependency of arctic communities; however, other energy challenges appear more easily solved. Known engineering options exist for building design and construction, water and sanitation, and renewable electricity that could greatly reduce overall fuel use. For these energy challenges, the challenge is only for institutions and policies to catch up with the technology. Unfortunately, the expense of the transportation systems alone provides a severe challenge to community sustainability, and engineering solutions remain to be found. Modern aircraft designs are only marginally more fuel-efficient. Four-cycle engines are available for snow machines and boats that are more fuel-efficient, but these heavier and more complex technologies are much more difficult to maintain in a remote, rural setting. New technologies are needed, but the Arctic provides a small market on a global scale, discouraging private investment in research and development, and innovation.

As higher fuel prices make air transportation to small communities increasingly difficult, some have raised consolidation of the rural population into regional centers as a solution. I would argue that such a consolidation, while it would save administrative costs for social programs, is also unsustainable. If communities grow larger, traditional livelihoods that require spreading out on the land become nonviable. These livelihoods are critical to sustaining the population and nurturing indigenous cultures. Their demise could invite depopulation of the hinterlands, turning the Arctic into little more than an expensive expanse of colonial enclaves overseeing local resource extraction and promoting state security.
Figure 1. Travel time to the nearest city

Travel time to major cities in hours and days (d) and shipping lane density. Source: Nelson (2008)
Figure 2. Global network of roads and tracks

Figure 3. Colonial Legacy: Air Transportation Network for Arctic Canada
Figure 4. Colonial Legacy: Air Transportation Network for Northern Alaska
Figure 5. Effect of remoteness on migration intent (error bars represent std. dev. of effect)

Source: Estimated from probit equations evaluated at sample means (data from Survey of Living Conditions in the Arctic).
## Figure 6. Statistically Significant Associations in Mobility Patterns of Canada and Alaska Inuit

**Equation for likelihood of moving**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Arctic Canada</th>
<th>Arctic Alaska</th>
</tr>
</thead>
<tbody>
<tr>
<td>Older adult</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Female respondent</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Children at home</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Inuit language used at home</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Pct old housing in community</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Pct new housing in community</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>“Inclusive value” of destinations</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

**Equation for predicted destination**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Arctic Canada</th>
<th>Arctic Alaska</th>
</tr>
</thead>
<tbody>
<tr>
<td>Predicted earnings</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Predicted harvest</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Poor housing</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Cost of living</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Number of air segments</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Jet service connection</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Winter iceroad connection</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Move up one level</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Move down one level</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

+ (red background) -- Indicates statistically significant positive association with decision to move or with predicted destination if a move took place.

- (blue background) -- Indicates statistically significant negative association with decision to move or with predicted destination if a move took place.

References


Heleniak, Timothy, Tobias Holzlehner, and E.V. Khlinovskaya Rockhill,"The Great Exodus: Demographic Trends in Russia's Northern Periphery" (Published in German, "Der große Exodus: Demographische Trends an Russlands nördlicher Peripherie"), Osteuropa, No. 2-3, 2011, pp. 371-386.


