Lac des Mille Lacs First Nation

Bingwi Neyaashi Anishinaabek

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Research Report | Fall 2022

Local Roads that Last

Nation Rebuilding Series, Volume 11

By: Mercedes Labelle and Mateo Orrantia

NPI – Who We Are

Land Acknowledgement

NPI would like to acknowledge the First Peoples on whose traditional territories we live and work. NPI is grateful for the opportunity to have our offices located on these lands and thank all the generations of people who have taken care of this land.

Our main offices:

- Thunder Bay on Robinson-Superior Treaty territory and the land is the traditional territory of the Anishnaabeg and Fort William First Nation.
- Sudbury is on the Robinson-Huron Treaty territory and the land is the traditional territory of the Atikameksheng Anishnaabeg as well as Wahnapitae First Nation.
- Kirkland Lake is on the Robison-Huron Treaty territory and the land is the traditional territory of Cree, Ojibway, and Algonquin Peoples, as well as Beaverhouse First Nation.
- Each community is home to many diverse First Nations, Inuit, and Métis Peoples.

We recognize and appreciate the historic connection that Indigenous peoples have to these territories. We support their efforts to sustain and grow their nations. We also recognize the contributions that they have made in shaping and strengthening local communities, the province and the country as a whole.

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Author's calculations are based on data available at the time of publication and are therefore subject to change.

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Animbiigoo Zaagi'igan Anishinaabek

Our people have been present in these lands for time immemorial. Our ancestors were strong, independent people, as we are today, who moved with the seasons throughout a large area of land around Lake Nipigon. We governed ourselves using the traditional teachings we still teach our children today. Now, our community members widely scattered throughout many communities, the majority of which are located in northwestern Ontario in and around the shores of Lake Superior. We are unified by our connection to the environment, our commitment to our traditional values, and our respect for each other.

Bingwi Neyaashi Anishinaabek

The people of Bingwi Neyaashi Anishinaabek – formerly known as Sand Point First Nation – have been occupying the southeast shores of Lake Nipigon since time immemorial. Our community is dedicated to fostering a strong cultural identify, protecting Mother Earth, and to providing equal opportunities for all. Furthermore, our community vision is to grow Bingwi Neyaashi Anishinaabek's economy and become recognized as a sustainable and supportive community where businesses succeed, members thrive, and culture is celebrated.

Lac des Mille Lacs First Nation

The community of Lac des Mille Lacs First Nation is located in Northwestern Ontario, 135 km West of Thunder Bay, and encompasses roughly 5,000 HA of Mother Nature's most spectacular beauty. Our people have held and cared for our Lands and Traditional Territories since time immemorial. To fulfill our purpose and in our journey towards our vision, we, the Lac Des Mille Lacs First Nation are committed to rebuilding a strong sense of community following a holistic approach and inclusive processes for healthy community development.

Partners

Northern Policy Analytics

Northern Policy Analytics (NPA) is a community-inspired applied policy and research consulting firm based in the Yukon and Saskatchewan. Founded by Drs. Ken Coates and Greg Finnegan in response to rapidly changing conditions and opportunities in the Canadian North, NPA recognizes that Northern and Indigenous communities often experience poorer educational outcomes, higher unemployment rates, receive fewer public goods and services, and lack the economic stability needed to optimize community well-being and quality of life. Yet these communities are often located in direct proximity to some of Canada's most valuable natural resources, resulting in both opportunity and conflict.

We address both policy and economic development issues and strive to effectively bridge the gap between Indigenous communities and settler government agencies by supporting community and economic development planning, grant writing, facilitating meetings, and by supporting entrepreneurship and the development of businesses in the region. NPA also helps communities marshal the information and resources they require to improve community and economic outcomes, while mitigating the impacts of colonialism and the over-arching resource extraction sector that dominates the regional economy.

Northern Policy Institute

Northern Policy Institute is Northern Ontario's independent, evidence-driven think tank. We perform research, analyze data, and disseminate ideas. Our mission is to enhance Northern Ontario's capacity to take the lead position on socio-economic policy that impacts our communities, our province, our country, and our world.

We believe in partnership, collaboration, communication, and cooperation. Our team seeks to do inclusive research that involves broad engagement and delivers recommendations for specific, measurable action. Our success depends on our partnerships with other entities based in or passionate about Northern Ontario.

Our permanent offices are in Thunder Bay, Sudbury, and Kirkland Lake. During the summer months we have satellite offices in other regions of Northern Ontario staffed by teams of Experience North placements. These placements are university and college students working in your community on issues important to you and your neighbours.

About the Authors

Mercedes Labelle

Mercedes Labelle graduated from McGill University in 2020 with an Honours Bachelor of Political Science and Urban Systems. During her studies, she focused on Canadian politics and public policy processes, specifically researching the uneven distribution of benefits and services between urban and rural communities. Having grown up in Canada, the United States, and Spain, Mercedes is eager to return to Northern Ontario, where her family now resides. In her free time, Mercedes enjoys listening to podcasts, cooking, and reading.

Mateo Orrantia

Born and raised in Marathon, ON, Mateo is proud to call Northern Ontario home. Currently in his first year of medical school at NOSM U, Mateo tries to bring an interdisciplinary approach to problem-solving. A firm believer in a self-directed and diverse North, he wants to apply his experiences in research and grassroots activism to help foster stronger and more sustainable communities across Northern Ontario. After spending his last few summers working at Pukaskwa National Park, Mateo has become passionate about protecting the region's unparalleled natural resources. Unsure of where his future will take him - other than back to the North - Mateo has gotten involved with initiatives across disciplines, from Strength & Conditioning coaching, to literary research and student governance. When he's not working, Mateo enjoys strength training, reading, and exploring the outdoors (which usually results in a little too much bushwhacking).

Contributions by Charles Cirtwill and Rachel Rizzuto.

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Executive Summary

This paper focuses on key transportation links, like roads and bridges. With the emergent threat of climate change, now more than ever communities are facing transportation challenges in getting supplies, and people, to-and-from their communities. The challenges faced revolve around unreliability. Shorter winter road seasons leave communities with shorter windows to transport essential supplies. Ever-rising sea levels threaten bridges providing crucial linkages. The case studies and innovative technologies examined, such as the Inuvik to Tuktoyaktuk all-season highway, new winter road maintenance techniques, or the use of airships and hovercrafts, provide examples and practices that should be studied further.

The **best practices** identified through this case study analysis include:

- Planning for climate change effects on transportation infrastructure;
- Adopt resilient materials and construction techniques specific to local climate;
- Use of traditional and local knowledge, local labour; and,
- Knowledge of, and research into, local community needs through community consultations.

The case studies also revealed that, when possible, the following things should be **avoided:**

- Surface-level ("bandage") solutions to aging infrastructure, that instead needs to be replaced entirely;
- Unwillingness to explore new technologies due to lack of pre-existing research; and,
- Attempting to entirely replace transportation infrastructure, such as winter roads, with innovative technologies – often, these technologies are used best to supplement existing infrastructure.

Introduction

Successful infrastructure development goes hand-in-hand with economic and social success and will be of utmost importance for Indigenous and non-Indigenous communities across Canada as they set their sights on recovery and prosperity in a post-COVID world. However, transportation infrastructure that Indigenous communities rely heavily on, such as (winter) roads and bridges, follow the "basic build" approach to infrastructure funding, design, and construction. The result: unreliable linkages to the communities which rely on this infrastructure for the transportation of goods and people. Basic build infrastructure often follows a "blanket approach" to funding, design, and construction, without accounting for a community's unique needs and circumstances, nor for long-term durability, which will be demonstrated when looking at the Lennox Island Bridge and winter road infrastructure in Nishnawbe Aski Nation's communities.

Although the basic build approach can sometimes allow for quicker infrastructure development with lower up-front costs, it often leads to negative project outcomes, such as unreliability and lack of durability. The significant benefits associated with more innovative methods of design, on the other hand, far outweigh its disadvantages—emphasizing the importance to shift away from the historically-used basic build approach towards more innovative methods.

The Basic Build Approach

New, innovative infrastructure must take climate change realities into account to pass the test of time. Transportation infrastructure, such as roads and bridges, are lifelines for many First Nations communities, especially those that are remote. A lot of basic build infrastructure is failing during shorter, warmer winters and rising sea levels. Basic build infrastructure hinders future development in many communities because of the varied impacts of climate change and climate uncertainty. Climate change impacts are wide-spread, and for infrastructure to stand the test of time, infrastructure must be resilient. Whether it be more innovative, climate-specific building materials, or different transportation alternatives entirely, more options must be explored to bridge the transportation infrastructure gap in First Nations communities.

Lennox First Nation, Prince Edward Island

Lennox Island Bridge is the only permanent infrastructure link between Lennox First Nation and Prince Edward Island (PEI). In recent years, the bridge has suffered the effects of coastal erosion, resulting in cracking, disintegration, loose bolts, broken signage, and vehicle impact damage (Canada, 2020). Prior to the bridge being built in 1973, community members had limited options. Beginning in the 1940s, a fishing boat serving as a public ferry was available. In the colder months, notably January to April, the ice had to be crossed by foot, horse, sleigh, and later, snowmobile, which proved dangerous in the spring months (Lennox Island, 2013).

Though the bridge does mitigate some dangers of crossing the ice, as well as providing added convenience, Lennox Island Bridge requires frequent maintenance. The bridge, spanning 252 meters, is made up of a reinforced concrete deck supported by pre-stressed concrete girders, pile caps, and steel pipes (Canada, 2016b). Since 2009, Indigenous Services Canada has invested into surface-level bridge improvements to avoid a full replacement of the structure (ibid). Despite investing over $3 million into the bridge since 2009, the repairs were not sufficient. The improvements made in 2009 were soon forgotten when, in 2010, a storm eroded a section of the bridge, reducing it to one lane. The single lane condition lasted six months while it was repaired (CBC News, 2015). In 2019, community members resorted to putting in various rock layers to provide shoreline protection to the existing causeway (CBC News, 2019).

The bridge contractors in the 1970s likely did not account for the affects climate change, such as rising sea levels, would have on the infrastructure. This reality is changing, as a storm surge of just three meters could cut Lennox Island entirely off from the mainland. A storm surge would wash out the underpinnings of the causeway connecting the island to the mainland (CBC News, 2015). Though temporary maintenance has marginally held the bridge together over recent years, the need for a more permanent, innovative fix is evident.

Nishnawbe Aski Nation, Ontario

Another climate change-related issue facing transportation infrastructure is the shorter winter/ice[1] road season. Winter roads are managed either by local communities, provincial/territorial governments, or the industrial sector (i.e. mines, energy) (Canada, 2018). First Nations communities in northern Canada rely on consistent cold weather to sustain their winter roads, often serving as the only link to other communities. In good years, the northern winter road networks generate anywhere between $5 million and $6 million in revenue, greatly advancing First Nations' socioeconomic positions (Gignac, 2016). In Ontario, the Ministry of Northern Development, Mines, Natural Resources and Forestry (MNDMNRF) provides information[2] on how to construct, inspect, and safely operate winter roads over a variety of terrain and water conditions.

There are countless examples where remote First Nations are accessible only by air or winter/ice road for one season a year. This significantly raises costs of everyday essentials due to increased transportation costs. In addition, the time frames to deliver supplies to the communities are severely shortened, with this trend expected to continue (see Table 1). The shortened time frame poses many challenges to the transportations of goods to remote communities. The most commonly transported commodity on Ontario's winter roads is diesel fuel. During the 2014-15 season, over 14 million litres of diesel fuel were trucked to remote communities by winter road (IBI Group, 2016, 11)[3].

[1] "Winter road" and "ice road" are used interchangeably. Winter roads often have sections where they cross frozen lakes or ponds, meaning sections of winter roads are ice roads.
[2] Available in First Nations Guidelines for the Construction and Maintenance of Existing Winter Roads, 2010, MNDM
[3] For full breakdown, see Appendix A

Table 1: Estimates of Winter Road Operations, Manitoba, 2020-2080

Season	Roads Open	Season Duration
2020's	3 days later	5 days shorter
2050's	5 days later	10 days shorter
2080's	7 days later	2 weeks shorter

Source: (Prentice, Thomson, 2013, 7)

In the case of Nishnawbe Aski Nation (NAN), which represents 49 First Nations communities in northern Ontario, 32 of which are isolated from Canada's highway network and electrical grid, the winter roads are their lifelines. The winter road system is relied on to transport stocks of fuel, food, building materials, and people. Some of NAN's communities nearly ran out of diesel fuel because an ice road opened several weeks late (Levin, 2017). According to NAN Grand Chief Alvin Fiddler, each community needs about 264,000 gallons of fuel per year, about 40 tanker trucks worth. Flying in the fuel would cost an additional $520,000 – an exorbitant cost for smaller reserves (ibid). With the winter road season reduced, however, some communities are forced to ship supplies, such as fuel, through air freight – an extremely costly endeavor.

In warmer years, the communities that depend on the unreliable winter road infrastructure for diesel fuel may be forced to shut down critical community infrastructure, such as health centres or schools. In a 2013 interview with CBC News, former NAN grand chief, Harvey Yesno, stated that it had been "several years since all remote communities that rely on winter roads for transportation were able to receive most of their fuel, building supplies and other materials over winter roads, because the weather has been too mild" (CBC News, 2013). More recently, as of January 15, 2021, only one NAN community's winter road was fully operational and open to full loads (NAN, 2021).

Though winter roads are largely a success story showcasing First Nations' efforts to connect their communities through a largely self-maintained network, unstable, warmer temperatures are threatening their existence. Despite proper management and maintenance, working against the warming climate is an uphill battle, amplifying the need for a long-term, innovative solution that will withstand changing climates.

Outcomes

The largest takeaway from the two previous examples is the inadequacy of its infrastructure when faced with climate change. Bridges and (winter) roads provide necessary linkages between many First Nations communities and the supplies needed to survive in them. But transportation infrastructure, often built decades ago, did not have climate change at the forefront of their design conception. Thus, bridge materials might not be resistant to salt-water erosion, or might be built before sea levels rose. Winter roads, a constant lifeline for decades, have now become unreliable, dangerous, and costly.

The problem with basic build infrastructure is, no matter the quality of management or maintenance undertaken, the infrastructure is destined to fail in its environment. What is worse, when these linkages erode, communities are left isolated and at the mercy of governments for assistance in bringing in supplies, such as diesel fuel. Not only does it make it impossible for these communities to be self-sufficient, but the negative financial impacts continuously pile up. Winter road maintenance workers are out of jobs, goods are more expensive since they must be flown in, and construction seasons might be severely shortened, if they happen at all.

All factors inhibiting connectivity make it all the more crucial to explore more innovative, forward-thinking approaches to transportation infrastructure, which will be looked at in the following sections. But first, these innovations take time to design, plan, fund, and build. In the meantime, let us review a few suggestions on increasing the safety and usability of winter roads.

Winter Roads Revisited

Winter and ice roads have been around for centuries; despite climate change worries, winter ice roads are not going away. Though innovative technologies are later mentioned in this paper, their implementation will likely not occur for years to come. In addition, their usage is often best complimented by other infrastructure, such as winter roads. Thus, adaptation measures must be implemented to help increase the safety and functionality of the seasonal winter road infrastructure. A report done by the National Research Centre for Natural Resources Canada lists adaptation measures to be implemented through the planning, construction, and maintenance phases of winter roads (Canada, 2018, 25); here are some of the suggestions[4]:

1. Extending the power grid to remote communities to reduce their reliance on diesel fuel (see Energy section);
2. Building all-weather road segments to replace problematic areas;
3. Planning route selection over the ice carefully – the shortest option may not be the best;
4. Re-locating an over-ice segment to the land.

Regardless of innovative technologies that may emerge, the need for ice/winter roads likely will not disappear. What can be done, in the meantime, is the implementation of measures to make them safer and to increase their utility.

A common theme throughout the communities was needing more information about clean, alternative energy sources. As it stands, diesel is familiar and jobs in the community exist because of it. The willingness to learn more about alternative energy sources again emphasizes the importance of community engagement and input during the formative stages of infrastructure developments. To start, energy efficiency and innovation can come from more than just generation; it can also tie into what was talked about in the housing infrastructure paper (Volume 7) whereas passive improvements, such as selecting environmentally friendly insulation and LED lightbulbs, reduces household electricity consumption (Mercer et al, 2018, 36).

[4] See Appendix B for full list of adaptation recommendations

Case Studies: Innovation in Practice

Highway 10: Inuvik to Tuktoyaktuk, Northwest Territories

Project Overview

Community Specifics: Tuktoyaktuk was only accessible by winter/ice road or air.

Challenges: Difficult terrain, permafrost soils, water crossings, swamps, and muskeg.

Solution: All-season, two-lane, 137 kilometer, gravel-packed highway between Inuvik and Tuktoyaktuk.

Funding sources: The federal government, the Government of the Northwest Territories, the private sector, Inuvialuit Regional Corporation, and local communities

Cost: $299 million for initial construction. Annual maintenance work is estimated to cost between $1.5 and $1.8 million per year.

Project length: Construction began in January 2014 and was completed in November 2017.

Outcomes: Year-round vehicle access between Inuvik and Tuktoyaktuk resulting in reduced costs of living, increased access to health care, educational and economic opportunities (by way of tourism).

The cost of extending all-season, gravel roads will vary. Looking to jurisdictions that have done so, such as Manitoba and the Northwest Territories, the average cost for all-season gravel roads is $3 million per kilometer (Prentice et al, 2013, 2). Cost-raising factors includes difficult terrain, permafrost soils, water crossings, swamps, and muskeg. The Government of the Northwest Territories completed the Inuvik-to-Tuktoyaktuk Highway in 2017, marking Canada's first all-weather road to the Arctic. At the project onset, Tuktoyaktuk had a population of 900 and was only accessible by winter/ice road or air. The all-season highway provided many economic opportunities for the community, as well as reliability and security that could not be provided by winter roads.

Initial Stages

Winter road reliance is common for many northern and remote First Nations communities, as it was for Tuktoyaktuk. The community, however, saw potential for a more permanent transportation infrastructure project. The concept of transitioning the road to Tuktoyaktuk from winter/ice roads to a permanent highway had been discussed since the 1960s, but final approval was only given in 2013. Once approved, construction was authorized to begin a year later in January 2014, the project company being EGT – Northwind Ltd. (Inuvik, n.d.).

The project conception occurred through an Indigenous Peoples joint venture partnership, Kiggiak-EBA Consulting Ltd. and Tetra Tech completed work with the Department of Transportation, Government of the Northwest Territories, the Town of Inuvik, the Hamlet of Tuktoyaktuk, and a joint venture of Indigenous contractors, EGT Northwind Ltd. The organizations designed the highway and prepared the documents needed to gain approval for construction and lobby the federal government for funding (Tetra Tech, n.d.).

The project had an estimated price tag of approximately $299 million. The federal government earmarked $200 million over five years for the highway construction (Canada, 2013a). The remaining monies were paid by the Government of the Northwest Territories (GNWT), the private sector, Inuvialuit Regional Corporation, and local communities. Annual maintenance work, including clearing the snow and grading the road, was estimated to cost between $1.5 and $1.8 million per year – about $12,000 to $15,000 per kilometer (CBC News, 2014a).

Design and Construction Process

During the design phase, the GNWT Department of Infrastructure prepared a comprehensive Environmental Management Plan to mitigate any adverse environmental effects from the highway construction project. An example of documents include: "Aquatic Effects Monitoring Plan," "Waste Management Plan," "Wildlife Effects Monitoring Program," "Spill Response Procedure/Spill Contingency Plan," among many more. The Environmental Impact Review Board appointed a five-member review panel that concluded the project can be constructed, operated, and maintained without significant impacts on the environment and the wildlife resources of the Inuvialuit Settlement Region (Canada, 2013b, 2).

The permafrost proved the most challenging as the design and construction approach required movement away from "traditional" engineering practices, as this was largely unchartered territory in terms of building all-weather roads to the Arctic. The priority was maintaining the overall integrity of the highway while also accounting for permafrost thaw caused by climate change (Tetra Tech, n.d.).

Research for the highway project was, and is still (at time of writing), ongoing. Both long-term monitoring projects and one-time measures are carried out to help further understanding of how the environment behaves. For example, better understanding of permafrost of hydrology helps develop strategies to manage risk and mitigate concerns (Northwest Territories, n.d.b.). Preliminary steps incorporated ground temperature monitoring for baseline conditions; ground-penetrating radar used at select locations to confirm the presence of massive ice; ground thermal analysis to predict freeze and thaw in the embankment structure; slope stability analysis in frozen, but unstable ground; among other techniques (Tetra Tech, n.d.). In addition, construction was only done in the winter months when there was less risk of damage or disruption to the permafrost. Also, the roadbed is at least 1.8 meters above the tundra to provide a large buffer preventing the permafrost from melting. Regardless, it was acknowledged that there would be some areas of sinking, which crews were ready to fill until the road "finds its steady state" (CBC News, 2014a).

Also, due to site remoteness and adverse climate conditions, the construction team designed all bridge elements to be prefabricated and assembled on-site, cutting down on construction time, making the most use of their seasonal construction period. In addition, either welded steel or precast concrete was used for all above-ground structural elements to accommodate the cold, winter construction schedule (Tetra Tech, 2018).

Preferential employment opportunities were given to qualified local residents and contractors for the project and priority hiring was given to companies included on the Inuvialuit Business List (Northwest Territories, n.d.a., 1). More than 70 individuals received heavy equipment operating training on both rock truck and excavator equipment. In all, the project training approximately 130 individuals as Class 1 and 3 drivers, equipment operators, summer students, and apprentices (Northwest Territories, n.d.b.). Other training opportunities included grader or excavator specialized training, water protection, habitat protection, sediment and erosion control measures, Predator Defense Training, and general workplace readiness (ibid). At the end of the project, it was noted that "more than 1,000 person years[5] of employment and several long-term jobs have been created as a result of the highway" (Northwest Territories, n.d.b.).

[5] A person year of employment represents the number of hours of full-time work in a one-year period. For example, this could be one person working for a full year, or four people working for three months.

Design Elements

The highway is a two-lane, 137-kilometer, gravel-packed road. There are eight bridges along the route and 68 areas where the highway has to pass over waterways larger than two meters. Approximately half the route is located on Inuvialuit private lands and is regulated by the Inuvialuit Land Administration. The remainder is on Crown lands and is regulated and administered by Indigenous and Northern Affairs Canada (Canada, 2013a).

The highway developer integrated goals of the Tuktoyaktuk and Inuvik Inuvialuit Community Conservation Plans to its environmental project management (Northwest Territories, n.d.a., 1). In addition, the raw resources required for the highway construction were sourced from locations near the proposed highway route, reducing environmental footprints and high costs and time associated with importing the materials from other regions. In total, approximately 5.8 million cubic meters of rock material were moved from a nearby quarry to the road site (Northwest Territories, n.d.b.).

An innovative design was implemented to help protect the permafrost – a design only using the "fill" technique, whereas the typical process involves a "cut and fill" technique. Geotextile fabric placed ("filled") between the existing ground and the construction materials along the entire highway (Northwest Territories, n.d.b.).

Project Completion and Outcomes

The highway was opened to the public on November 15, 2017 allowing year-round vehicle access between Inuvik and Tuktoyaktuk (Inuvik, n.d.). The territorial government says the road will save them the $560,000 a year it typically costs to build and maintain their winter road.

The region is now benefiting from a reduced cost of living, as goods can now be brought in by ground year-round, instead of during the short ice/winter road season, or by aircraft, which is significantly more expensive. Also, continuous ground access has increased access to health care, education and economic opportunities (Northwest Territories, n.d.b.)

More than just the year-round delivery of goods, the highway has brought many economic opportunities to Tuktoyaktuk, specifically by way of tourism. The completion of the highway has resulted in a substantial tourism increase in the region. In fact, tourism is projected to increase by $2.7 million annually, in turn creating 22 full-time equivalent jobs in the Northwest Territories (Northwest Territories, n.d.b.).

Foreword:

The next two emerging, innovative technologies are still primarily in their formative stages. Neither airships nor hovercrafts have been largely tested nor implemented in Canada, or even North America, for the purpose of delivering supplies and/or people from point A to point B. In fact, airships have not been flown commercially at all in recent decades[6]. Regardless, there has been research done on the two innovations, which will be explored, but location-specific research should continue to be done on the topics.

Airships

In the Draft 2041 Northern Ontario Multimodal Transportation Strategy (NOMTS), an identified improvement to current transportation realities is to "facilitate adoption of new and emerging innovative methods of goods movement, where appropriate, such as airships and hoverbarges" (Ontario, 2017, 64). Newer technologies might seem far-fetched or overly optimistic at the onset, but this is largely due to lack of location-specific research and development. As mentioned, with the added time constraint posed by climate change on winter roads, it is anticipated that innovative technologies will emerge into the mainstream construction market.

Some airships have broken into the formal design and construction phase, with some anticipated to begin test flights in the next few years (Norbury, 2019). Lockheed Martin, a U.S.-based aircraft company, signed an agreement with Montreal-based Quest and Straight Aviation to provide air services for the transportation of ore concentrate, supplies, and personnel using their airships (Murray, 2016). The airship being considered, the LMH-1, proved to be better economically than constructing a winter road that would also cut across caribou migration habitat (ibid). The LMH-1 is unique as it is part helium dirigible, part cargo helicopter, part passenger airline, and part hovercraft. Cost-wise, constructing and maintaining the 168-kilometer road was expected to cost $350 million, compared to $85 million annually to operate the airships (Topf, 2016). In addition, more airship models are in the works, which could expand cargo capacity and again, cut transportation costs.

[6] With the exception of advertising blimps (ex. Goodyear)

Table 2: Aircraft Models (Lockheed Martin) LMH-1 and LMH-2 Specificities

	LMH-1	LMH-2
Cargo	21.3 tonnes	100 tonnes
Passengers	19	n.d
Crew Member	2	n.d.
Cargo bay	10 x 10 x 60 ft	20 x 20 x 160 ft

Source: Norbury, 2019

Figure 1: LMH-1 by Lockheed Martin

Source: Norris, n.d.

Airships are said to operate "more like fast boats than slow airplanes" (Prentice, Hochstetler, 2012, 1). The size of airships allows them to accommodate more awkward shapes and larger loads than trucks which are constrained to bridge and road limits. Airplanes are limited to the size and shape of freight that will fit through their cargo doors (Prentice, Hochstetler, 2012, 14). The flexibility of an airship allows larger goods to be transported year-round – via ice roads in the winter months with airships moving cargo in the warmer seasons. This provides added flexibility to construction projects requiring large equipment or materials.

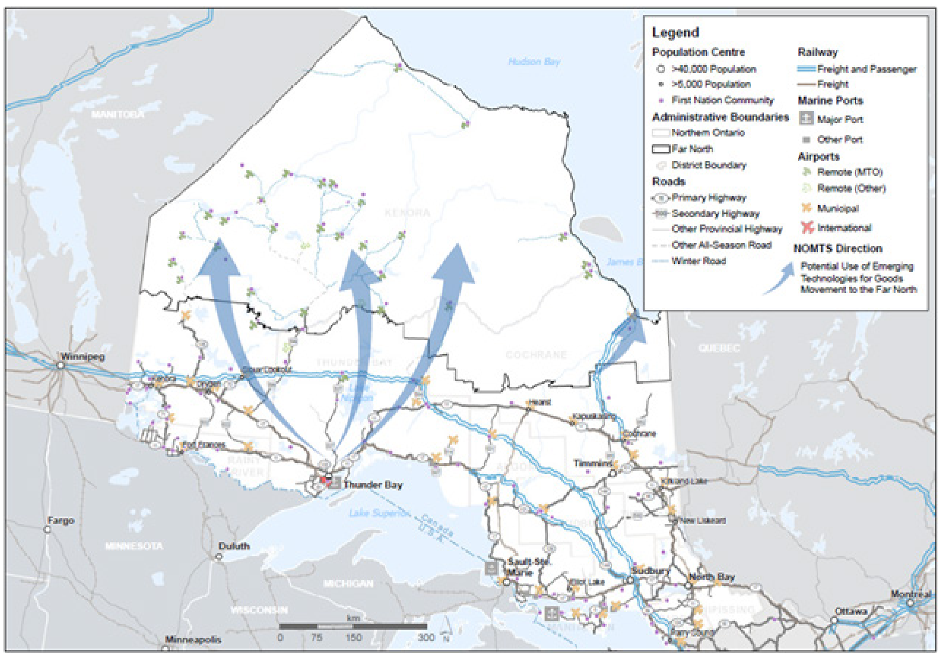
Along with their flexibility in goods transported and cost savings, two other advantages of airships include their relationship with infrastructure, or lack thereof, and their ability to relocate.

1. **Infrastructure:** Many airships can land on any flat surface including water, ice, meadows, etc. This means the ships do not require airports or runways to be built, maintained, operated (Prentice, Thomson, 2013, 15) But airships do need an airdock for scheduled maintenance. This innovation is seen in the LMH-1, where its innovative landing system reverses the air-flow, resulting in the landing gear acting as three giant suction cups. This makes it possible to land and grip onto any field, including ice, snow, mud, sand, and water (Topf, 2016).

2. **Relocation:** Airships can be deployed, and redeployed, as needs change. Roads, on the other hand, are fixed in place after construction (Prentice, Thomson, 2013, 15).

Both airships and hoverbarges need a transportation linkage at the end and beginning of their journey; they are unable to do last-mile delivery. In the scenario explored in the NOMTS, innovative technologies would make the bulk of the journey from larger urban centres. Once arrived in the community, goods would be off-loaded and existing winter roads would be used to transport the goods the rest of the way (see Figure 2).

Figure 2: Potential Routes for Innovative Goods Movement in the Far North



Source: Ontario, 2017, 78

Hovercrafts

An innovative, emerging technology is the use of hoverbarges for freight-hauling, specifically in remote mining activities. Though the hoverbarge/hovercraft technology has not been thoroughly tested in bringing supplies to remote First Nations communities in Canada, it has been used for select mining activities in the country.

Figure 3: Hovercraft

Source: DiNardo, 2017

Figure 4: Hoverbarge

Source: Barry, 2011

The Ring of Fire, Ontario

Indigenous communities are not the only groups interested in increasing transportation linkages to remote communities; mining and energy industry players also have a stake in the regions. For example, the Ring of Fire, a hard-to-reach, 5,120 km^2 mineral deposit in Ontario's Far North, has stoked speculation on how to efficiently and effectively extract resources and import people and machines.

The mineral-rich region, surrounded by waterlogged James Bay lowlands, has posed a challenge for communities, investors, and Canadian governments. But, the Sudbury-based Centre for Excellence in Mining Innovation (CEMI) proposed the use of hoverbarges/hovercrafts, or air cushion vehicles (Tollinsky, 2014). Hoverbarges travel on a cushion of air and can carry hundreds of tonnes of material year-round. Already, this is an advantage over ice roads, which are only in operation for a few months every year.

Hoverbarges were last considered in relation to Ring of Fire resource extraction. The Ontario Chamber of Commerce (OCC) conducted a report on the economic potential of the Ring of Fire, where OCC considered the hybrid use of hoverbarges and roadways. A proposed plan would be using hoverbarges to transport infrastructure material to communities and mine sites in the short-term to accelerate development while permanent transportation routes are being constructed (OCC, 2014, 19). Though, more than five years later, no concrete plans have materialized for their use.

Snip Mine, British Columbia

Hovercraft were used to service the Snip gold mine in northern British Columbia. The innovative technology allowed the mine to open ahead of schedule and resulted in substantial savings in transportation costs (Dickins Engineering & Environmental Research, 2013). Snip mine was a high-grade mine that produced approximately one million ounces of gold from 1991 to 1999. Historically, Snip faced the challenge of being a stand-alone operation in a fly-in community, resulting in high operation costs. Eventually, the mine gained augmented support by a hovercraft from Wrangell, Alaska. The hovercraft was used about eight months of the year; it was used to haul concentrates to Wrangell, and back-haul freight, mostly fuel. About half of the tonnage is handled by hovercraft, the rest by air (Northern Miner, 1993). The craft travelled on the Iskut and Stikine rivers (MEND, 2005, 2).

The owners of Snip mine, Comico Metals, commissioned Dickins Associates to survey the proposed operating routes and evaluated alternative methods to service the mine in northern British Columbia. The innovative technology, hovercraft, was highly successful in its mission, contributing to substantial savings in transportation costs. In addition, the use of a hovercraft led the mine to open ahead of schedule. The transportation method also came with many environmental benefits (Dickins Engineering & Environmental Research, 2013).

The use of hovercraft was not without opposition and criticism. The Tahltan First Nations, whose territory encompasses the Iskut River, were critical over the lack of discussions and the limited protections put in place when using the Iskut estuary as a service base for the hovercraft. The First Nations claimed that, despite the huge production volume and profits of the mine, no efforts were made to protect the fragile riparian zone. In turn, the salmon spawning habitat in the river was endangered, consequently also impacting the Tahltan way of life (Tahltan, n.d.). In addition, hoverbarges have been previously discarded as a northern transportation method because of the challenging terrain, high operating and maintenance costs, and noise (Prentice, 2017, 2).

If technologies are to be rolled out in proximity to First Nations territories, the communities must be consulted before, during, and after the rollout. In addition, resource-extraction industries must ensure adequate environmental protections are in place to mitigate the use of wide-reaching technologies, whether innovative or basic. Finally, though hoverbarges were once written-off, technology is ever evolving, and more timely research must be done on the transportation mode to gauge its current usability.

Outcomes

In the case of hovercrafts, more research needs to be done. The technologies are still relatively untested in northern Canadian conditions, especially when it comes to supplying remote communities with needed supplies. Admittedly, hovercrafts are probably not the perfect solution to Indigenous infrastructure difficulties. However, in specific circumstances, potentially in collaboration with a mining company, hovercrafts can be used to supplement other infrastructure, like winter roads. The more options tested in adverse weather conditions and readily available for use, the less remote communities are reliant on a short window of adequate winter road conditions. The additional options can help increase food and fuel security, decrease costs associated with flying in goods, and further Indigenous peoples' self-sufficiency. What is important to remember when considering transportation options is the far-reaching impacts on all groups.

Advantages of Innovative Transportation Design:

Environmentally Friendly

Northern communities are sparsely located and spread throughout a large land mass, meaning transportation vessels must travel vast distances to reach the communities. Both trucks travelling over winter roads and cargo planes flying into these communities produce a large amount of emissions. Two of the innovative technology examples explored, airships and hoverbarges, significantly reduce the net emissions produced when transporting goods and people. In addition, as airships and hoverbarges do not require significant amounts of fixed infrastructure, such as roads, the direct environmental impact is minimal.

Also, in the case of all-season roads, there will be an increase in cars and trucks on the routes. It is likely however, that the increase in vehicle traffic will be offset by the reduction of CO^2 emissions from fewer planes flying in and out of communities.

Finally, many innovative technologies are still in their research and development phases; nothing has concretely been tested. Thus, they do not have the luxury of being "grandfathered in" to outdated environmental protection plans. As seen with the Inuvik Tuktoyaktuk Highway, a comprehensive environmental protection plan was laid out, and approved, before construction was allowed to begin. With climate change posing an increased threat to existing infrastructure, innovative technologies must have the environment front-of-mind.

More Consistent, Reliable Linkages

Winter road seasons are getting shorter. Some bridges are disintegrating because of higher seawater levels. With climate change, ice road seasons are starting later and ending earlier. In addition, sudden changes in temperature cause instability in the ice, resulting in closures sometimes lasting days. As discussed in a prior section, many remote communities rely on imported diesel to provide energy to their communities. The unreliability of ice roads can drive costs up. In some cases, communities might not get the necessary supply of diesel to last a season, forcing them to resort to planned blackouts. In less-than-ideal circumstances, communities might be forced to ship fuel and supplies by airplane, a significantly higher option. But, airplanes do not supplement the ability of large trucks to haul construction machines and materials to these remote communities - simply put, their cargo spaces are not large enough.

Innovative technologies and the infrastructure they rely on, such as airships and hovercrafts, are virtually unaffected by climate change because physical, fixed infrastructure is non-existent (sans a docking station). Additionally, the materials/technologies used for all-season road construction are specifically suited for the diverse environmental circumstances in the Far North, including thawing permafrost. There are options to be explored beyond basic build infrastructure to afford Indigenous and remote communities the stability necessary to establish self-sufficiency and development.

Economic Opportunities

As continuously stated, many First Nations communities are dependent on unreliable transportation infrastructure to provide them with a year's worth of food, medicine, and fuel. The instability of external factors, such as the climate, drive price volatility. In turn, everyday necessities are significantly more expensive in remote communities than those with vast transportation linkages. A reliable form of transportation, especially year-round, to bring commodities into the communities will lower food basket costs, leaving more money in the pockets of residents. Communities will no longer have to rely on an ever-shortening winter road season to bring a year's worth of food, building materials, and fuel. Then, when seasons are shorter than expected, community leaders will not be forced to supplement the shortages with expensive emergency air transport.

Also, with more transportation options comes increased accessibility for inter-community travelers. As seen with the Inuvik Tuktoyaktuk Highway, the completion of the all-season road as greatly increased tourism, also contributing to full-time permanent jobs in the tourism sector. There are also tourism companies marketing airship trips to the Arctic with the expected launch date being in 2022. Additional jobs are created with the construction of the infrastructure, sourcing of the materials, and upkeep post-completion.

Disadvantages of Innovative Transportation Infrastructure Design

High Costs

The innovative infrastructure, as it is new, has costs associated with its design and development processes. For example, building all-season gravel roads has a higher upfront cost than seasonally rebuilding winter roads. There are, however, long-term economic advantages that accompany the high upfront costs, like increased tourism, lower cost of goods, and increased inter-community travel.

When looking at airships, their infrastructure requirements, though not as vast as thousands of kilometers of fixed-road infrastructure, are still quite costly. Airships require extremely large hangers, or "airdocks." Each airdock can, though, accommodate approximately 25 airships, as each airship would only require use of the facility for about two weeks per year (Prentice, 2017, 2). Depending on how ownership of the airdocks is managed, costs could make private ownership very expensive is each company must provide its own hanger (Prentice, 2017, 2). Before even getting to the stage of building airdocks, the airship itself has high costs associated with its construction, Building a working airship prototype is estimated to cost around $100 million, with subsequent airship construction costs decreasing once the initial design is perfected (Norbury, 2019). Airships have the advantage of being mobile; airships can be reassigned to different locations and routes as needs changed, something which obviously cannot be done with gravel roads.

Figure 5: Airship in a large hanger

Source: Burgess, 2017

Environmental Difficulties

Infrastructure in remote communities is difficult to plan, build, and maintain because of environmental volatility. Permafrost poses a huge logistical issue when planning both winter and all-season roads. The added precautions, materials, and construction adaptations also significantly drive up costs. Also, materials used have to be durable; the extreme cold and harsh precipitation need to be front-of-mind when designing infrastructure. Also, planning needs to go beyond current climate conditions and look ahead five, ten, 20 years to ensure infrastructure reliability and longevity amid a growing climate crisis.

Lack of Location-Specific Testing

With unique environmental difficulties comes the need to test innovative infrastructure in the environments they will be used. Though there is a thorough case study available for an all-season road in Canada's north, there still is a large gap in non-basic build infrastructure in the regions. With hoverbarges and airships, cases where these technologies are used to transport goods to communities, especially in the north, are non-existent. Lack of research and development severely limits opportunities for innovation moving forward, hindering development as a result.

Longer Timelines

With the new, innovative nature of these technologies and the lack of testing to-date comes longer project timelines. As mentioned above, airships are untested in northern Canadian environments, and the use of hoverbarges has been limited largely to private sector operations, like resource extraction. Commercial use of either of these technologies has not been largely explored, meaning the time between now and the implementation of these innovative technologies in the remote communities will be long. Like it should, it will take time for thorough research and development, and for private companies to have enough confidence in the technology to invest in it, if that is the chosen way forward.

Also, tying into the environmental difficulties, construction seasons might be significantly shorter. The Inuvik Tuktoyaktuk Highway construction took four years because the highway could only be worked on in the winter months, as to not work against thawing permafrost. Even getting materials up to these remote regions, the ones with limited transportation options in the first place, is a lengthy process.

Successful Practices

Less On-Ground Infrastructure

Current infrastructure options connecting First Nations communities in the Far North are limited to thousands of kilometers of winter roads cutting through large sections of otherwise pristine environment. Not only is building winter roads seasonally expensive, maintaining them throughout the winter months is a difficult task, especially given the sparse population and distance between communities. A benefit of more innovative technologies is the lack of fixed infrastructure needed to operate them. Airships require a small landing pad; similarly, hovercrafts rely on a docking station; both can leave the routes underneath them untouched. If airplanes were more economical and able to transport large construction equipment, they would be afforded similar advantages.

Also, one must take into account the goods being transported on the ground. All season roads, where available, are gravel lined. Ice roads are often snow-covered and do not offer smooth rides to its transported cargo. Airships, though slower, are much larger and more stable, preserving the integrity of the transported cargo.

Infrastructure that Accounts for Climate Change

Some basic build infrastructure built decades ago were not designed with climate change in mind. For example, some bridges might have been constructed lower than is currently ideal with rising sea levels. Also, winter road infrastructure is becoming less and less reliable as winter months are less cold, and the cold temperatures do not last as long when they do arrive. Both examples of basic build road and bridge infrastructure are becoming increasingly less functional with the changing climate. Innovative solutions to the failures of transportation infrastructure must take into account the realities of climate change, and the fact that the process will not heed anytime soon.

Community Involvement in Projects

Since airships and hovercrafts are untested in Canada, the successful practice of community engagement is largely taken from other innovative infrastructure studies. Community involvement in all phases of infrastructure projects is arguably the largest factor contributing to their successes. To begin, like other categories of infrastructure, First Nations communities must be involved, and their needs identified. Innovative infrastructure might not be the best option for all First Nations communities; but this is difficult to pinpoint without community-led discussions. Open communication also avoids the environmental downfalls that was caused using a hoverbarge for Snip mine; Indigenous peoples were not consulted over the use of the transportation mode frequenting their stream system. This resulted in the endangerment of the salmon species living in the river and took authority away from the community. Now, since hovercrafts and airships have not been constructed or used for commercial purposes in Canada, companies looking to fill this infrastructure gap must take the opportunity to connect with communities in and around their potential operating areas. The ground level of the design process —as soon as possible—is the best time to start.

Also, whenever possible, jobs that result from the new innovative infrastructure technologies should be given to members of the community. As seen in previous sections, community involvement helps foster a collective sense of ownership. In addition, having community members aiding in the construction process builds capacity, and their training can be utilized when repairs or maintenance needs to be done. This knowledge is a step towards Indigenous self-determination.

Innovative technologies will not completely replace the need for basic build infrastructure such as winter/ice roads. Instead, technologies such as airships and hovercrafts, in specific circumstances, can be used as a cost-saving mechanism to supplement winter/ice roads. Generally, multi-modal combinations tend to be more economic than a single mode of transport (Prentice et al, 2013). It is evident with the emergent threat of climate change, more long-term, reliable solutions must be thoroughly researched.

Conclusion

Though adverse climates and lack of location-specific research on newer technologies can lead to higher costs and longer project timelines, the case studies above demonstrate there are many benefits to be had from pursuing innovative transportation infrastructure: For instance, the new technologies are often more environmentally-friendly, are more reliable and durable, and even result in more economic opportunities for the communities in which they connect. Basic build infrastructure does not account for the long-term implications of climate change, such as shorter winters or rising sea levels. But, innovative infrastructure, by nature, does. There are means available to pursue consistent, reliable, environmentally friendly alternatives to transportation basic build infrastructure, though there might be higher costs and longer timelines associated with the new innovations.

Appendix A: Self-Reported Volumes of Goods Transported on Ontario Winter Roads, 2014-15

Source: IBI Group, 2016, 11

NOMTS Backgrounder: Winter Roads

Commodity	Bulk Fuels	Other Commodities	
	Volume (1,000 litres)	Truck Trips	Total Weight (tonnes)
Diesel	14,290	-	-
Gasoline	5,801	-	-
Housing Fuel	761	-	-
Hydro One Fuel	1,138	-	-
Housing Material	-	143	375
Food	-	146	68
School Supplies	-	420	-
Equipment	-	12	-
Other	187	107	6
Total*	**21,416**	**828**	**449**

Note: Goods in the "Other" category include chemicals for water treatment/sewage treatment, cement, and fire wood. Several communities did not report the quantity of their imports. Several communities did not report the weight of their truck loads.

*Incomplete due to incompletely reported information across winter road corridors.

Note: This dataset is based on a survey of remote communities with 27 of 30 submitting information on transported goods.

Appendix B: Adaptation Measures

Source: National Research Council, 2018, p. 25-26

Following is a non-comprehensive listing of adaptation measures – as can be seen, most apply to over-ice segments.

Planning, Construction and Maintenance

- Extending the power grid to remote communities, so as to reduce their reliance on diesel fuel.
- Laying structural bridges or permanent culverts at river and creek crossings when these become choke points.
- Building all-weather road segments to replace problematic areas.
- Planning route selection over the ice carefully – the shortest option may not be the best, because bathymetry has to be factored in.
- Re-locating an over-ice segment to the land.
- Building and maintaining multiple routes, in case one becomes unusable, or allowing contingency room for a by-pass, as required.
- Conducting stress analyses to estimate ice bearing capacity under static or dynamic loads.
- Including improved standard operating procedures on ice that are embedded in contracts.
- Improving means of monitoring the ice thickness, notably by optimizing ground penetrating radar technology, temperature and strength.
- Limiting the size of windrows (snowbanks on each side of the over-ice segment), which can cause a longitudinal crack to form in the center of the road. Periodic monitoring of the ice surface, notably to detect wet cracks.
- Maintaining a minimum width for the road so as to allow the traffic to make its way around flooded areas.
- Relying on spray ice at some locations where this method is better than surface flooding to help maintain or increase ice thickness.
- Using snow on the ice surface to maintain a high albedo – that stored in snowbanks can be used for that purpose, or from snow cache constructed and maintained for that purpose.
- Achieving a high albedo can also be achieved by laying out on the road surface, at vulnerable locations, a light-colored artificial material (mats).
- Preventing the accumulation of dirt.
- Covering the ice with a sufficiently thick layer of saw dust to insulate it against warm air temperatures.
- Widening road corners to improve sightlines and increase safety.

Traffic Management

- Using the road at night, while the ice is stronger.
- Restricting daytime use of roads.
- Enforcing speed limits.
- Driver awareness campaigns.
- Allowing one lane to be faster for empty loads.
- Improving the overall traffic control.
- Proper monitoring of vehicle weight.

Access to Ramps

- The access to and from the ice cover (ramps) can be a weak link. Means of mitigating this include:
- Considering north to east facing slopes for these ramps, which are not as exposed to the sun.
- Maintaining a thick snow layer over the ramp throughout the winter, so that the bare ground does not become exposed.
- Preventing exposure of that surface to the sun by covering it with a mat or other materials.

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