POLICY PRIMER

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Arctic Highways as Critical Infrastructure

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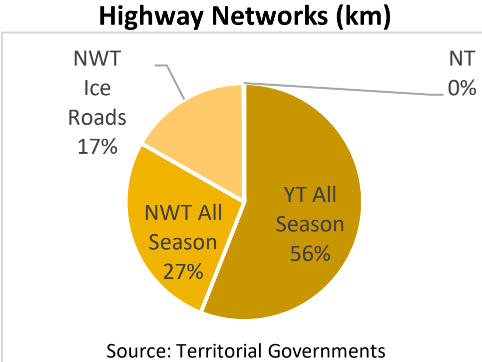
Key Considerations

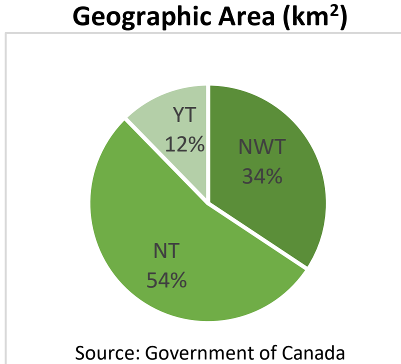
- MINDS Research Question: "What should be considered critical Arctic infrastructure in the context of continental defence and climate change?"
    - Critical Infrastructure (CI) refers to processes, systems, facilities, technologies, networks, assets and services essential to the health, safety, security or economic well-being of Canadians and the effective functioning of government.

- Research Focus:
    - Because of their role in the regular function of the supply chain, highways are frequently cited as critical transportation assets.
    - The highway network in the Yukon Territory (YT) and Northwest Territory (NWT) have a limited number of 'alternative' routes.
    - Where the functioning of a highway becomes compromised, there may be immediate impacts to residents and commercial users, including community re-supply.
    - Geographically, YT is the smallest territory, but hosts the most developed highway network.
    - Nunavut (NT) does not have an inter-regional highway system.

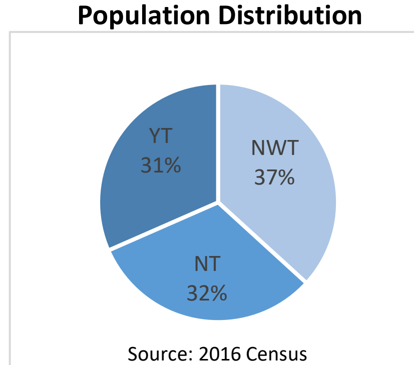
Arctic Territories
Highway Networks (km)



Arctic Territories
Geographic Area (km²)



Arctic Territories
Population Distribution



Purpose

This policy primer identifies opportunities and vulnerabilities for the maintenance of existing and planned highways in Canada's Arctic Territories.

Roads that are not adequately maintained pose a safety risk and become a liability. Roadway lifecycle analysis and capital planning ensure state of good repair (SOGR) standards are met, supporting community re-supply and preventing collisions and fatalities.

Background

Critical infrastructure (CI) refers to processes, systems, facilities, technologies, networks, assets, and services essential to the health, safety, security or economic well-being of Canadians and the effective functioning of government. [1] Canada's National Strategy for Critical Infrastructure emphasizes intergovernmental communication and cross sector collaboration.

Because of their role in the regular function of the supply chain, highways are frequently cited as critical transportation assets.[2] The highway network in the Arctic territories has a limited number of 'alternative' routes. Where the functioning of a highway becomes compromised, there may be immediate impacts to residents and commercial users, including community re-supply.

The Government of Canada uses a risk-based approach for strengthening the resiliency of Canada's vital transportation assets. To examine the risks posed to public infrastructure by climate change, the Public Infrastructure Engineering Vulnerability Committee (PIEVC) has developed a standardized protocol to assess vulnerabilities.

Existing Highway Network Assets

The Territorial government of the Yukon (YT) maintains 4,821 kilometers of Yukon roads. Of these, 350 km are paved, 1,976 km are covered with Bituminous Surface Treatment (BST) and 2,487 km are gravel.[3] In 2019, the Yukon Territory adopted a highway classification system to manage the lifecycle needs of the highway network as a whole. Road operations will follow a 3 to 6-year maintenance cycle, depending on the classification level of the roadway.[4]

The Northwest Territories (NWT) maintains a 3,780-kilometer highway network consisting of 2,345 km of all-weather roads and 1,435 km of winter roads. This highway system includes four vehicle ferries and a number of winter roads constructed by mining companies to facilitate mine resupply. The Northwest Territories Highway Traffic Report summarizes key usage metrics.

Both YT and the NWT maintain digital road advisory maps. Yukon territory's 511-digital map, broadcasts closure and state of repair information as well as road conditions information by highway section. The NWT highways conditions map broadcasts road closures and advisories. These digital communications assets include highway cameras that stream real-time images of highway conditions.

Road Maintenance Operation Types and Costs

Territorial Road maintenance staff working in the Arctic context undertake many other tasks directly, including but not limited to:

- Gravel blading
- Gravel resurfacing
- Calcium Application
- BST surface rehabilitation
- BST surface shimming
- Potholing
  Sanding (winter)
- Snow and Ice removal
- Ditching
- Culvert streaming, repairs and replacement
- Guardrail Repairs
- Stream channel maintenance
- Erosion Repairs
- Sweeping
- Vegetation control
- Beaver control
- Rest stop maintenance, cleaning, repairs
- Glacier control
- Highway access evaluations
- Road Inspections
- Bridge cleaning, inspection and repairs
- Fleet and heavy equipment repairs
- Sign Manufacturing, Repairs and Installation

Maintenance costs vary by location, however the development of “unit costs” is useful, as it allows for maintenance budget allocations as new road segments are added to the road network. For planning purposes YT operational staff cite the following estimates:

- Gravel resurfacing = $20,000/km
- Calcium application= $2,500/km (2T/km)
- BST rehabilitation = $55,000/km

Although many operations are undertaken directly by territorial staff, it is noted that asphalt rehabilitation and maintenance (including some vegetation control / rest stop maintenance) is tendered to private contractors.

While individual unit costs are not available for each of the operations listed, YT road maintenance staff identified their budget as $44M in 2018, $41M in 2019 and $42M in 2020.[5]

The NWT 2019-2020 Budget reports $65M spent in 2018, $67M in 2019 and $80M forecast for 2020. The maintenance of winter roads is a separate budget line, representing approximately $6.4M annually.[6] Discrepancies between these territorial expenditures may be attributed to whether projects are classified as ‘maintenance’ funded within an operational budget or as a capital project expenditure.

Capital Infrastructure Planning

Canada’s road network underwent a major expansion in the post-war years between 1950 and 1975. Consequently, many paved roadways built in the 1950s are now reaching the end of their lifecycle nation-wide. For example, between 2020-2027 the North Klondike highway (Yukon Highway 2) will require an estimated $157.6M in resurfacing and reconstruction work.

Infrastructure Canada and the YT 2019-20 Five-year capital plan have highlighted a number of significant highway projects, within the 2016-2027 planning horizon

- Yukon Resource Gateway Project 458M
- Klondike Highway Reconstruction and Safety Improvements 163M
- Alaska Highway Restoration and Safety Improvements 28.8M
- Campbell Highway Reconstruction 13.9M
- Other road resurfacings and safety improvements 82.8M

Infrastructure Canada and the NWT Infrastructure Plan similarly highlight significant highway projects, within the 2016-2023 planning horizon;

- Preliminary Steps for the Mackenzie Valley Highway 102.5M
- Slave Geological Province Corridor 40M
- Mackenzie Highway Improvements 63M
- Yellowknife Highway 32.5M
- Other road resurfacings and safety improvements 201M

Discussion

Network Vulnerability 1 – Loss of Ice Roads

The Northwest Territories' road network includes both all-season roads and seasonal ice roads. Road networks will be affected by climate change in the near future because the Canadian North is warming at about three times the global average rate.[7] As climate change advances, unusual and unpredictable seasonal temperatures and precipitation will, result in shortened seasons or closures.[8] Sections of the Mackenzie Valley have experienced flooding and closures and Tlicho Winter has experienced closures in sections due to flooding.[9]

Federal funding has been allocated for the planning and design of a number of new all-season roads. A $102.5M funding allocation began in the summer of 2018 for the preliminary steps for the Mackenzie Valley Highway. Another $30M in federal funding has been allocated for the Slave Geological Province Corridor, targeting a Spring 2023 project start date.

However, the design of all-season roads to serve communities and industry previously served by ice roads will require careful hydrological engineering. The construction of ice roads utilizes the frozen surfaces of lakes rivers, and in some cases sea-ice fastened to the shore. Establishing all-season roads will require the construction of structures that cross waterways as part of their design. The speed of global warming and ice melt may in some cases challenge the speed at which all-season roads can be achieved.

From a mitigation standpoint, the presence of private roadways must be recognized. Substantial portions of the ice roads in use today are privately constructed and maintained. For example, the 570-km Tibbitt to Contwoyto winter road is used by both industry and the public. Where ice roads are no longer viable, the costs of resource extraction may change impacting nearby communities.

Network Vulnerability 2 – Loss of All-Season Roads

The stability, integrity, and longevity of a road depends on its foundation. Arctic lands include both stable bedrock and thaw-unstable ice-rich permafrost soils. These thaw-unstable conditions threaten existing roadways and infrastructure currently being planned for construction. Permafrost melt will impact all assets (e.g. buildings, runways, homes) where foundations move, although linear assets may be particularly vulnerable. Soil instability due to permafrost melt has been identified as an important risk for linear infrastructure[10].

Because the permafrost is unlike other building environments, and widespread thawing has never been observed, the hydrological implications of permafrost thaw and water movement are not yet fully understood. Following the PIEVC protocol, an assessment of NWT Highway 3 identified the need to collect baseline information to document:

- locations of ice-rich permafrost;
- how climate change affects local environments, such as vegetation growth, surface and ground water flow, and ground thermal regimes; and
- road embankment performance, especially those sections requiring repeated repairs.

Aware of these risks and the need for new measures and standards by which to build, Transport Canada is administering funding for various data-collection initiatives. In partnership with the Royal Military College of Canada and the NWT, a $3.3M study of climate-driven geohazards and impacts on transportation corridors in Canada's Territorial North began in 2019. A $3.5M climate change resilience study of transportation infrastructure along the Inuvik-Tuktoyaktuk Highway also began last year. Beginning in 2024, the University of Toronto will initiate a $1.4M project to develop a tool that would optimize the effectiveness of the winter road network in the Canadian North.

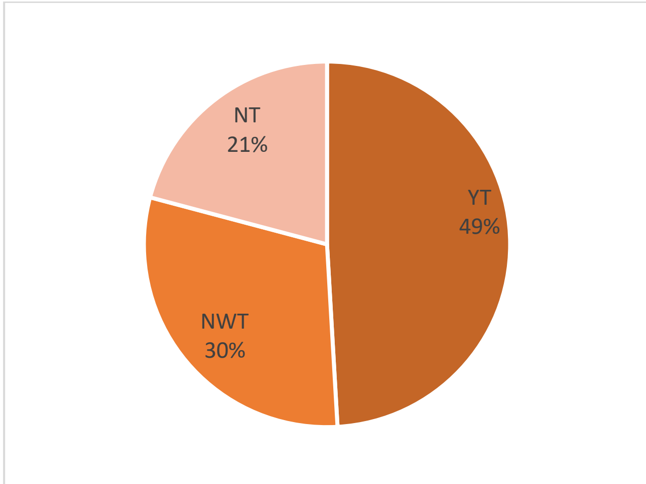
In addition to the road stability and drainage issues noted, regional infrastructure may be particularly vulnerable to the increasing the frequency and intensity of climate change storms, fires, and floods.

Concluding Remarks:
Importance of Intergovernmental Coordination

Although geographically the smallest, YT accounts for almost half of federal infrastructure spending. This distribution of funds can be attributed in part to the high cost of maintaining and refurbishing the extensive network of highways located in this territory.

Current programs to establish infrastructure in the Arctic are heavily predicated upon federal financial support. In Canada's provinces, federal infrastructure funding typically amounts to 30% of project cost estimates (following an even 3-way split between local, provincial, and federal governments).

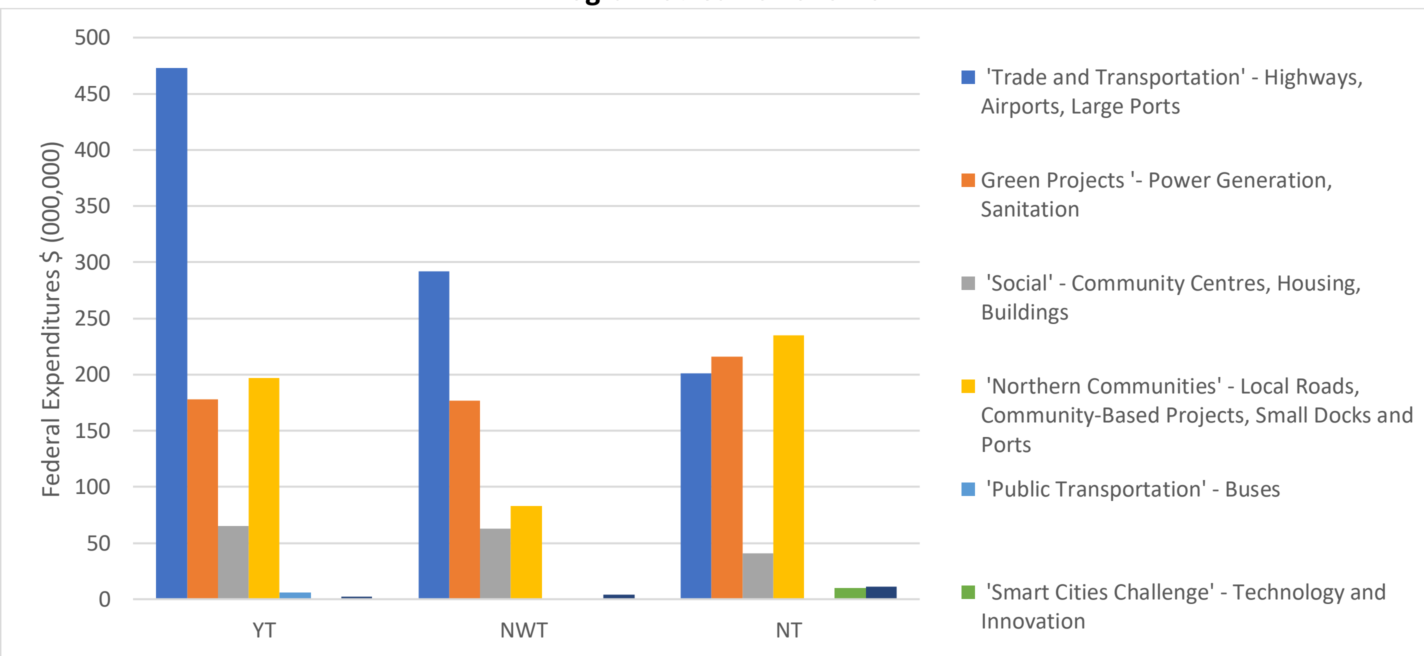
Approved Infrastructure Canada Funding (All Infrastructure Program Streams) 2016-2027



Data Source: Infrastructure Canada

Conversely, analysis of federal cost estimates at the project-level and approved federal spending indicates that federal funding contributions account for approximately 65% of project cost estimates in YT, 85% in NWT and 72% in Nunavut. The federal government plays a significant role in both the maintenance of existing highways, and the construction of new highways.

Federal Infrastructure Expenditures All Program Streams 2016-2027



Data Source: Infrastructure Canada

The high cost, vast geography and low population density of the Arctic have compelled federal financial commitments. According to the 2016 Census, the combined population of the Yukon, North West Territories and Nunavut is just 113,600 people.[11] Although very few citizens are served by these Territorial infrastructure investments, transportation infrastructure is seen to support resource extraction, primary industries and by extension, the Canadian economy at large. From a strategic defense standpoint, the maintenance of Canada's territorial highways as Critical Infrastructure assets demonstrates our national presence in the region.

While infrastructure funding is led by the federal government, the execution of maintenance operations is led by the Territories. Particularly with the severe and changing soil, drainage and weather conditions of the North, regular maintenance and timely reconstruction of assets at the end of their lifecycle will be vital. As federal funds support road construction and reconstruction, timely and coordinated intergovernmental coordination will be important as additional data becomes available regarding permafrost melt and the implications for roadway planning, construction, and maintenance.

> "The fundamental differences in engineering infrastructure between the South and the North need to be recognized, regardless of the effects of climate change. The continued application of southern standards in the North often results in infrastructure failure."
>
> Transport Canada, Minister-Led Roundtable: The North, Iqaluit, Summary of Discussion, 7 July 2016.

Endnotes

[1] Public Safety Canada (2020) *Canada's Critical Infrastructure*. Government of Canada.
[2] See *various resources related to Critical Infrastructure in Canada and the OECD*.
[3] Department of Highways and Public Works (2020) *Department of Highways and Public Works*. Government of the Yukon Territory.
[4] CKRW News (2019) Yukon Highways Get a New Plan.
[5] Information Request by Author to Ingram, Mackenzie (2020) Yukon Territory Road Operations.
[6] North West Territories (2020) *North West Territories Budget*, p. 248.
[7] Canada's Changing Climate Report (Government of Canada, 2019), pp. 84, 85, 118, 125, 434.
[8] Pendakur, K. (2017). Northern Territories. In K. Palko and D.S. Lemmen (Eds.), *Climate risks and adaptation practices for the Canadian transportation sector 2016* (pp. 27-64). Ottawa, ON: Government of Canada.
[9] Deton'Cho-Stantec. (2013, August). *Change and challenge: Climate change adaptation plan for the Northwest Territories Department of Transportation*. Prepared for Department of Transportation, Government of the Northwest Territories. Yellowknife, NT.
[10] Government of Northwest Territories, Department of Transportation (2011) *Highway 3 – Climate Change Vulnerability Assessment* (conclusion).
[11] Statistics Canada (2017) Highlight Tables – *Population and Dwelling Counts*. Government of Canada.