Climate Change Adaptation of Transportation Infrastructures in Permafrost and Marine Environments in Nunavik: Transports Québec R & D Programs & State of Adaptation

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Special session: CC Impact & Adaptation of Nunavik Transportation Infrastructures and Northern Villages: From R & D to application

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Quebec’s Arctic territory north of the 55th parallel: Nunavik

Isolated communities (14 Northern Villages and 1 Cree village)

Presence of permafrost

Served by air & sea

MTQ’s Airports

- 13 airports
- Runways: gravel
- Roads: paved and gravel
- Construction: 1984 to 1991
- Permafrost was considered as a stable foundation

MTQ’s Mining Roads

- 2 mining roads: Deception Bay to Purduiniq & Donaldson and Douglas Harbour

Municipal Marine Infrastructures

- 14 brakewaters, access ramps and docks
- Construction: 1999 to 2011

Climate change was not anticipated when the infrastructures were built
Issues

Impacts of Permafrost Thaw on Transportation Infrastructures

- Settlement along embankment and disruption of drainage system at the embankment toe

- Settlement localized across the entire width of the infrastructure

- Landslide along infrastructure

- Fence frost jacking
Research & Development Program: Objectives

Climate Change Impact & Adaptation of Transportation Infrastructures and Accessibility in Nunavik

- Develop knowledge on weather extreme events and natural risks induced by CC
- Develop instrumentation network to increase the monitoring of natural hazards, phenomena/environmental conditions and infrastructures behaviour
- Assess the vulnerability of transportation infrastructures and their accessibility
- Assess the impact of CC on management and operation (maintenance, mobility of people and goods, etc.)
- Test adaptation solutions/technics
- Experiment new technologies to anticipate potential degradations
- Develop adaptation strategies, new design criteria and new construction and operating practices
Monitor the effectiveness of previously tested adaptation solutions.

Assess the cost-benefit ratio and efficiency of implementing non-experimental adaptation solutions.

Implement adapted transportation infrastructure management and maintenance practices to ensure ongoing mobility of people and goods.

Develop transferable management and maintenance criteria/standards and decision making tools to support adaptation.

Disseminate the knowledge and share expertise.
Data Capture & Monitoring
Document the Impact of CC on Transportation Infrastructures

- Identification and monitoring of damage caused by permafrost thaw (settlements, cracks, snow/water accumulation, etc.).

- Documentation of the characteristics of the surrounding natural environment and any changes (snow conditions, state of ice wedges, permafrost degradation, etc.).

- Monitoring of the permafrost thermal regime, embankment behavior and climate conditions when infrastructures are vulnerable to climate change.
Management & Monitoring Tools
Adapt Transportation Infrastructures Management

- Review the methods used to inspect infrastructures.
- Develop management tools (inspection and monitoring) and georeference information.
- Train staff and transfer knowledge.
Geotechnical Investigations & Modelling
Assess Impact of CC on Transportation Infrastructures

- Carry out permafrost geotechnical investigations and surface deposits mapping (geophysical surveys, deep drillings, laboratory tests).

- Obtain reliable climate projections for the useful life of the infrastructures.

- Produce geothermal modelling based on climate projections and characteristics of infrastructures and geophysical environment.

- Assess the vulnerability of airports infrastructures in a context of CC.
Develop test sites to assess the effectiveness of experimental adaptation technics on transportation infrastructures in Salluit and Tasiujaq.

- Heat drain embankment
- Air convective embankment
- Gentle slope embankment

Test sections at Tasiujaq airport
Develop adaptation strategies for MTQ’s vulnerable infrastructures to permafrost thaw.

Use new technologies for embankment thermal stabilization (heat drain) and linear detection instrumentation (optic fiber) to monitor permafrost degradation.

Monitor permafrost conditions and effectiveness of implemented large scale adaptation strategies to develop design criteria and document the costs-benefit.

Revise and adapt operations of MTQ’s airports to ensure resilient and safe access (maintenance best practices, services, etc.).
Since 2010, large scale adaptation strategies and works are implemented:

**Completed from 2010 to 2019**
- 6 Runways: Puvirnituq, Salluit, Quaqtaq, Kangirsuk, Umiujaq & Tasiujaq
- 5 Access Roads: Salluit, Ivujivik, Umiujaq, Kangiqsualujjuaq & Tasiujaq

**To be completed by 2022**
- 2 Runways: Inukjuak & Akulivik
- 1 Access Road: Akulivik
Research & Development

CC and Natural Risks for Marine Environment and Infrastructures and Adaptation Solutions

- Should the frequency of the maintenance works must be increased?
- Are the infrastructures strong enough to resist storms to come and changing marine environment?
- Should the infrastructures need to be strengthened in short/mid or long term?
1. **Data acquisition (since 2010)**

a) **CLIMATE** (Weather Stations – MTQ/MELCC/coll. EC):
1. **Data acquisition (2-3 years / 2010-2013) (cond’t)**

b) **WATER LEVEL** (Tide Gages – Environnement Illimitée/MTQ):

1. **Data acquisition (since 2009 and 2015) (cond’t)**

1. **Data acquisition** (3 years / 2017-2020) (cond’t)

d) **WAVES, CURRENT, WATER LEVEL AND ICE CONCENTRATION**
(AWAC, etc. – UQAR/ISMER/MTQ.): Quaantaq & Kuujjuaqapik.
2. **Analysis, modeling and projections**

a) **ANALYSIS OF COASTAL ICE CONDITIONS**: Understand the movement and thickness of ice cover by analyzing photos, satellite images and from interviews carried out with locals in Umiujaq, Quaqtaq and Kuujjuaq (INRS-ETE/MTQ/KRG, INAC).

b) **STORM MODELING**: Assess and characterize changes in storm patterns, intensity, recurrence, speed and dimensions, etc. (Ouranos/MTQ).

c) **WATER LEVEL MODELING**: Based on Earth’s crust rebound, understand phenomena which make the high water levels variation during storms (storm surges) (Groupe-Conseil LaSalle/MTQ/TC/Nr Can/Ouranos).
2. **Analysis, modeling and projections (cond’t)**

d) **SEA ICE MODELING**: Predict sea ice concentration and thickness at 10 km$^2$ scale and its interaction with coastal ice (UQAR-IMER/MTQ/TC).

e) **WAVES MODELING (to be completed)**: Evaluate waves height, direction and dynamic near the marine infrastructures during storms (UQAR-IMER/MTQ).
Conclusion

- Review design criteria and infrastructure management in light of CC adaptation knowledge.
- Data collection and use of new technologies are essential to validate hypotheses on the impact of CC on infrastructures and adaptation solutions effectiveness and to improve risk management.
- Few basic data available on arctic marine environment and climate limiting CC adaptation R & D and sustainable development of the North.
- Consideration of CC projections and in-depth geotechnical investigations of the permafrost are vital to assess the vulnerability, develop adaptation strategies and manage risk of northern infrastructures.
- Combined analysis of hazards is essential to identify/quantify risks and develop adaptation strategies.
- Adaptation technics tested generally performed well, but can be costly and complex to implement.
- Despite the performance of the adaptation technics, increased maintenance will be the best solution in some cases.
Conclusion (Cond’t)

- Costs of adapted infrastructure (maintenance and rehab) to CC have increased (partial reconstruction: 20% to 30% and full reconstruction: 160%).
- Involvement of multidisciplinary stakeholders and community partners in the development of adaptation strategies is essential.
- Systematic inclusion of CC adaptation knowledge in infrastructure projects can be challenging.
- Need of training on cold region engineering and quaternary geomorphology to develop competence and expertise.
- Enhance knowledge transfer (training, decision making tool, scientific vulgarisation, expert forum, etc.) to support:
  - Adaptation of governmental, local and regional infrastructures to ensure the resilience of transportation network.
  - Sustainable planning and development of the North.
  - Capacity building.
Merci beaucoup, Thank you, Nakurmik!