Knowledge and Implementation of Climate Change Adaptation in the Infrastructure Sector in Nunavut, Canada

Timothy Giger & Kelly Ramsauer

Division of Risk Management & Societal Safety
LTH | LUND UNIVERSITY, SWEDEN

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Abstract
The Arctic is at the forefront of climate change and is considered to be the most at risk, warming at twice the rate of the global annual average. The environment and its inhabitants are and will be subjected to deep transformational shifts, with changes in temperature and climate having potentially worldwide repercussions. Global attention for the Arctic region has further risen by the increasing natural resource opportunities and changes in its accessibility, emergence of new transportation routes and geopolitical shifts. In the context of the Canadian Arctic, debates over appropriate policy action on climate change adaptation is a prominent topic for policy at all levels of government and across all sectors. While mitigation is certainly needed both in Canada and internationally, in the context of the territory of Nunavut, preparedness and adaptation are perhaps the most important and immediate need. Assessing climate change adaptation considerations in the infrastructure sector in particular is crucial as both society and individuals are dependent on it. Infrastructure in Nunavut is built to withstand harsh seasonal conditions and is reliant on shipments of resources and material for maintenance and construction. Most of this infrastructure is susceptible to climate variability and thus vulnerable to climate change. The purpose of this thesis project is to identify and understand in what ways existing knowledge plays a role in the infrastructure sector and how this is implemented and operationalized for infrastructure development and policy in the context of Nunavut. The research hopes to contribute to the knowledge of climate change adaptation in infrastructure in vulnerable environments and foster greater dialogue on the topic, as well as encourage proactive action for climate-sensitive infrastructure development in Nunavut.

Riskhantering och samhällssäkerhet
Lunds tekniska högskola
Lunds universitet
Box 118
221 00 Lund

http://www.risk.lth.se

Telefon: 046 - 222 73 60

Division of Risk Management and Societal Safety
Faculty of Engineering
Lund University
P.O. Box 118
SE-221 00 Lund
Sweden

http://www.risk.lth.se

Telephone: +46 46 222 73 60

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List of Acronyms

AMAP	Arctic Monitoring and Assessment Programme
APF	Adaptation Policy Framework
CBVA	Community-based vulnerability assessment
CCA	Climate Change Adaptation
CCS	Climate Change Secretariat
DRM	Disaster Risk Management
GC	Government of Canada
GN	Government of Nunavut
ICSP	Integrated Community Sustainability Plan
ICT	Information and Communication Technologies
IPCC	Intergovernmental Panel on Climate Change
M&E	Monitoring & Evaluation
MLA	Members of the Legislative Assembly
MSB	Swedish Civil Contingencies Agency/Myndigheten för samhällsskydd och beredskap
NGO	Non-governmental organization
NTI	Nunavut Tunngavik Incorporated
NWT	Northwest Territories
PCF	Pan-Canadian Framework on Clean Growth and Climate Change
PTAP	Pan-Territorial Adaptation Partnership
SBVA	Sectoral-based vulnerability assessment
TK	Traditional Knowledge
UNFCCC	United Nations Framework Convention on Climate Change
VA	Vulnerability Assessment

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1. Introduction

The following chapter introduces the topic and the context of the thesis project, starting with the background and the geographic and thematic research focus of the study. This is followed by the scope of the thesis, specifically the research purpose and research questions. Finally, the overall structure of the thesis and the limitations are outlined at the end of the section.

1.1. Background

The Arctic is one of the Earth's main climate regulators (IPCC, 2018). Large areas of sea ice and snow reflect solar radiation. Permafrost traps large quantities of carbon in the ground. And the Arctic's influence on water levels and currents, coastal winds and shifts affects biodiversity and ecosystem stability around the globe (IPCC, 2014). It is a region experiencing dramatic climate change and has been identified to be undergoing the most pronounced projected warming (IPCC, 2018). As the region warms, snow and sea ice decrease, resulting in the area absorbing more solar radiation, permafrost thaw releases carbon dioxide and methane into the atmosphere, and changes in water flows and wind patterns affect seasonal and climatic patterns (IPCC, 2018; Comiso and Hall, 2014; Serreze and Francis, 2006). Changes such as these, create positive feedbacks loops in the climate system, meaning the changes themselves create further changes in the same direction (Bell and Brown, 2018). The latest Intergovernmental Panel on Climate Change (IPCC) report also indicates that "climate-related risks to health, livelihoods, food security, water supply, human security and economic growth are projected to increase with global warming of 1.5°C and increase further with 2°C" (IPCC, 2018: 11). With potential global repercussions, there has been an urgent need to understand how climate change affects the Arctic region (Flynn, Ford, Pearce and Harper, 2018; AMAP, 2018; Ford et al., 2014; IPCC, 2014).

Global attention for the Arctic region has further risen by the increasing natural resource opportunities in the region and changes in its accessibility, emergence of new transportation routes and geopolitical shifts (AMAP, 2018; Ebinger and Zambetakis, 2009). Similarly, questions of how and to what extent these new opportunities can be pursued in a sustainable manner and in a way to benefit the people living in the Arctic, in order to develop into a more prosperous region while still retaining their unique identities and connection to their land, have been of particular focus in academic and professional spheres (Ford et al., 2014; IPCC, 2014; Marino, 2012).

1.2. Geographic Research Focus: Context and Case Study

The Arctic is a polar region located at the northernmost part of the Earth, consisting of parts of 8 different countries, the United States, Canada, Finland, Greenland, Iceland, Norway, Russia and Sweden. The focus of this thesis is on the Canadian Arctic. The Canadian Arctic usually refers to the three federal territories of Canada, the Yukon, the Northwest Territories (NWT) and Nunavut. This area covers approximately 40% of Canada's total land mass but has less than 3% of Canada's total population of 37 million (Statistics Canada, 2018). Unlike provinces that exercise constitutional powers in their own right, Canadian territories exercise delegate powers under the authority of the Parliament of Canada (Ebinger and Zambetakis, 2009). Historically

this has meant that the three territories of Canada were largely ruled by federal officials. This has somewhat changed in recent years as governance structures and powers have devolved to the respective territories (*ibid.*). Calls for more self-governance, particularly indigenous self-governance and self-determination, have influenced power distribution (Measham et al., 2011). However, due to their unique social, demographic, economic and geographic situation and challenges, a significant amount of the territories' funding still comes directly from the federal government.

The geographic research focus of this thesis project is specifically on the territory of Nunavut, which is the newest and northernmost territory of Canada (See Figure 1). Created in 1999 via the *Nunavut Act* and the *Nunavut Land Claims Agreement Act* it takes up 20% of the Canadian landmass and has a population of approximately 40,000 living in 25 remote communities, spread across the vast territory (Statistics Canada, 2018). Most of these communities are geographically isolated and are only accessible by air or sea. The largest number of people live in the capital Iqaluit with approximately 7,740 people and the population density in Nunavut is one of the lowest in the world (Statistics Canada, 2018). 85% of Nunavummiut people identify as Inuit, a group of indigenous peoples sharing common cultural heritage that inhabit the Arctic regions of Greenland, Canada and Alaska (NTI, 2016). Depending on traditional Inuit knowledge, strong social networks and high flexibility in resource-use, Inuit have exhibited significant adaptability in the face of current climate conditions and changes (Calihoo and Romaine, 2010).

Figure 1 - Location of Nunavut in Canada (Source: Adapted from wikimedia commons, 2011)

1.3. Climate Change Adaptation for Infrastructure in the Canadian Arctic

In the context of the Canadian Arctic, debates over appropriate policy action and capacity development on climate change adaptation (CCA) is a prominent topic for climate change policy at every level of government in Canada (Oldenborger et al., 2016; GN, 2011b). While mitigation is certainly needed both in Canada and internationally, in the context of the territory of Nunavut, preparedness and adaptation are perhaps the most important and immediate needs, requiring urgent action in order to reduce the already occurring negative effects of climate change (Ford, Pearce et al., 2010). These forecasted changes and increases in intensity and frequency of climate variability and extreme weather events have direct effects on major infrastructure (Auld et al., 2006). Almost all of this infrastructure is susceptible to climate variability and thus vulnerable to climate change (Melvin et al., 2016).

Both society and individuals are dependent on infrastructure, i.e. shelter, electricity grids, information and communication technologies (ICT), roads, airports, railways and port transportation, water and waste-water management services. Much of this infrastructure is also interdependent and designated as critical infrastructure, meaning failure in one can result in negative consequences in another. In many countries, large amounts of resources are invested to support its resiliency to negative stressors (Instanes, 2007).

Areas of particular concern in Nunavut include natural resource development, livelihoods human health, transportation and infrastructure (Ford et al., 2017; Labbé et al., 2017; Government of NWT et al., 2011). Adaptation initiatives to climate change in these sectors have often fallen into five main categories: (1) planning and preparedness tools to support decision-making, (2) awareness-raising and education, (3) monitoring and gathering data, (4) training and (5) mainstreaming (Ford et al., 2017; Arctic Council, 2013). Many of these initiatives (such as municipal adaptation plans, hazard and vulnerability mapping, development of training resources, etc.) are characterized as adaptation enabling and reflect an immediate need to respond to the increasing impacts climate change has on infrastructure (Ford, 2009b).

In the Canadian Arctic, permafrost degradation has been identified as one of the main concerns (GN, 2013). Additional issues in Nunavut include coastal erosion, slope instability, flooding and freshwater access (Hovelsrud and Smit, 2010), but permafrost underlies almost half of Canada's landmass and all of Nunavut (Heginbottom, 2002). Changes in permafrost are already negatively impacting infrastructure of all types, requiring the study of permafrost, the physical consequences of its degradation and land-use adaptation strategies to minimize the risks and consequences of its thawing (Heginbottom, 2002).

With the realization that Nunavut is and will experience climate change, efforts to increasing infrastructure resilience must be viewed as central to climate policy (Ford, 2009b). Risk management and planning are key activities to integrate climate change considerations and governing climate change at the local level, where climate adaptation is concerned. While there is a large amount of academic scholarship and interest on climate change vulnerability in the Arctic, only a limited number of studies have assessed the risks and vulnerabilities of infrastructure specifically to climate change (Ford 2009b) and how better planning and adaptation can contribute to the resiliency of more climate-sensitive critical infrastructure development and policy for vulnerable environments such as Nunavut (Ford and Furgal, 2009). Assessing risks and CCA for critical infrastructure in particular, gives rise to the opportunity of identifying and understanding which factors are and are not considered when infrastructure

policy and prioritizations are formed in planning and preparing for a more climate-sensitive infrastructure development approach in vulnerable environments. While many climate change impacts are locally specific, and the Arctic region is a unique context on its own, good practices and lessons learnt can be drawn from other vulnerable environments and communities dealing with similar negative consequences on their infrastructure networks. Understanding the strengths and weaknesses of different approaches can contribute to better incorporating CCA in infrastructure development for Nunavut. An assessment of the current situation and potential impacts of climate change adaptation measures for infrastructure can contribute to synergies between adaptation strategies and other infrastructure policy arenas.

1.4.Scope of Thesis

1.4.1. Purpose

The purpose of this thesis is to identify and understand in what ways existing knowledge plays a role in the infrastructure sector and in what way this is implemented and operationalized in infrastructure development and policy in the context of Nunavut. The research hopes to contribute to the knowledge of CCA in infrastructure in vulnerable environments and foster greater dialogue on the topic, as well as encourage proactive action for more climate-sensitive infrastructure development in Nunavut.

1.4.2. Research Question

The research purpose will be addressed by the following two research questions:

1. *What is the current state of climate change adaptation knowledge and ongoing measures for critical infrastructure in Nunavut?*

2. *In what way is this knowledge implemented in critical infrastructure development and policy prioritization for current and future government projects?*

1.5.Limitations

Scarcity of time and resources resulted in several limitations for this research study. The limited number of interviewees that were involved in the data collection also presents some limitations. The distance, timeframe, lack of formal contacts for interviewees and use of the snowballing sampling technique resulted in a limited pool of respondents. Had more time been available to conduct interviews with a larger group of key informants and/or a different sampling technique applied to get a more diverse group of interviewees, this limitation might have been minimized (Bryman, 2016: 188). Additionally, the definitions and understandings of key terminology such as *vulnerability, adaptation, critical infrastructure, planning, preparedness, climate-sensitivity* and *resiliency* might differ between the authors and interviewees. Lastly, the limitation of the inherent subjectivities and biases of the authors themselves during the data collection, analysis and interpretation of the results is also present and should be recognized.

The conclusions drawn from the interviews in combination with the geographic and thematic boundaries set, cannot be regarded as a complete image of CCA for infrastructure in the Arctic. However, it is large enough to provide an analytical generalization (Cresswell, 2014; Yin, 2003: 10) for the research questions and contribute to the knowledge pool of the research area.

1.6. Thesis Structure

Following the Introduction chapter, this study is divided into six main chapters, along the following:

- **Conceptual Framework**, which identifies and analyses the main concepts and key terminology that influence the research thesis, as well as CCA for critical infrastructure in vulnerable environments,
- **Context and case study of Nunavut,** which discusses the geographic and thematic focus of this thesis and what the current landscape of actors and actions are in this area,
- **Research Methodology**, which describes the research approach based on literature review and semi-structured interviewing methods, and outlines the challenges and limitations,
- **Empirical results**, which summarize and categorize the data gathered through the scoping study and interviews,
- **Discussion**, which connects the results to the theoretical background presented in the previous sections and discusses some of the key findings and themes that provide the basis for recommendations regarding CCA consideration for infrastructure in Nunavut, and
- **Conclusion**, which provides a final summary of the main insights and information that addresses the overall research purpose of this study and summarize some of the key insights and recommendations.

2. Conceptual Framework

This section outlines the general concepts dominant in the focus area of the thesis and their relevance in the context of Nunavut and the Arctic environment. Certain conscious delimitations had to be drawn in terms of what definitions and understandings of concepts to follow in order to have consistency and clarity throughout the research, which are outlined in the text below. Additional information on this process is outlined in the following chapter of *Research Methodology* and *Conceptual Background*. Terms discussed here include critical infrastructure, climate change adaptation (CCA), resilience, vulnerability and risk management which dominate this field and as such are defined in more detail.

2.1. Concepts

2.1.1. Critical Infrastructure

Today's individual and society are provided with almost all basic services and goods (e.g. housing, water, food, electricity, etc.) by critical infrastructure, and as such are essential in continuing to function. Critical infrastructure exists both at the national and provincial/territorial, as well as local level and can be identified within different sectors. This has meant that as societies become increasingly complex, the dependency on these services, and in turn on critical infrastructure (e.g. shelter, electricity grids, transportation networks, water and waste-water management grids, etc.) has also increased in complexity (MSB, 2014).

The majority of academic literature conceptualizes critical infrastructure as anything that if disrupted or destroyed by an event results in severe impact on a country's security, economy and/or social well-being (MSB, 2014; Brown, 2006; Rinaldi et al., 2001). Additionally, critical infrastructures are often also highly complex systems that are interdependent and interconnected (Melvin et al., 2016). Although a number of definitions exist, in the context of this thesis the Public Safety Canada (2009) definition for critical infrastructure as "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" is used (Public Safety Canada, 2009: 2). This is similar to how the Swedish Contingency Agency (MSB) (2017) conceptualizes critical infrastructure as "the activities, facilities, nodes, infrastructure and services that maintain the function that they are a part of" (MSB, 2017: 1). Canada for example has identified ten critical infrastructure sectors, including (1) energy and utilities, (2) finance, (3) food, (4) transportation, (5) government, (6) ICT, (7) health, (8) water, (9) safety and (10) manufacturing (Public Safety Canada, 2018).

While Nunavut spans across 20% of the Canadian landmass, it does not have any roads connecting the 25 communities in the territory and within the communities most roads are unpaved, few of the communities have port infrastructure even though 24 of the 25 communities are situated on the coast, with Nunavut having the longest shoreline of any province or territory in Canada. The territory also has limited airport infrastructure, relying exclusively on satellite networks for its connectivity needs as the geographic and arctic conditions still present challenges in building a more substantive land-based ICT network, and is a territory completely dependent on imported petroleum products to fulfil its energy needs (GN, 2012a, 2012b). Overall, in the case of Nunavut significant challenges exist. Considering the sheer landmass of 2 million km^2 that Nunavut encompasses, means connecting 25 remote communities that are currently only accessible year-round by air and with limited shipping (GN, 2018). This presents

a number of geographical, financial, logistical, etc. issues for the territory and thus constructing it in the first place, but also making it resilient and adaptable to the change in climate, has been an ongoing concern.

2.1.2. Climate Change Adaptation

The term adaptation refers to both a process and its outcome, thus leading to many interpretations and debate over its definition (Simonet, 2010). The term adaptation encompasses different terms, functions and processes depending on the field of study (Smit and Wandel, 2006). This thesis will use the definition based on the United Nations Framework Convention on Climate Change (UNFCCC) definition, which refers to CCA as the adjustments in natural or human systems in response to actual or expected variability in the climate (UNFCCC, 2019). It refers to changes in processes, practices and structures to moderate potential damages or to exploit beneficial opportunities that are associated with climate change (*ibid.*). Adaptation solutions to climate change take many shapes and forms and are highly context specific, as there is no "one-size-fits-all-solutions".

In the context of the Arctic, the impacts of climate change have already been documented and are predicted to increase (IPCC, 2018; IPCC, 2014). With experienced and projected climate change, adaptation has become essential to reduce damages and take advantage of new opportunities. It has also become an important part of climate policy in the Arctic context (Berrang-Ford et al., 2014). Indigenous population in the Arctic have a long history of coping and adapting to harsh and changing environmental conditions (Ford, Pearce et al., 2010). However, the rapid changes linked to anthropogenic climate change in addition to socio-economic changes, have reduced or negated the potential effects of historical adaptation efforts (Pearce et al., 2015).

2.1.3. Resilience

The concept of resilience has also become a dominant concept in several academic research sectors, including engineering, climate change, psychology, sustainability, company performance, security and disaster risk management (DRM). Many interpretations of the term do not fulfil the purpose of ensuring sustainable development for communities and for the concept to provide any actual use for communities vulnerable to climate change, there must be a clear link from the theoretical to the practical. While there are several different interpretations for the term (Cutter et al., 2010; Becker, 2014), and thus different operational implications, resilience of communities in response to climate has emerged as a priority concern for all levels of governments and societies (Bergström and Dekker, 2014). This paper follows in line with the thinking of Becker (2014) who defines resilience as "the capacity of a human-environment system to continuously develop along a preferred expected trajectory, while remaining within human and environmental boundaries" (Becker, 2014: 140). However, it is especially important to understand the concept and how it differs in various disciplines when dealing with CCA and infrastructure in vulnerable environments. Understanding has moved from the traditional engineering concept – with emphasis on physical intervention and mechanical measures – towards a more holistic understanding of needing both 'hard' and 'soft' measures for resiliency (Alexander, 2013).

2.1.4. Vulnerability

The concept of vulnerability has been widely adopted throughout the disaster risk management and climate change adaptation field with explicitly being referred to in the UNFCCC (UNFCCC, 1992), wherein assurances for adaptation efforts are made for vulnerable regions and people (Smit and Pilifosoya, 2003). In general, it shares many principles in common with resilience and sustainability (Kofinas, 2005; Gunderson and Holling, 2002). Many of the interpretations of the concept include aspects of the occurrence of extreme physical events and their effects, and the respective social, political and economic factors that determine people's ability and adaptive capacity to cope with the hazardous consequences (Houghton et al., 2001; Kelly and Adger, 2000). Coppola (2015) further highlights that measurement of the above listed factors "are the primary determinant features that dictate how the likelihood and/or consequences components of risk are increased or decreased" (Coppola, 2015: 176). Vulnerability for this thesis project is related to people's ability to cope with and respond to stimuli (Pelling, 2002; Blaikie et al., 1994), recognizing that the adaptive capacity itself occurs within the context of wider social, cultural economic and political conditions, and possible constraints (Thomas and Twyman, 2005).

Climate change is already occurring in the Arctic with strong scientific evidence and indigenous observations recording large-scale implications for the ecosystems and the communities living there, depending on them (Pearce et al., 2010; Ford and Smit, 2004; George et al., 2004; Fox, 2002). With warming, changes in the sea-ice thickness, increased precipitation, melting of permafrost and more erratic weather patterns, many Nunavummiut livelihoods, their way of living and the infrastructure networks around them are directly affected and at risk due to the climate conditions (Ford and Smit, 2004). Particularly for Inuit communities – 85% of the territory's population – these changes pose significant risks; indigenous peoples often spend significant amount of time hunting and travelling on land, relying on livelihoods, harvesting and sources of food that are directly impacted by climate change (Fox, 2002). This has been facilitated by extensive traditional knowledge and experience about the environment and the changing conditions (Magdanz et al., 2011). However, with traditional knowledge no longer as reliable as it used to be, many communities throughout Nunavut are experiencing increased exposure and risks to their way of life and well-being (Ford and Smith, 2004). The increased likelihood of adverse impacts of climate change have resulted in a growing urgency for Nunavut to understand how to mitigate these risks, decrease vulnerabilities and increase capacity to cope with changes occurring and yet to come.

2.1.5. Risk Management

The concept of risk management has several definitions depending on what sector or organization one looks at. The word risk is fundamental in the concept, but continues to be an ambiguous and vague term, with also many varying definitions depending on what discipline and peoples' perspective one uses it in. Most however, involve aspects of uncertainty and likelihood, as well as the negative consequences that might occur on something humans' value (e.g. human life, economic resources, etc.) (See e.g. Aven and Renn, 2010 for an overview of definitions). Risk management is often described as a process that analyses and assesses a potential risk in a given system, and subsequently preventing or mitigating the risk to an acceptable level for the exposed system (Coppola, 2015; Aven and Renn, 2010). A system in turn, can be an individual, an organization or sector (e.g. critical infrastructure) or even a whole

society (e.g. Nunavut). The concept of vulnerability, previously discussed, is closely related to risk and risk management, as it informs the impact of an adverse impact and to what degree a system can manage the negative disturbance (MSB, 2014).

In the Canadian context, the government defines risk management as "a systematic approach to setting the best course of action under uncertainty by identifying, assessing, understanding, making decisions on and communicating risk issues." (Government of Canada, 2010: 1). Adapted from the five-step risk management cycle of the Government of Canada, Figure 2 illustrates the integrated risk-based approach used throughout the different levels of government when managing different risks. In this study, risk management is defined in line with the Government of Canada understanding of risk management.

Figure 2 - Five-Step Risk Management Cycle adapted from Government of Canada (Source: GC, 2010)

3. Context and Case Study

With its distinctive demography, geography, economy and government, Nunavut is notably different from other Canadian provinces and territories. As such, this section briefly provides some background on Nunavut's distinct character in terms of demography, geography, economy and political system to facilitate the rest of the research that follows and to elaborate on the general context in which CCA and critical infrastructure converge.

Figure 3 - Map of Nunavut communities (Source: Government of Nunavut, 2019)

3.1. Demography

Inuit ways of life, traditions and cultural aspect dominate much of society and the characteristics of Nunavut, although non-indigenous people, mostly located in the capital of Iqaluit, also live in Nunavut. Along with French and English, Inuit Languages (Inuktitut and Inuinnaqtun) are the official and dominantly spoken territorial languages. Nunavut's population growth rate is approximately three times the annual national average, many attributing this to a drastic and historic demographic transition the area is undergoing (Ford, 2009a). Generally, the territory is challenged by low socioeconomic status, high unemployment rates, extremely limited access to health care and services, limited housing availability and limited access to basic services such

as quality water and waste-water management services (IWGIA, 2000). Many Inuit communities in Canada share characteristics with that of developing nations, with low health and well-being indicators compared to other communities across the country (Statistics Canada, 2018).

Figure 4 - Iqaluit, Nunavut. (Source: THE CANADIAN PRESS / Paul Chiasson, April 25, 2015)

3.2.Geography

The territory of Nunavut, meaning "Our Land" in Inuktitut, takes up 20% of the Canadian landmass. At 2 million km^2, Nunavut is the northernmost and largest territory in Canada, and more than half of the territory is comprised of islands (GN, 2018). It is roughly the size of Western Europe. The landscape has been shaped by ice sheets and glaciers, creating deeps valleys and fjords (Bell and Brown, 2018) (See Figure 4). Nunavut is located in the Arctic climate zone, characterized by low temperature and sparse low-lying vegetation. The region has extremely cold and long winter seasons and short, cool summer seasons. The length and time of frozen sea ice varies depending on the location within the territory, ranging from seven months to nearly year-long ice coverage in the northernmost areas. The sea ice provides an important transportation link between communities due to the territory's few paved roads, however it also acts as a barrier to boat transport. The ice is also a space for cultural and economic harvesting activities (Ford, Bell and St-Hilaire-Gravel, 2010) and the Nunavut land surface area is composed entirely of continuous permafrost (Labbé et al., 2017) (See Figure 5).

3.3.Political System

The Canadian territory of Nunavut was created from the Northwest Territories (NWT), with its own government in 1999 as one of the central provisions of the *Nunavut Land Claims Agreement* of 1993, a treaty signed between the Inuit of Nunavut, represented by the Tungavik Federation of Nunavut and the Government of Canada (Hicks and White, 2015). Territories such as Nunavut get their powers and large parts of their funding from the Government of Canada, while provincial governments have their power embedded in the Canadian Constitution (GN, 2018). Nunavut has no political parties at the territorial level and instead has

a consensus-style government, similarly to that of the NWT. All Members of the Legislative Assembly (MLAs) are elected as independent candidates through plurality vote (GN, 2018; Göcke, 2011). MLAs select the Speaker, Premier and Ministers by majority vote in a secret ballot. Unanimous agreement is not necessary for decisions and for many matters a simple majority vote is required (GN, 2018). The consensus-style governing system is considered to be closer to the ways Inuit have traditionally made decisions.

3.4.Economy

The region has undergone sweeping socio-economic and cultural changes, beginning in the 1950s, with shifts from semi-nomadic hunting communities to permanent settlements (NTI, 2016). Livelihoods traditionally and culturally derived from the land and harvesting, were transformed in a matter of a couple of decades with the introduction waged economy, imposition of hunting regulations and licensing, compulsory education and enforcement of Western governance and legal system *(ibid.)*. The wage-based economy is largely tied to public administration, seasonal resource extraction jobs, and tourism, arts and crafts playing a role in some regions of the territory. Today, Nunavut continues to have somewhat of a mixed economy wherein a variety of sources contribute to a household income, with hunting and harvesting from the land supplementing food sources for communities (IWGIA, 2000).

3.5.Infrastructure

Nunavut encompasses 25 communities that are spread across the 2 million km^2 Arctic landscape. As such providing infrastructure across the territory has been a challenging task, both in terms of financial and capacity resources, but also in terms of not being able to share services across the distances, building infrastructure for an environment dominated by extreme weather and ground underlain completely by permafrost (GN, 2012) (See Figure 5). All expect one of Nunavut's communities (i.e. Baker Lake), are coastal, highlighting their close association to the sea and reliance on marine resources and its use for transportation (Ford, Bell and St-Hilaire-Gravel, 2010).

The infrastructure is primarily built with imported materials and designed to reduce the impact on the permafrost landscape using piles, space frames or thermal siphons that limit the heat transfer through the ground (Ford, Bell and St-Hilaire-Gravel, 2010). Water and sewage tanks are built either raised above ground or insulated to prevent permafrost thawing only a few communities have piped water and sewage systems and most rely on trucks for water delivery and sewage removal (*ibid)*. Potable water comes from local ponds, rivers and reservoirs and wastewater is usually discharged in stabilization ponds (Daley et al., 2015). Homes are generally heated by imported oil, and diesel generators are used to provide electricity to all communities in Nunavut (QEC, 2019). Communities generally lack harbour infrastructure except for small crafts. Large vessels that visit communities rely on barges or specialized landing crafts to access the communities (Ford, Bell and St-Hilaire-Gravel, 2010). The challenges of providing infrastructure that supports the continuation of the unique social, cultural, environmental and economic needs of the different communities spread across such vast territory are considerable (GN, 2012), with private homes for example making up only one-fifth of Nunavut dwellings (NHC, 2016).

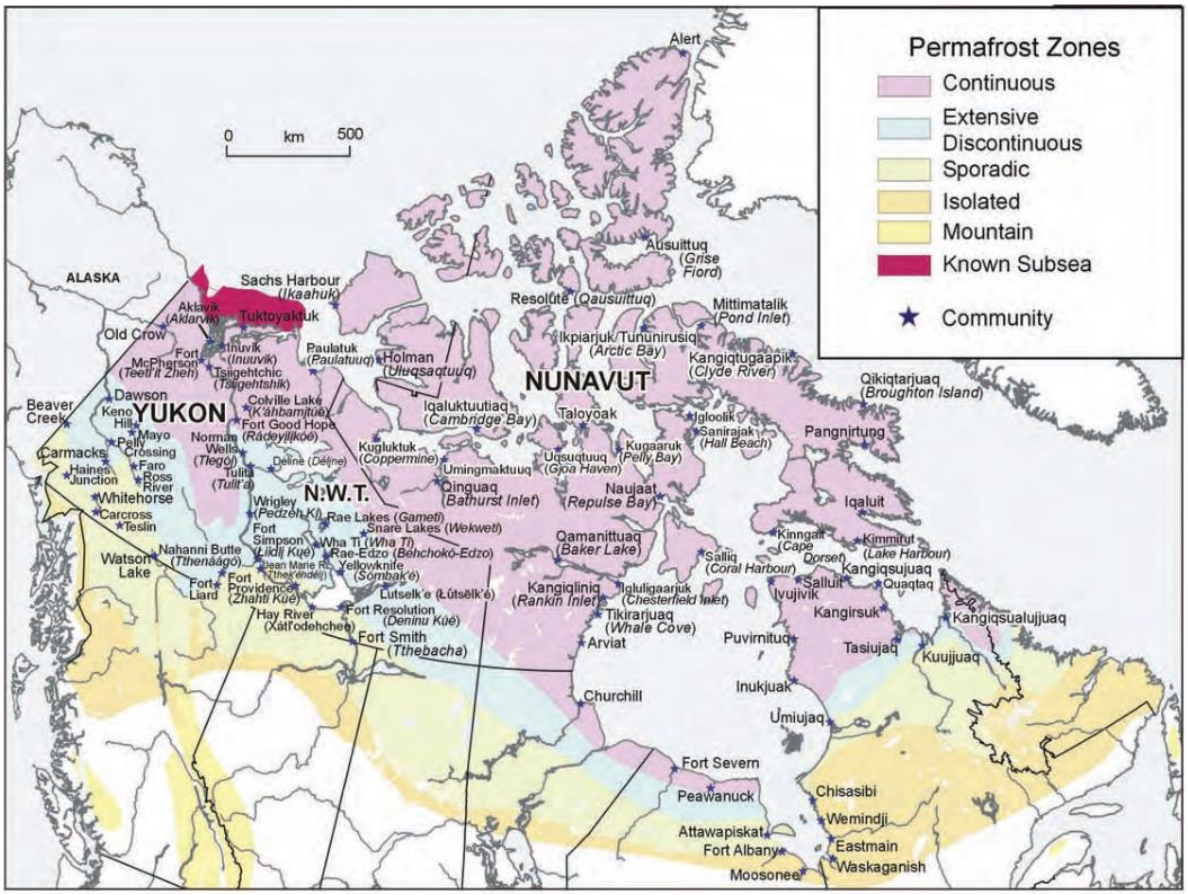

Figure 5 - Political boundaries and communities of the Canadian North, superimposed on a map permafrost zones (Source: Frugal and Prowse, 2008: 61)

4. Research Methodology

This section introduces the research methodology used for the thesis project, focusing specifically on the case study approach utilized and the case selection process of the research. Thereafter, the focus is on the literature review and the interviews conducted, and the challenges and limitations of the chosen data collection methods that emerged from this research approach.

4.1. Case Study Approach

A qualitative case study approach was chosen in order to understand the processes and in what way CCA knowledge and ongoing measures are implemented and integrated in critical infrastructure projects and policies in the context of Nunavut (Creswell, 2014). A qualitative approach is deemed suitable particularly in the case where knowledge, relationships, experiences or processes are studied (Yin, 2009; Denscombe, 2010; Neuman, 2013). A case study approach allows working with real life situations (Flyvbjerg, 2011). Thus, it helps to understand the interrelationship between the processes, looking at the general phenomenon while at the same time trying to understand the complexities of a specific context (Stake, 2005). Using a case study approach allowed us to start with a literature review in order to understand some of the larger thematic areas and research issues in the field, which in turn influenced the formulation of the research purpose and research questions, as well as the questions generated for the primary data collection phase.

4.2. Case Selection

Nunavut was purposively selected as a case study due to the severity of observed and projected changes in climate and established research need and adaptation initiatives that have tried to create some larger transformational change (GN, 2003). Efforts to increasing infrastructure resilience must be viewed as central to climate policy for Nunavut, as current and future climate change impacts will have lasting repercussions on the area, the environment and its inhabitants (Ford, 2009a).

4.3. Research Methods

The research study gathers qualitative case data by utilizing two methods of data collection in order to gain a better understanding and insights for the overall research purpose and research questions, using (1) a scoping study and a review of grey literature and publications, in combination with (2) semi-structured interviews with experts and researchers in the field. Details of these two parts, as well as their respective limitations, are discussed in detail further below.

4.4. Scoping Study

To answer the research questions a scoping study was used in order to provide an overview of the scientific and grey literature in the field as well as provide a baseline of existing information and knowledge. A scoping study is a type of literature review, and while there is no consensus on a universal definition or purpose, the main characteristic of this method is to provide an overview to a broad topic or research question (Peterson, 2016; Daudt et al., 2013). The aim of the scoping study is to map and provide an overview of the existing available knowledge and

research in a specific field. It is used to identify the main sources and key concepts, research gaps as well as types and sources of evidence to inform (Arksey and O'Malley, 2005).

While a scoping study is deemed to be the best method for this specific thesis project, limitations of scoping study should also be highlighted. Due to the sheer potentially large and diverse body of literature that pertain to any given research question, a scoping study can often lack completeness because the searching is determined by the time, resource and scope constraints of the researchers themselves and thus scoping studies cannot be seen as final outputs. This also means that scoping studies usually are descriptive in nature without critically analysing the individual research studies, and the lack of quality assessment in the process should not be used as the only input for conclusions (Grimshaw, 2010; Daudt et al., 2013). However, this was overcome to a certain extent, due to the multidisciplinary research team allowing for "expertise to map a subject" that is "not necessarily always found in one researcher" when assessing literature (Daudt et al., 2013: 8).

Based on the scoping study and the primary data collected from semi-structured interviews, the purpose of this thesis is to provide an overview of the current CCA consideration in Nunavut and highlight in what way CCA considerations could be integrated more or improved to provide a more focused climate-sensitive infrastructure approach. The scoping study was conducted on 22nd of February 2019 adapted from the methodological framework (See Figure 6) outlined by Arksey and O'Malley (2005) and Dault, Mossel and Scott (2013). The next section describes the framework and its execution.

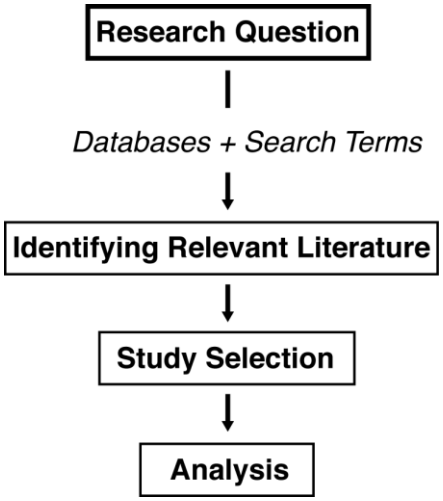

Figure 6 - Methodological Framework for Scoping Study, adapted from Arksey and O'Malley (Source: Arksey and O'Malley, 2005)

4.4.1. The Research Questions

The first step in a scoping study is identifying the research question. Arksey and O'Malley (2005) advise to keep a wide approach and use a broad research question in order to reduce the likelihood of missing relevant articles and generate a breadth of coverage of the topic (Arksey and O'Malley, 2005). At the same time, this can lead to an inconceivable number of entries to review.

4.4.2. Database and Search Engines

The sources used for finding relevant academic literature review include the LUB search engine, which publishes peer-reviewed academic literature, as well as the ScienceDirect database which is an academic database with peer-reviewed articles. Lastly, Google Scholar is used for access to grey literature to complement the theoretical foundation of the topic and include other reports and government publications.

4.4.3. Search Terms

Using the Boolean Operator approach, the following search string was used to attain a comprehensive list of sources.

(‘climate change adapt*’ OR ‘risk assessment’ OR ‘knowledge’ OR ‘critical infrastructure’ OR ‘infrastructure’ OR ‘climate-sensitive infrastructure’) AND (‘Nunavut’ OR ‘Arctic’)

4.4.4. Identifying Relevant Literature

Another step in the scoping study is identifying relevant literature. In order to get a complete picture of the current state of knowledge of CCA knowledge and ongoing measures for critical infrastructure in Nunavut, academic peer-reviewed articles and grey literature such as reports and government studies, are assessed and reviewed. Since peer-reviewed literature as well as grey literature are included, all results from the database search are referred to as *entries.*

4.4.5. Study Selection

The third step is the selection of relevant entries found during the keyword search. The search results are reviewed through the analyses of their title, date, institution and abstract and must be publicly accessible. Entries that are clearly irrelevant are removed, while the others are retained. All retained entries are then further reviewed in greater detail by studying their title, date, institution, abstract and body of text to verify if they meet the inclusion criteria (See Table 1). The initial search retrieved 16,752 documents. A sub-total of 350 documents were identified as relevant and reviewed, amounting to the final total of 150 documents to be retained, once duplicates were removed. Following the review including the search criteria, 103 entries were included in the study for further analysis while the other 47 were excluded (See Figure 7).

Table 1 - Inclusion and exclusion criteria for document selection

Inclusion	Exclusion
English	Non-English
Published between 1999 - 2019	Pre-1999 or post-March 2019
Indexed in peer-reviewed databases or from grey literature (government reports)	Others (e.g. blogs, meetings, news, etc.)
Available online through Lund University	No significant mention of Arctic and/or Nunavut
Mentions Arctic and/or Nunavut	Does not mention climate change and/or adaptation
Vulnerability/resilience/Risk assessments focus	Human systems are excluded
Mentions climate change and/or climate change impacts	Focus is on prehistoric impacts
Mentions human system or build environment adaptation strategies	Focus is on mitigation strategies only
Mention adaptive strategies / practical focus	Focus is on sustainable development only
Mentions critical infrastructure	Focus is on the effects of climate change on natural systems only
Mentions key infrastructure sectors	Presents a conceptual and methodological approaches only
Presents case study of CCA in vulnerable environments and/or the Arctic context	(Critical) infrastructure completely excluded
	Article outside the scope/relevance of study

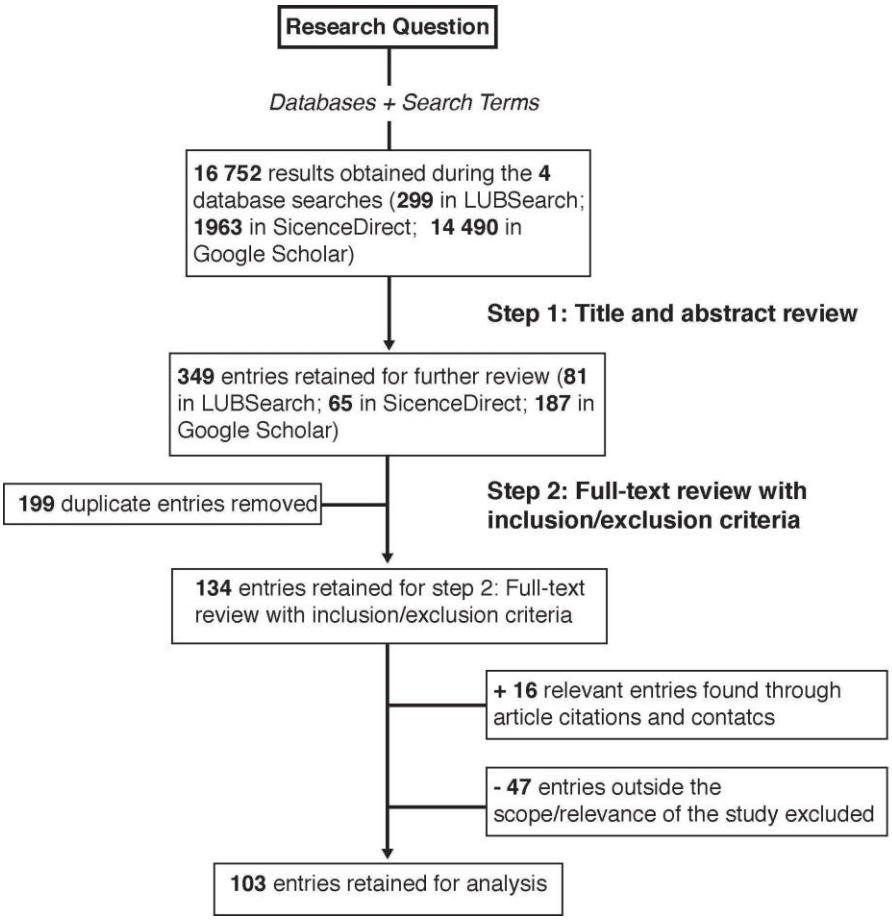

Figure 7 - Flow chart of the process of selecting studies for review, according to stipulated inclusion/exclusion criteria (own figure).

4.4.6. Analysis

The analysis was performed in two steps, Arksey and O'Malley (2005) recommended to begin the analysis process by charting and sorting the collected data in key themes and trends. They suggest that the data should include a mixture of general information about the entry and specific information related to the research questions.

The information collected through the review and the analysis of the entries was recorded in an excel database as follows:

- Author(s), publication date, document type, institution and publisher
- Aim of the study
- Methodology
- Sector and geographic study area

Secondly, an in-depth analysis focusing on gathering specific relevant data to answer the research questions was carried out in order to identify data on current and projected measures undertaken in Nunavut as well as in similar Arctic context for climate-sensitive critical infrastructure.

The information gathered during the scoping study is presented in the *Empirical Results* section on page 21 and was used to motivate the choice of interview questions and to fuel the discussion found on page 27.

4.5. Interviews

In combination with the scoping study, key informant interviews are utilized to gather information in an open-ended format with experts working in relevant fields. Semi-structured interviews are a standard research method for collecting information (Huntington, 1998), having been used to obtain further understandings and insights for various research areas and contexts (Oldenborger et al., 2016; Measham et al., 2011). Semi-structured interviews complement the scoping study and facilitate the answering of the two research questions.

4.5.1. Interview Guide and Process

The respondents were identified through a purposeful sampling[1] strategy where having expert knowledge and/or in-depth experience in the relevant field is the important criterion (Cresswell, 2014: 217; Blaikie, 2000: 205). Knowledge in the research field was important although emphasis was initially put on seeking a cross-section of participants that reflected age, gender, experience or type of employment. Additionally, within the identified group, the 'snowballing technique' was used in cases where interviewees provide further contacts to additional potential respondents (Cresswell, 2014). For the relevant participants to be selected, a letter outlining the background information on the thesis research area and the thesis purpose was attached to every initial email sent to potential respondents (see Appendix 2). Short background information about the research purpose, area and thematic focus was briefly provided again at the beginning of each interview. This process resulted in a total of 5 interviews being conducted by the

[1] "The purposive sampling technique, also called judgement sampling, is the deliberate choice of an informant due to the qualities the informant possesses. It is a non-random technique that does not need underlying theories or a set number of informants. Simply put, the researcher decides what needs to be known and sets out to find people who can and are willing to provide the information by virtue of knowledge or experience" (Tongco, 2007: 147).

authors, with a relatively small number of respondents but in-depth engagement (Appendix 5). The interview process took 30 - 45 minutes.

With two research questions as the main guiding principles, a set of interview questions was developed in order to facilitate the discussion. The opening questions related to the participants role and responsibilities within their respective organization, as well as briefly discussing their background and relevant years of experience in the area of study.

The main questions focus specifically on the conceptual background and key terminology and in what way key informants understand and work with concepts of CCA, vulnerability, resilience, etc. This facilitates answering the first research question dealing with what the current state of knowledge is for CCA in critical infrastructure in Nunavut. Additional central questions focus on answering the second research question which seeks to understand in what ways this knowledge and information is operationalized and translated within current and future critical infrastructure projects and throughout the processes of risk assessments, M&E and other frameworks guiding critical infrastructure development.

Additional probing questions were utilized throughout the interview process in order to gain more clarity or additional information if necessary. Space was left in the interview process and at the end, for participants to highlight any additional concerns or themes they thought would be important to include and/or were not covered by the authors' questions.

4.6.Ethical Considerations

In line with the methodology, it is also important to note that this research involved collecting data from people and a unique context different from the researchers' own surroundings and lived experiences. As such, carefully considering the context with which the authors work with and being cognizant of the challenges and benefits that this research brings, facilitates several ethical responsibilities the authors have.

Firstly, related to the primary data collection process, some key ethical considerations include the interview process and the resulting information gained from them. Ethical responsibilities to the participants include (1) informed consent of interviewees, (2) voluntary participation in interviews, (3) confidentiality and anonymity, (4) clearly stating if research is intended to be published, (5) providing copies of the research project to participating interviewees, i.e. sharing project results, (6) considering publication in different languages (i.e. native language of interviewees and/or study context if possible) and (7) trying to examine several perspectives from a wide range of actors in order to get a fuller picture.

Further ethical consideration pertains to the academic research process. Ensuring a transparent research process results in more validity and legitimacy of the final research project. Clarity in terms of the author's own understanding of key terminology and concepts can further facilitate this and is demonstrated in the *Conceptual Framework* section. Similarly, any assumptions, limitations and delimitations of the research made throughout the research processes should also be clearly outlined to preserve ethical obligations to the academic validity of the research.

4.7.Challenges and Limitations of the Research Methodology

As part of the research process some challenges and limitations in both data collection methods of literature review and semi-structured interviews are highlighted here.

The lack of coherent definitions of key concepts and terminology, i.e. different understanding of concepts such as *CCA, resilience, vulnerability*, etc. present a challenge when conducting such a wide literature review through a scoping study. To minimize the risk of overlooking articles, multiple search engines were used with a variety of keyword search combinations in order to get a comprehensive collection of literature. It is also important to recognize that the review of research and publications was limited to the English language, which did produce a large amount of literature but failed to include any publications in the local indigenous languages for example.

Additionally, the focus on peer-reviewed articles and grey literature sources will inevitably have missed other sources of knowledge. This is particularly relevant in the case of Nunavut where traditional knowledge and Inuit ways of understanding and recording information regarding human-environmental interactions (e.g. such as stories, traditions, observations, etc.) continues to challenge researchers and academics in terms of how to include, capture and methodologically review such knowledge (Jasanoff, 2010). The number of documents however that were reviewed for in-depth analysis is believed to be comprehensive and allowed for a wide breadth and depth of understanding.

A clear challenge in collecting primary data through interviews is the 'interview effect' (Halperin and Heath, 2016), meaning the respondents' answers are influenced by the researcher present and the questions posed. This limitation can be minimized by allowing flexibility and thus the interview guide was consciously designed in a way to allow respondents room to add anything. An additional challenge is present as the semi-structured interviews often end up being limited to a small group of participants, both due to the limited number of participants targeted and available but also due to the authors' time and resources constraints. At the same time, a small number of respondents allows for a more in-depth discussion with each. The 'snowballing technique' also meant that there is a high probability that a more homogenous group emerged from the potential participant pool, which again would reflect on how much diversity would be present in the interviewees and therefore in the discussions and results of the project.

5. Empirical Results

This section examines the empirical results found in the interviews and the literature of the scoping study and highlights the main publication trends related to CCA knowledge and its considerations and implementations in critical infrastructure development, policy and prioritization in the context of Nunavut. Throughout the interviews and the review, a number of entries were gathered related to the thesis topic and offer insights into the current state in terms of structural, human and policy adaptation, as well as future needs for adaptation, research and knowledge for CCA.

Analysis of relevant published documents were identified from the global adaptation dataset created by Berrang-Ford et al. (2011) (Berrang-Ford et al., 2011). The 150 documents were retained for a secondary in-depth analysis from which 103 were included to provide a basis for answering the two research questions, inform the interview guide for the primary data collection process and specify research trends and gaps. The majority of the documents reviewed can be classified as academic in nature, published in peer-reviewed journals (73 documents), reports (15 documents) and books (10 documents) (See Figure 8). The remaining documents can be classified as grey literature and were published through non-governmental organizations (NGO), governments, consultancies, community organizations or businesses (See Figure 8).

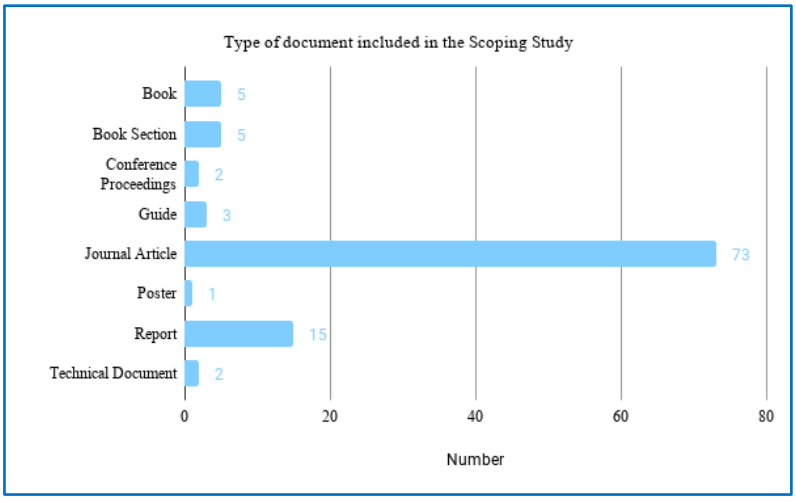

Figure 8 - Types of documents included in Scoping Study (own figure)

While setting out to map the state of knowledge of CCA in the infrastructure sector in Nunavut, the scoping study results highlighted clear thematic trends and correlate with some of the interview discussion results that also emerged. Of the 25 communities in Nunavut for which literature was reviewed as part of the scoping study, 8 communities were found to have engaged in some form of academic or research collaboration, with the capital city of Iqaluit having the highest number of articles published per community (See Figure 10). A number of key themes emerged in the scoping study outside of the initial research focus on CCA in the infrastructure sector, and were deemed still relevant for a systematic overview and understanding of the adaptation landscape in the region.

The first dominant feature of many articles in the scoping study was the focus on overall general adaptation necessity in the territory (Bell & Brown, 2018; Pelling & O'Brien, 2015; Ford, McDowell & Pearce, 2015; Berrang-Ford et al., 2014; Ford, McDowell & Jones, 2014),

with larger adaptation frameworks and guidance materials for all scales of Nunavut. Besides highlighting the larger holistic CCA approach in the research, the second scoping study theme that emerged was a distinct preference for remote and rural communities still practicing harvesting and hunting activities to supplement livelihoods and food sources and how adaptation impacts this area (Bell & Brown, 2018; Archer et al., 2017; Ford et al., 2016; Ford & Pearce, 2012). Thirdly, community focused research and publications found in the scoping study pointed towards the increasing importance of knowledge management and knowledge production sources. The importance and role of traditional knowledge (TK) was a prominent thematic trend of the scoping study, particulars as it relates to individual adaptation strategies practices by those living in the territory (Pearce et al., 2015; Ford, McDowell & Pearce, 2015; Daley et al., 2015; Ford et al., 2010; Wall & Marzall, 2006). A fourth trend was that much of the research literature focused on the state of the health and livelihood sectors and what the specific vulnerabilities were that were brought about by climate change (Bell & Brown, 2018; Ford et al., 2018; Daley et al., 2015). Utilizing the general themes from the scoping study and the interview discussions, four empirical results for the research focus were formulated.

5.1.Community Focused Research and Publications

Based on the set boundaries of the scoping study and the timeframe, the number of included publications in the scoping study reporting on adaptation knowledge, research and activities in relation to infrastructure in Nunavut has increased over the past two decades, from 2 publications in 2003 to 10 in 2018 (See Figure 9). This increase follows the general trends and growing interest globally in research and knowledge-generation that focuses on ‘adaptation science’ and its operationalization throughout different sectors.

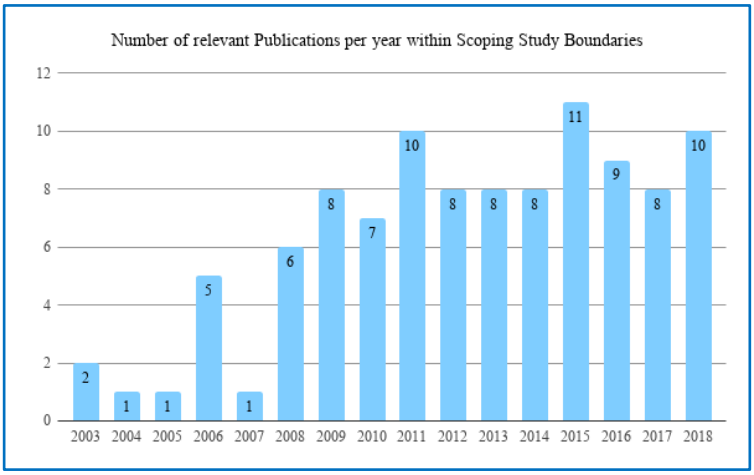

Figure 9 - Number of relevant publications per year within the scoping study boundaries (own figure)

The geographic distribution of the publications and research was intentionally limited to the Arctic region, Northern Canada and in particular Nunavut, due to the aim of the thesis project. Research in Nunavut is well represented in general literature as well as within the scoping study (See Table 2); the territory has a long history of scholars working in the area and collaborating with research institutions (Ford et al., 2012a). However, it should be noted here that even within these set boundaries, a distinct research focus and publishing trend on some smaller, remote and rural communities within Nunavut emerged from the retained entries (See Figure 10). Ford

et al. (2012a) noted that distinct research hotspots had emerged, "with highly studied communities and regions mirrored by research deserts characterized by communities where no studies [had] been reported" (Ford et al., 2012b: 816). One informant interviewed, mentioned that several pilot studies were happening in 7 communities, with the aim of rolling it out to the remaining 13 throughout Nunavut, in order to get comprehensive data coverage on the whole territory (Interview 3). A major challenge to this however is that "most of the work has to be contracted out because there's such low staff capacity in Nunavut" and as a result, southern researchers or southern departments are hired to conduct research and analysis in the north, many with limited understanding of the local dynamics and realities.

Table 2 - Geographic distribution of publications

Geographical Area	References	Geographical Area	References
Nunavut	35	Other	9
Arctic Region	19	Quebec	3
Northern Canada	16	Newfoundland and Labrador	3
Canada	14	Alaska	3
North-Western Territories	13		

5.2. The Importance of Knowledge Management and Growing Need for Different Knowledge Production Sources

Throughout the scoping study, knowledge trends and thematic areas reflected the need for further enhancement of knowledge and research, as well as knowledge production from different sources.

Over a third of articles discussed the need for increasing the evidence-base and knowledge around CCA in infrastructure. The scoping study highlighted that the stakeholders working in Nunavut in the climate change realm and the infrastructure arena are increasingly aware of the value of generating knowledge and research on CCA and climate change impacts on infrastructure, as well as mainstreaming climate change data as a factor in decision-making processes and policies around infrastructure development. The interviews further reflected the need for knowledge management through collaboration and knowledge sharing between departments and at different levels of government, particularly when it comes to local input for higher-level policy development and negotiation.

In addition to knowledge management and production, the importance of different knowledge production sources was also highlighted as essential for any CCA activities to be successful. Different knowledge sources both in terms of different communities (i.e. all 25 communities, not just the ones that are highly researched) in order to get a more comprehensive coverage of the region and a better understanding of the differences and similarities of each communities vulnerabilities and level of resilience for CCA planning in infrastructure, but also different knowledge sources in terms of different types of knowledge sources such as TK. One informant commented on the risk of using global assumptions for local decision-making, citing the example on net-zero energy buildings and aims of making this a mandatory regulation

across Canada by the federal government, which would be socially, economically, financially and capacity-wise not feasible for the territory and its current budget, capacity and resources:

> [If a federal policy] doesn't allow for regional or local input [...] there could be unintended consequences. For instance, the energy code. If the energy code is so strict that they push for something like a net-zero requirement, the cost of implementing that kind of requirement in Nunavut would be exorbitant to the housing. So I think any kind of high level policy has to be informed with the policy consequences that they're going to actually create on the ground [otherwise it's not realistic] (Interview 3).

Another quote below reflects this statement in relation to the issues that occurs in communities when local knowledge is not integrated into larger policy decisions and lack of flexibility in implementation at community-level with the example sea-level rise:

> In some cases around Foxe Basin...there tends to be isostatic rebound. So even considering scenarios for sea level rise globally, there could be isostatic rebound of the land [...] so there could be shoreline accretion actually as opposed to degradation. But if the policy is made that says [...] we [should] move all development 30 meters from the shore...we could be making policy decisions that are not suitable for local situations. So I'd say there's a risk in terms of using global level assumptions [with local consequences] (Interview 2).

TK was widely recognized throughout the literature as essential for inclusion in any adaptation knowledge production and CCA initiatives in Nunavut. Inuit have a long history of adapting to the extreme weather and environment and as such have a plethora of valuable knowledge that is key to consider. Several authors, however, have highlighted the difficulties of fully integrating local stakeholders in a meaningful and engaging way and few reviewed literature presented evaluation of such efforts to show the learnings, challenges and successes.

5.3.Limited Infrastructure Focus in Climate Change Adaptation Planning

The scoping study highlighted that much of the research and knowledge remains largely focused on adaptation in general, with limited focus on infrastructure in particular, or what role CCA considerations have for this particular sector. Integration of climate change is well acknowledged. However, the scoping study highlighted the challenges of moving from so-called 'adaptation science', i.e. theory and knowledge, to actual practical implications or effective policy influence, planning and development. When adaptation action does occur, it is often incremental with limited reporting of transformational change. Some research on infrastructure in the Arctic is being done, the majority of it is quantitative research from the engineering discipline, and is not directly linked to climate change, but rather on how infrastructure has to be built to withstand the harsh environmental realities of the region.

At the same time, one interviewee also commented that often existing territorial and federal infrastructural policy or guidance material lags behind what is being practiced on the ground and that any higher-level guidance, even if existing, is not felt to be necessary to build robust and resilient local infrastructure. The quotes below reflect this statement:

> [The climate change strategy] is going to involve changing a whole lot of other things with respect to building codes and energy codes and all these sort of things. So [...] those are pretty high level objectives while we here are really dealing with what we need to right now on the ground as an end user. We may be further ahead in terms of [...] addressing stuff now and there may be like lag between what actually happens with respect to changes versus higher level policy which takes longer. (Interview 2)

Although several databases and search combinations were used resulting in a comprehensive list of literature to be reviewed, there was a limited amount of literature in the scoping study that was specifically focused on CCA in relation to infrastructure and infrastructure development. The literature does discuss the current state and future needs of CCA for infrastructure, however, a lack of precision on what type of infrastructure was noted throughout the scoping study. A number of articles make few distinctions between different types of infrastructure and their respective uses and needs, only referring to it in general terms.. This lack of focus or distinction influences how effective policy and decision-making is when dealing with different types of infrastructure requiring different needs and adaptation priorities.

During the scoping study, general themes related to CCA and infrastructure emerged, with entries assigned different sector tabs related to their respective area of focus within the research topic. From this, a number of publishing trends and research gaps also became apparent within the infrastructure sector. When infrastructure was indeed the central topic of an article, the focus was most often on the transportation and road infrastructure sub-sector. Existing climate-sensitive infrastructure intervention in the transportation and road infrastructure sector in turn, was found to often focus on how climate change impacted harvesting and hunting trail networks, as well as all-weather roads or sea routes.

Any additionally relevant findings were found in grey literature (i.e. technical reports, government documents, etc.) regarding the construction of housing and buildings in relation to the increasing threat of permafrost thaw that is occurring in Nunavut. Additional critical infrastructure sectors such as water and waste management, energy and ICT or other additionally important sectors such as health and medical infrastructure were not found in any significant or meaningful way in the articles that were retained for in-depth analysis.

5.4. Existing Policy Guidance for Climate Change Adaptation at different Governance Levels

During the scoping study process a number of relevant high-level federal and territorial policy and framework documents were identified and were considered important to analyse the existing CCA policy that provides guidance for different levels of government throughout Canada on matters of CCA and/or infrastructure. The Adaptation Policy Framework (AFP) outlines the federal government's role and the general direction needs to effectively integrate climate change considerations into programmes, policies and operations (GC, 2011). The federal government is responsible for generating and sharing knowledge, building adaptive capacity to respond and helping Canadians take action. In the context of Nunavut, this has led to funding for territorial and community-based adaptation initiatives (Labbé et al, 2017). The AFP has also fostered the development of northern-focused adaptation programmes and

partnership such as the *Northern Infrastructure Standardization Initiative*, which created a series of construction standards to promote long-term sustainability and resilience of Canada's northern infrastructure. The Pan-Canadian Framework on Clean Growth and Climate Change (PCF) developed in collaboration with the provinces and territories lays out another federal strategy along four main pillars: (1) pricing carbon pollution, (2) complementary actions to reduce emissions, (3) adapting and building resilience and (4) clean technology, innovation, and jobs creation (GC, 2016b). Within the Adaptation pillar, the document present five new actions for the federal, provincial and territorial governments: (1) translating scientific information and traditional knowledge into action (2) building climate resilience through infrastructure (3) protecting and improving human health and well-being (4) supporting particularly vulnerable regions and (5) reducing climate-related hazards and disaster risks (Ford et al., 2017; GC, 2016).

An important piece of additional literature found in the scoping study, which was promoting cross-territorial collaboration, came as a result of the Pan-Territorial Adaptation Partnership (PTAP). It is a collaboration between the Government of Nunavut, the Northwest Territories and Yukon, to work on adaptation planning and its implementation in the region. In 2011, the *Pan-Territorial Adaptation Strategy* was published, describing the challenges and goals of the territories to address climate change and ways to support current and future adaptation projects. The partnership is viewed as having a strong voice and being an important coordinating role in the region.

Another particularly important document was reviewed and included in the scoping study with the Government of Nunavut's climate change and adaptation strategy presented in *Upagiaqtavut: Setting the Course* (2011), which outlines the territory's priorities and objectives for adaptation. The strategy is structured around building adaptive capacity through four main components: (1) partnership building, (2) research and monitoring of impacts, (3) education and outreach, and (4) government policy and planning. The strategy gives principles for how to approach adaptation and acts more as a guiding document rather than a clear path towards concrete adaptation actions (Ford et al., 2017; Labbé et al, 2017). From this, the *Atuliqtuq: Action and Adaptation* project came about, which was aimed at building adaptive action through awareness raising, planning and research (GN, 2011b). The project has resulted in climate change adaptation plans for seven communities and the creation of *The Climate Change Adaptation Planning: A Nunavut Toolkit (2011a)*, to help other communities develop adaptation strategies. Additionally, the Government of Nunavut has a number of toolkits, guidelines and recommendation that strengthen territorial and local adaptive capacity. Federal and territorial strategies and frameworks have led to projects such as *A Homeowner's Guide to Permafrost in Nunavut* (2013) which outlines different methods to assess permafrost conditions and suggestions to counteract permafrost degradation close to housing for the general public, or the *Integrated Community Sustainability Plans (ICSPs) toolkit* to help communities create community profiles of existing infrastructure and future infrastructure needs (GN, 2019). Several communities have conducted different environmental impact assessments for their land-use planning and current infrastructure as part of pilot studies being launched at the territorial level. One interview participant mentioned the valuable data this produces for the larger community plans, which in turn informs future infrastructure development plots in a community, but a general lack of data was also acknowledged. Data scarcity due to the lack of monitoring station often results in access to only some generalized projects and information, but no downscaled climate change data that could support community-specific information, one

informant commented “we see those kind of world maps with data [and Nunavut] is white because there’s insufficient data to do a lot of the analyses” (Interview 5).

Policy guidance for climate change adaptation at different levels on how different levels of government work together can foster the mainstreaming process and integration of knowledge into different sectors as well as how policies are understood and operationalized by communities throughout Nunavut and Canada in general. Throughout the scoping study and the discussions with informants, effective guidance and collaboration between all levels of governance and in different sectors, in particular infrastructure, has been identified as crucial if long-term resiliency wants to be achieved in Nunavut.

6. Discussion

To further analyse and answer the two research questions, this section discusses some of the key themes and factors that impact CCA knowledge and learning for the infrastructure sector and in what way this knowledge is implemented and operationalized in infrastructure development, policy and prioritization in the context of Nunavut. The sections are primarily fuelled by our research and the findings of the scoping study outlined in *Empirical Results* section, along with the themes that emerged from the primary data collection with the key informants and outlines some short recommendations at the end of this section.

6.1. Research Disparities in Groundwork Initiatives

The geographic distribution of academic and grey literature was intentionally limited to Nunavut and the Arctic region more generally in order to get a concise view and understanding of the current research and thematic trends in the region. Overall, research on and publications of Nunavut are well represented within the scoping study. The increase in publication however upon further analysis revealed that there were distinct geographic disparities in research and academic collaboration between different communities in Nunavut. Some communities were highly researched (e.g. Iqaluit or Igloolik), while other communities had no or limited history of research. This does not necessarily mean however, that the communities with more research publications were more vulnerable than others with less research. Ford et al. (2012b) discussed this, noting that these research hotspots can often be tied to (1) different geographic locations of the communities and/or (2) local leadership and willingness within the communities to engage in research and adaptive capacity development (Archer et al., 2017; Ford, 2009b; Wall and Marzall, 2006). Most commonly, the scoping study highlighted the documentation on climate vulnerabilities of specific communities, with the end product often being community-based vulnerability assessments (CBVA) (Instanes et al., 2016; Ford and Pearce, 2012). The focus of the research was often centred on the respective community's resilience and vulnerabilities to climate change, with the built environment being one of several other components including social, economic, etc. (Prowse and Furgal, 2009) and what resulting adaptation strategies should be initiated and are feasible in the given community (Ford, McDowell and Pearce, 2015).

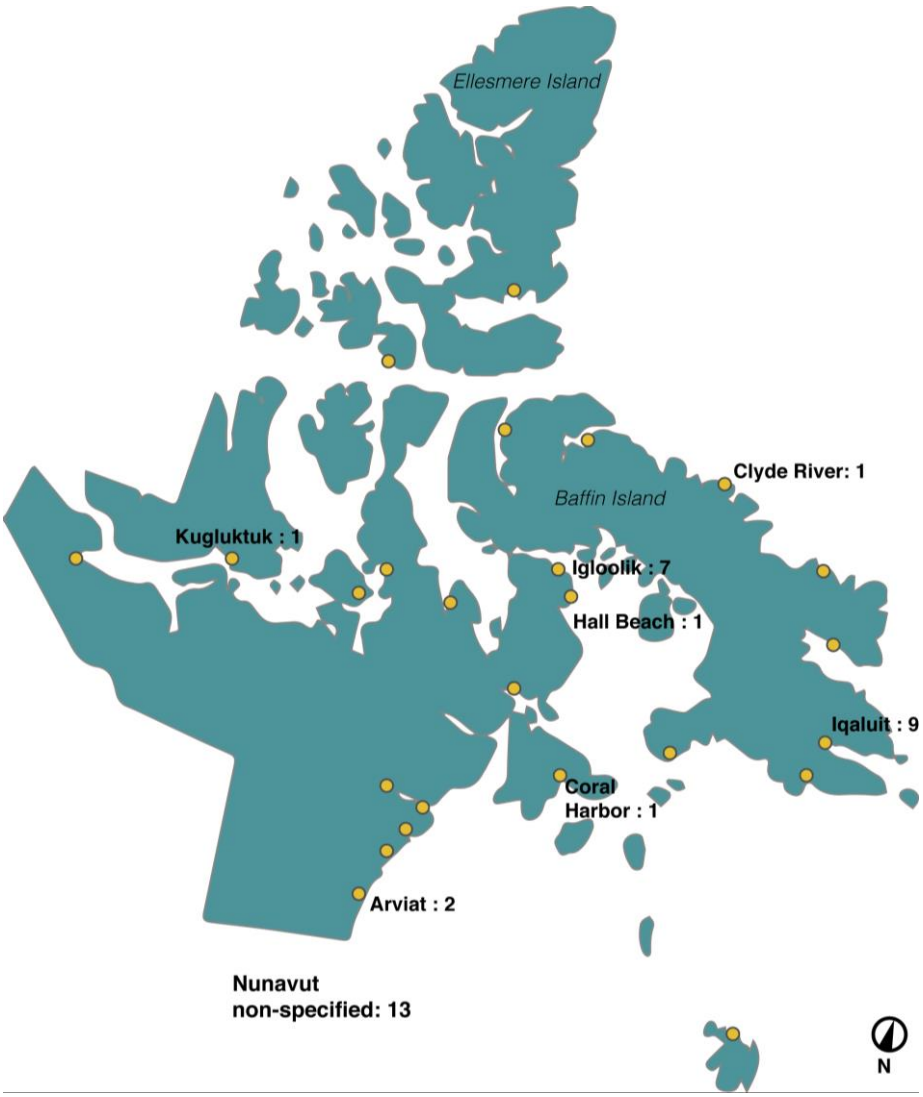

Figure 10 - Map of Nunavut showing the number of articles per community (Source: Adapted from The Government of Nunavut, Health Facilities Map, 2019)

This disparity between communities in the territory could signal a potential entry point for further research and filling the knowledge gaps that still exist, in turn providing data for policy intervention at the local level where levels of resilience might significantly differ between respective communities (Bell and Brown, 2018). A cautionary note here is that the increase in good publications and research is promising and shows interest in this field and region is growing, but the increase is limited to certain kinds of topics in research and certain individual localities (See Figure 10). There is a risk that this kind of uneven pattern results in the formulation of blanket policies applied at a larger level for all 25 communities, while the context may differ from one community to another. A move towards more contextually-based studies and research across all communities more evenly, will reduce the risk of homogenized CCA planning in infrastructure.

It should be noted here that in order to address some of these geographic differences in research publication and potentially resulting differences in adaptation efforts and/or funding, the territorial government also launched an infrastructure consultation process in 2008 that allows communities to build *Integrated Community Sustainability Plans (ICSPs)* which result in community-specific infrastructure profiles, detailing the current state of infrastructure and

helping in identifying future infrastructure needs and goals (GN, 2019). This toolkit was particularly highlighted as a significant step towards creating a path for individual communities to capture their specific infrastructure needs and highlight their community challenges and risks in order to build a community-specific strategy. This type of process is also seen as a way for this knowledge to be integrated into the larger territorial community development and CCA strategy and agenda, contributing to an increased dialogue and knowledge-sharing that allows for more informed and effective decision-making.

Mainstreaming processes have shown to be most successful if both vertical and horizontal integration pathways are combined (Nunan et al., 2012) and are a key recommendation, using knowledge sharing networks, working groups, etc. of both technical experts and policy makers as a way to exchange information and experience in order to make well-informed decisions and allow for local realities and practices to be reflected in policy development. Some respondents identified this as a potential avenue to reduce high-level policy lagging behind the CCA knowledge that is gathered in practice by practitioners. Additionally, increased dialogue and collaboration are also seen as a success factor to raise awareness amongst both technical experts and high-level policy makers for CCA concerns in relation to infrastructure prioritization and development of a better understanding of its importance. Closely connected to this is the capacity development and communication in relation to M&E in order to create accountability, transparency and regular reporting mechanisms that outline lessons learned which can be crucial for future directions and resilience building efforts.

6.2.Knowledge: Connecting Climate Change Adaptation and Infrastructure in Research

'Connecting the dots' in research between the CCA research realm and that of infrastructure research is central in addressing some of the challenges of achieving a more climate-sensitive infrastructure approach in Nunavut. The need for connecting climate change adaptation and infrastructure has continually been cited throughout reviewed literature and by interviewees as relevant and necessary, however current trends indicate that much knowledge investment remains focused on adaptation in general, with limited infrastructure-specific adaptation focus.

Overall, the scoping study found literature on infrastructure is underrepresented, particularly when it comes to infrastructure in an Arctic context where climate impacts are already extreme and varied. The limited literature and research found during the scoping study that did touch on infrastructure CCA, was limited to the transport and road infrastructure sub-sector. This focus in the literature can be tied to several reasons, including the high financial investment often required for transportation and road network developments and the potential projects that would require a long lifespan, withstanding potentially very different climatic conditions in the future (GN, 2013).

It should be noted here that a wider review beyond the scoping study literature supported this argument. It was not so much the lack of literature around CCA and/or infrastructure individually, but more specifically the lack of connecting the two. While there is a lot of research on the infrastructure sector, it often only considers quantitative aspects of resilience. Infrastructure development is often hard to link with active CCA efforts instead of just good building practices and in the case of Nunavut, historical technical knowledge and know-how of building in the Arctic context. Qualitative considerations such as questions about what ways infrastructure will be used, what the different needs and what the different challenges are in

different communities, etc. are important qualitative indicators to consider and can highlight individual communities' experiences (Johansson et al., 2014). Integrating local knowledge into overall data collection, planning and decision-making process has been shown to be key towards long-term resilience of any sector or efforts, including CCA activities (Borie et al., 2019; Pelling et al., 2015).

For example, a risk mentioned earlier in the empirical findings was that adaptation research was often not infrastructure-specific and knowledge material not locally specific. Research on the infrastructure sector often tends to focus on engineering-based vulnerability assessments (VAs), that tended to be much more technical and quantitative in nature (Bakaic et al., 2018; Du et al., 2017; Perreault and Shur, 2016). Many of these VAs focus on specific individual infrastructural assets (i.e. a specific building, port, a stretch of road, etc.), particularly in relation to the risk of permafrost thaw (Ford et al., 2015; GN, 2013). This area of academic literature tends to be dominated by private engineering businesses, the territorial and federal governments and consultancy companies that conducted geo-technical profiles, modelling exercises, projections of future costs, etc. (Hatcher and Forbes, 2015; Canadian Standards Association, 2014a, 2014b; Instanes, 2007). All these technical efforts are required and necessary, but what also must be considered is how climate change will translate into different infrastructure needs at the societal level, in order to reduce the potential of exacerbating set risks and vulnerabilities of the built environment.

Provincial and territorial climate change plans reviewed, found to frequently cite the importance of interdisciplinary research and generating knowledge for strategic planning purposes in adaptation integration and mainstreaming processes (GC, 2017; GC, 2016a, 2016b; GN, 2011). One informant identified mainstreaming as important throughout the region, saying that, "[...] we see our role in climate change adaptation within infrastructure more like [working towards] mainstreaming it into infrastructure and other GN government departments" (Interview 5). Nunavut has a long history of formalized agreements with research organizations and collaborating with academia (Ford et al., 2012b). Lack of interdisciplinary research caused due to weak research bonds between CCA and infrastructure has real-world ramifications for a context that is experiencing higher warming rates than the global annual average (IPCC, 2018).

While there is a large amount of academic scholarship and interest on climate change vulnerability in the Arctic, our study found limited number of research that has connected the CCA scholarship with that of infrastructure scholarship (Ford 2009b; Ford and Furgal, 2009). Research and knowledge management remains largely focused on adaptation in general, with limited focus on infrastructure in particular, or what particular role CCA planning must have for particular sectors, such as infrastructure (Ford, Knight and Pearce, 2013). 'Connecting the dots' between these two research fields, as well as expanding research into different types of infrastructure and their respective uses and needs (e.g. water and waste-water management, ICT, etc.) could substantially contribute to effectiveness of policy development in those sectors. This is also in line with fostering a more comprehensive coverage of knowledge across all 25 communities in the region, not just the "research hotspots" that have a past of engaging with academia and research. More localized research to fill the research disparities between communities will decrease the risk of the creation of blanketed policies that are not feasible or not appropriate for a given community.

6.3. Implementation: Prioritizing Climate Change Adaptation in Infrastructure Policy and Action

The challenges of planning, constructing and maintaining infrastructure in Nunavut where 25 communities are spread across an area of nearly 2 million km^2 are considerable. Connecting the fields of CCA research with that of infrastructure has continually been identified as a precursor towards prioritizing and applying it in practice, both in terms of policy development and adaptation action in the infrastructure realm.

A review of different provincial and territorial climate change policies and strategies across Canada, as well as the respective infrastructure department plans, showed limited cross-sectorial and multilevel programming or funding specifically focusing on infrastructure CCA (Dickenson and Burton, 2011; Howlett and Lindquist, 2004). While provinces and territories each have their own respective policies or strategies related to climate change, they generally lack specifics or what good practices and concrete actions should be followed for a given sector, including the infrastructure sector (Stoney and Graham, 2009).

It is rather the lack of knowledge uptake and mainstreaming of local realities that is not reflected in larger federal policies that was identified to be an issue, which could lead to blanket policies that do not allow for flexibility or adjustment to local realities. Similarly, a number of studies reviewed, identified the need for adaptation engagement in the infrastructure sector, although many of them do not go beyond an "wish list" (Ebi and Burton, 2008), which one interviewee identified as "good to know or good to have" but not reflecting local realities where efficiency, effectiveness, cost, acceptability and other issues weigh heavily on decision-makers and practitioners.

At the territorial level, the Government of Nunavut (GN) has spearheaded some notable developments around climate change adaptation planning and risk management for establishing more climate-sensitive infrastructure policy and projects (GN, 2013; GN, 2012). Significant work has also been done with establishment of the Climate Change Secretariat (CCS) in 2016 as part of the Government of Nunavut Department of Environment, allowing them to play an important role in fostering the advancement of adaptation at territorial and community-level, while also working on engagement with the federal government.

However, some interview participants highlighted the difficulty of prioritizing CCA activities with such limited funding and a number of other more pressing social and economic issues throughout the territory. Housing has continually been an infrastructure challenge with direct social consequences in the territory, highlighted throughout the research and discussions with interview participants stating: "When we look at housing development in Nunavut, we've got a severe overcrowding in our housing. We've got a whole raft of social issues [...] simply for the fact that there isn't enough housing" (Interview 2). Keeping up with the construction needs and maintenance cost often takes priority over whether or not it takes into account future climate changes and risks scenarios, particularly with the limited budget of the territory.

The focus to-date has primarily been at the community level, with small-scale actors taking on much of the work around adaptation efforts and knowledge production, aiming at informing and preparing for adaptation (i.e. through impact assessments, adaptation planning exercises or stakeholder engagement sessions). Much of the literature in the scoping study highlights the significantly more advanced stage of adaptation Nunavut appears to be compared to other regions of the world due to the high number of reported initiatives and many adaptation champions (e.g. CCS, PTAP, etc.). However, much of this seems to be focused on groundwork

initiatives and while building adaptation readiness to climate change is key, evidence of implementation is often lacking. Closely connected to this point is the limited evidence found on monitoring and evaluation (M&E) across scales of government in the reviewed literature of the scoping study. Processes of M&E involve tracking progress and informing decision-making and knowledge and learnings are captured for the future and informed decisions being made (Bours et al., 2013). Many authors have discussed the lack of publicly available reporting on evaluation by both the federal and territorial level in their research; some have commented on the possibility that the governments engage in M&E activities but do not make the results publicly available (Labbé, 2017; Ford, Knight and Pearce, 2013). Overall the scoping study found minimal literature touching on M&E reporting, yet for public transparency and accountability to be ensured, as well as learnings to be mainstreamed into the larger institutional and social fabric, it is important to communicate results and progress of adaptation initiatives. It should be noted that overall the lack on reporting of M&E is not unique to this context and has been a wider issue noted throughout CCA literature by several prominent authors of adaptation (Ford, McDowell and Pearce, 2015; Berrang-Ford, 2014; Bours et al., 2014)

There is high-level interest for infrastructure adaptation, with funds and programmes being created for infrastructure CCA, although much falls short of actual transformational action and policy change (Craft et al., 2013; Ford, Knight and Pearce, 2013). Canada's approach to adaptation has been described by many authors as ad-hoc and unsystematic (Austin et al., 2015; Dickinson and Burton, 2011), currently still lacking a national adaptation plan that directly engages with and guides, different levels of governments, establishes action points and respective responsibilities or clearly outlines at timeline on implementation.

Given the potential risks, and uncertainties of climate change to infrastructure prioritizing actions and policy development for CCA in infrastructure continues to be a major challenge throughout the territory and at a federal level. In Nunavut, where resource constraints present a significant challenge to options and decisions available, present-day policy priorities such as pressing socio-economic issues, financial resource constraints and geographic location, but also the uncertainty of future climate change impacts, have posed significant barriers and often overshadow the focus on longer-term, less immediate concerns such as adaptation (Labbé et al., 2017). Perhaps one way of prioritizing CCA is to rethink climate change as a development issue rather than a future biophysical threat that can be prepared for. This includes thinking of it in a more sustainable way, as (1) how climate variables in the present and the future can threaten current infrastructure, but also (2) how climate change can multiply and exacerbate present-day socio-economic risks and impacts, resulting in even higher financial cost.

Adaptation plans and programmes from the Government of Canada and the Government of Nunavut have led some innovative and successful adaptation initiatives, although many acts as more of a guiding document and not a statutory responsibility and are often ad-hoc. Federally, Canada lacks a formal national adaptation plan that could direct how different levels of government work together and what systematic integration of CCA would look like across different sectors with vertical integration. A clear and formal plan for mainstreaming CCA across all sectors, including infrastructure, would be a helpful step to outline each departments responsibility for taking action on adaptation for their relevant mandate, what the needs are for provinces and territories in the short, medium and long term and what role the federal government has for communities in the Canadian Arctic. Better guidance on how different levels of government work together could also aid in the mainstreaming of climate change

adaptation in different sectors. Achieving CCA mainstreaming in infrastructure or mainstreaming of any issue is particularly difficult as stand-alone or add-on activities will not be enough to create a wider systematic change that ensures long-term success. A vision of change needs to be laid out with actors taking responsibility and driving the mainstreaming progress forward throughout different sectors including infrastructure, with support from both federal and territorial governments. While a blanket national policy that can't allow for reflection of local realities is not suggested here, setting a minimum standard across all sectors for CCA considerations could be brought forward from the top in order to ensure government-wide prioritization and recognition of the importance of CCA as a central cross-cutting issue.

7. Conclusion

The thesis research set out to identify and understand the current state of CCA knowledge in the infrastructure sector in the context of Nunavut, and in what way this knowledge is integrated into infrastructure development and policy prioritization in the territory.

A scoping study and semi-structured interviews were used to answer the two research questions. *What is the current state of climate change adaptation knowledge and ongoing measures for critical infrastructure in Nunavut?* In a region like Nunavut, that encompasses 2 million km^2 with 25 remote communities, constructing and maintaining infrastructure that can withstand climate impacts and variability and, developing the capacity and policy prioritization of CCA for the infrastructure sector requires continued efforts from across different sectors and scales, by both professional, academic and community stakeholders. A lot of knowledge is present in the territory, although inconsistent in terms of geographical coverage of communities, as well as of different sectors. The type of knowledge, its sources and where knowledge is collected and considered as input data for higher-level decision making and policy development has real-world impacts. General data scarcity coupled with research disparities between communities in the region, as well as between different sectors, remain a major obstacle and pose a risk towards blanketed policies being applied to communities where it could not be appropriate, feasible or acceptable. 'Connecting the dots' between the CCA research realm and the infrastructure research realm has been highlighted as a crucial point throughout this research.

In what way is this knowledge implemented in critical infrastructure development and policy prioritization for current and future government projects? Based on the scoping study and interviews our research found limited number of case studies or examples in Nunavut where concrete action in line with planned and prepared adaptation took place. The Nunavut case demonstrates a lot is happening at the community level on the ground with community and territorial government championing the importance of CCA planning for infrastructure and with communities willing to engage with research and actions on the topic. Several innovative federal funding programmes that target adaptation specifically also indicate high-level interest, yet there seems to be a disconnect between the two governance levels as many actions are often ad-hoc and lack the long-term commitments that mainstreaming, and integration of adaptation action and decision-making require. The results show that although adaptation has been taking place, a need for continued dialogue between federal, territorial and community-level stakeholders is key to develop a long-term resilient Nunavut. Nunavut is on the path towards adaptation across all sectors and governance levels, although continued efforts are needed to fully integrated climate change considerations in decision-making and policy development for the infrastructure sector.

The Arctic region is and will continue to experience dramatic transformational changes (IPCC, 2018). Nunavut is at the forefront of climate change and increasing infrastructure resilience must be central to government efforts and policy development. Contributing to Nunavut's ability to cope with the upcoming changes and allowing the region to tackle challenges and take advantage of new opportunities in a sustainable manner to benefit the people of the region.

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9. Appendix

9.1. Appendix 1 – Scoping Study Search Keywords and Results

Search Keywords	# Total Entries	# Reviewed
(1) LUBsearch		
climate change adapt* AND Nunavut	260	53
climate change adapt* AND Nunavut AND infrastructure	15	10
climate change adapt* AND infrastructure AND Canada AND Arctic	22	17
climate sensitive infrastructure AND risk assessment AND Arctic AND Canada	2	1
Sub-total	299	81
(2) Science Direct		
climate change adapt* AND Nunavut	335	23
climate change adapt* AND Nunavut AND infrastructure	110	17
climate change adapt* AND infrastructure AND Canada AND Arctic	989	17
climate sensitive infrastructure AND risk assessment AND Arctic AND Canada	529	8
Sub-total	1963	65
(3) Google Scholar (first 100 entries reviewed)		
climate change adapt* AND Nunavut (1999-2019)	9530	55
climate change adapt AND Nunavut AND infrastructure (1999-2019)	4960	49
climate change adapt* AND infrastructure AND Canada AND Arctic (1999 - 2019)	17 200	45
climate sensitive infrastructure AND risk assessment AND Arctic AND Canada (1999-2019)	17 500	38
Sub-total	14490	187
Entries from other sources (contacts and reference lists)	16752	16
Total [including 199 duplicate]		349
Final total reviewed		**150**
Excluded articles (outside of scope of study)		47
Total included articles in the scoping study		**103**

9.2.Appendix 2 – Interview Letter

Advance Letter to Key Informants

Dear [Name],

Our names are Kelly Ramsauer & Timothy Giger, and we are graduate students, enrolled in the MSc Programme in Disaster Risk Management and Climate Change Adaptation (DRMCCA) at Lund University in Sweden.

We are currently working on our master thesis research project on preparedness and adaptation to climate impacts in the Canadian Arctic, specifically risk assessment approaches for climate-sensitive critical infrastructure in the context of Nunavut, Canada.

In our research, we are looking into climate-sensitive critical infrastructure development and in what ways climate change adaptation factors into current and future infrastructure development, policy and prioritization.

As part of our data collection process, we plan to conduct semi-structured interviews with individuals working or conducting research in this field. To this end, we would like to kindly ask if you would be willing to be interviewed in the context of our master thesis project. Your support would be an immense help for our studies.

Ideally, we would like to complete the interviews by the end of March 2019. The interview would last around 30 - 45 minutes. It will take place via Internet (Skype or other preferred communication mediums) and can be scheduled at your convenience. In case you agree to be interviewed and/or have any questions, please feel free to contact us anytime.

Thank you in advance for your time and consideration.

Sincerely,

Kelly Ramsauer
MSc Candidate
Disaster Risk Management and
Climate Change Adaptation
Email: ke5806ra-s@student.lu.se

Timothy Giger
MSc Candidate
Disaster Risk Management and
Climate Change Adaptation
Email: timothy.giger.0606@student.lu.se

9.3.Appendix 3 – Interview Outline sent to Interview Participants

Interview Outline

The local character of climate change impacts has increasingly put local actors and governments at the front line in adapting to climate change. In the Canadian Arctic, debates over appropriate policy action and capacity development on climate change adaptation (CCA) is a prominent topic for every sector and climate change policy at every level of government in Canada.

Assessing risks and CCA for critical infrastructure in particular, gives rise to the opportunity of identifying and understanding which factors are and are not considered when infrastructure policy and prioritizations are formed in planning and preparing for a more climate-sensitive infrastructure development approach. Due to societal dependence on infrastructure and the interdependencies between different types of critical infrastructure, its vulnerability to climate change is key when addressing levels of resiliency and capacity development for a region. While many climate change impacts are locally specific, and the Arctic region is a unique context on its own, good practices and lessons can be drawn from other communities experiencing negative impacts of climate change on their critical infrastructure.

Understanding the strengths and weaknesses of different approaches as well as current challenges in integrating CCA approaches and frameworks, can contribute to better incorporating CCA in infrastructure development. This research aims to improve our understanding of CCA considerations in critical infrastructure development, policy and prioritization in the Arctic, specifically in Nunavut, Canada. In doing so, this research seeks to identify and understand what the current state of CCA knowledge is and what the ongoing measures are and in what way this knowledge is implemented and operationalized in critical infrastructure risk assessments, monitoring and evaluation for current and future government critical infrastructure projects.

Interview Structure

Interviews will be semi-structured, with a length of 30-45 minutes. For the purpose of analysis, the interview will be recorded, with notes taken during interview, although the option exists to stay anonymous and pause the recording for certain sections if desired.

The main questions focus specifically on the conceptual background and key terminology and in what way key informants understand and work with concepts of *CCA*, *vulnerability*, *resilience*, etc. This facilitates answering the research question dealing with what the current state of knowledge is for CCA in critical infrastructure in Nunavut. This is followed by questions focusing on answering the second research theme which seeks to understand in what ways this knowledge and information is practically implemented and operationalized within current and future critical infrastructure development process.

9.4.Appendix 4 – General Interview Guide and Questions

Part I - Opening questions

1. Your name
2. Your current role and organization, and the field in which you operate
3. Previous roles (if any) you have held, in relevant fields
4. Your academic background, and professional training/experience

Part II - Conceptual use of key terminology

1. Are the terms & concepts climate change, climate change adaptation, resilience, vulnerability and risk assessments something you encounter in your everyday work?

   If so:

   1.1. To your knowledge, does your organization have a climate change adaptation policy? If so, could you describe it a bit and how you understand it? How is that policy different from other issues that you deal with? And for how long have you had it/when was it introduced?

   1.2. Does your organization have a common definition for resilience and vulnerability? If yes, could you describe it a bit?

2. Do you conduct risk assessment processes? And if so, could you describe the process and whether climate change factors are taken into account?

3. Do you think the above concepts are linked and taken into consideration particularly when it comes to Nunavut and in the critical infrastructure sector?

4. Do you think climate change adaptation plays a role in critical infrastructure development?
   4.1. If so, why and in what way?

5. Do you see any risks from climate change for critical infrastructure?
   5.1. If so, to what extent?

Part III – Central Questions

Context and Case of Nunavut

1. What role does critical infrastructure play in Nunavut and the Arctic? How do you think it is different in Nunavut then in other contexts?

   1.1. What kind of risks and vulnerabilities do you perceive to be important and in turn not so important when it comes to critical infrastructure in Nunavut?

2. In your opinion, what are some current and future difficulties and challenges faced by climate change adaptation and/or critical infrastructure development in Nunavut and more broadly in the Arctic?

Organizational Capacity & Relationships

1. What would you say is your institutions/workplaces role in connection to climate change adaptation of the sectors in general and critical infrastructure in particular in Nunavut?

2. What has been your experience in working with climate change adaptation (CCA)?

3. In your geographic area, who/which department is responsible for working with climate change adaptation? Since when and why do they work with this?

4. With whom outside of your geographic area and work focus do you work with and for what reason? Which of these groups/persons do you see as supporting and/or conflicting with your work in relation to climate change adaptation?

Current Knowledge & Practices

1. What assessment or frameworks do you use to guide your work or when designing programmes/policy for critical infrastructure projects?

2. Who is involved in an infrastructure development and design process?

    2.1. To what extent do you consult with people in the area? What are the methods for doing so?

3. Is community knowledge in the risk screening process considered? And if so, in what way and to what extent?

4. To your knowledge, is there some kind of training given when it comes to the integration of climate change adaptation? What do you think about this integration and mainstreaming process?

Planning, Policy & Operationalized Processes for Critical Infrastructure

1. What adaptation approach and risk assessments to climate change in the planning of critical infrastructure in Nunavut is used?

2. What is the process of assessing risks of climate change impacts on critical infrastructure? What is the M&E process and what is its purpose?

3. In your opinion, what planning steps are, or should be considered for future infrastructure projects to be more climate-sensitive? And why?

4. In what way do you think ongoing analysis/risk assessments aid in more resilient critical infrastructure? In what way do they not? What challenges (in this area) does the organization encounter, and how could these be overcome?

Part IV - Current and Future Challenges

1. What do you see as challenges towards integrating knowledge around climate change adaptation into practical application in critical infrastructure development?

Part V - Closing Questions and any other comments

1. That concludes the formal questions. However, are there any other statements, information or ideas you might like to share or add from your experience in CCA/critical infrastructure/Risk assessments/northern context challenges / vulnerability, etc.?
2. Is there anything additional that you think could be better understood to improve in climate-sensitive infrastructure development and policy prioritization process in Nunavut?

Probing Questions

Would you care to elaborate on…?	Why do you consider...to be this way?
Could you perhaps provide an example?	Why do you think...matters?
Can you think of other ways to…?	Why do you regard...as import?

9.5.Appendix 5 – Overview of Interviews Conducted

No.	Initials	Organization & Field	Current Job	Interview Date & Length
1.	BR	University of Tromsö (UiT) Critical Infrastructure & Resilience research	Phd student at UiT Norway	22/03/2019 19 min.
2.	SH	Nunavut Housing Corporation Government of Nunavut	Chief Operation Officer (COO)	08/04/2019 33:16 min.
3.	WP	Community and Government Services Planning and Lands Division Government of Nunavut	Manager, Community Planning	15/04/2019 46:05 min.
4.	FB	Transport Canada Environmental Affairs Government of Canada	Environmental Officer	20/03/2019 n/a
5.	SP	Climate Change Secretariat Department of Environment Government of Nunavut	Climate Change Adaptation Specialist	02/05/2019 45:33 min.